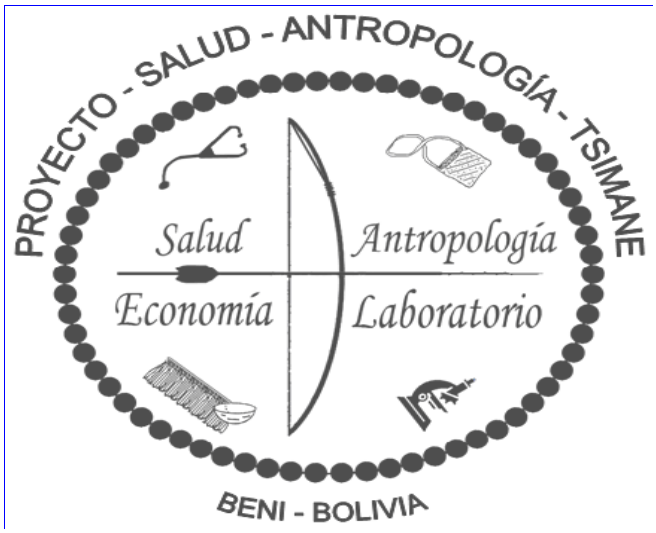

INFORME DE LAS ACTIVIDADES DE ATENCIÓN EN SALUD Y LAS INVESTIGACIONES MÉDICAS

AÑO 2013

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1. INFORME DE ACTIVIDADES MEDICAS

1.1. PROCEDENCIA DE FONDOS, DIRECTORES, ACUERDOS Y CONVENIOS PROYECTO TSIMANÉ

El Proyecto Salud y Antropología Tsimane, esta bajo la dirección de los Señores Julio Kaplan y Miguel Gurven. Ellos son profesores de Antropología en la Universidad de Nuevo Mexico y California Santa Barbara.

El dinero para las investigaciones y la atención médica viene desde el Instituto Nacional de Salud de los Estados Unidos.

El Trabajo del Proyecto cuenta con la autorización de las siguientes instituciones:

- En Estados Unidos del comité de Ética de los Estados Unidos, la universidad de California Santa Barbara, La universidad de Nuevo México
- En Bolivia del Gran Concejo Tsimane, el Gobierno Municipal Autónomo de San Borja, el Honorable Concejo Municipal de San Borja y el Viceministerio de Salud de Bolivia

Además contamos con convenios y acuerdos de trabajo con las siguientes instituciones:

- En San Borja con el Gran Concejo Tsimane, el Hospital Municipal de San Borja y el Gobierno Municipal Autonomo de San Borja
- En San Ignacio con la ONG Solidaridad Médica Canaria.
- En Cochabamba con la ONG Mano a Mano Bolivia y con Solidarida del Arzobispado de Cochabamba
- En Trinidad con Caritas Trinidad, el Centro de Salud Pompeya, la Fundación Miradia Solidaria
- En Santa Cruz con el Centro Nacional de Enfermedades Tropicales Santa Cruz (CENETROP)
- En La Paz con el Instituto Nacional de Laboratorios de Salud (INLASA) La Paz, el Hospital de Clínicas y el Hospital de la Mujer

1.2. CAMPAÑAS CIRUGÍA GENERAL SAN IGNACIO

El año 2007 por iniciativa de la ONG Solidaridad Médica Canaria, se realizo la primera campaña de cirugías para los pacientes Tsimane, en esa oportunidad el proyecto Tsimane logro operar 27 pacientes de todas sus comunidades atendidas además de tratar a 16 pacientes de Leishmaniasis. En esa oportunidad el Proyecto se encargo de seleccionar a los pacientes, así como cubrir los gastos de transporte a San Ignacio y la alimentación en SB para todos ellos.

El año 2009, tras la primera exitosa experiencia, se lanza la segunda campaña de Cirugías nuevamente en cooperación con la ONG Solidaridad Médica Canaria, en esta oportunidad se operan 70 pacientes.

Gracias a estas dos campañas se logra disminuir en gran forma los problemas de hernias que sufrían la gente de la etnia Tsimane.

Tabla 1. Detalle de pacientes atendidos en Campañas Quirúrgicas San Ignacio 2007 y 2009.

	Número de Pacientes		
Tipo de enfermedad	Campaña 2007	Campaña 2009	Total
Cirugía general	25	67	92
Leishmaniasis	16		16
Ginecológicas	2	3	5
Desnutrición		2	2
Total	43	72	115

1.3. CAMPAÑAS CIRUGIAS OFTALMICAS CARITAS

El año 2010, se inicia contacto con el equipo médico del Centro de Salud Pompeya, quienes en colaboración con la Fundación Mirada Solidaria realizan operaciones de pterigion (carnosidad en el ojo) y cataratas a la gente más pobre a precio más bajo. Decidimos en una reunión iniciar un plan de tratamiento de estas enfermedades a las personas de la etnia Tsimane, especialmente a los ancianos, por lo que deberíamos revisar los ojos de todas las personas para seleccionar las que deben ser operados. DE este modo , es que el año 2011 se realiza la primera campaña de cirugías oftálmicas en Trinidad llevándose 14 personas, a las que se cubrió todos los gastos del tratamiento, así como de transporte y alimentación durante 10 días.
El año 2012 se firma un convenio con la Fundación Mirada Solidaria para cubrir los costos de alimentación, alojamiento y transporte en un 50% de cada paciente que necesita ser operado, y se operan en esta segunda campaña 22 personas.

Tabla 2. Detalle de Pacientes atendidos en Campañas Oftálmicas Trinidad 2011 y 2012

Enfermedad	Campaña 2011	Campaña 2012	Total
Cataratas	2	3	5
Pterigion	12	19	31
Total	14	22	36

1.4. CAMPAÑA GINECOLOGICAS HOSPITAL MATERNO INFANTIL TRINIDAD

El año 2006, se realizan reuniones entre el Instituto Nacional de Laboratorios de Salud y el Proyecto Tsimane con el objetivo de iniciar un proyecto de detección de cáncer cervicouterino en mujeres de la etnia Tsimane. Durante los 4 años se realizaron 952 papanicolaos en las 90 comunidades del territorio indígena ofreciendo tratamiento inmediato de las infecciones encontradas en comunidad.

El año 2012, en un acuerdo con el Hospital Materno Infantil de Trinidad se envían 20 mujeres con hallazgos sospechosos en el papanicolao para que se les realice la atención médica especializada, también en el examen ginecológico se logro detectar a otras 9 mujeres que necesitaban cirugía ginecológica para tratar el descenso de vejiga, que también fueron atendidas por el especialista en Trinidad con cooperación de la Fundación DOA, quienes realizaron la operación totalmente gratis, mientras que el proyecto cubrió los gastos de traslado, alimentación y alojamiento para todas las mujeres por casi 10 días.

Enfermedad	Número de Pacientes
pap	20
cistocele	9
Total	29

1.5. TRANSFERENCIAS PACIENTES GRAVES A TRINDIDAD, COCHABAMBA Y LA PAZ

El año 2007, se inicia contacto con la Hermana Adelina Gurpegui, directora de Solidaridad del Arzobispado de Cochabamba. Esta institución ofrece apoyo a personas con bajos recursos y se llega a un acuerdo en que Solidaridad facilitaría y apoyaría al Proyecto Tsimane con los pacientes graves que necesiten atención especializada en Cochabamba y el Proyecto asume los gastos de tratamiento y transporte de todas esas personas. Desde ese año hasta la fecha se han enviado 72 casos de enfermos graves a Cochabamba, que van desde quemaduras graves, cáncer, heridas de bala, infecciones de hueso, leishmaniasis resistente, enfermedades endocrinas, fracturas y otras.

El año 2010, a través del servicio de trabajo social del Hospital Materno Infantil se inicia un acuerdo de cooperación con el Proyecto Tsimane para la atención de lso niños y mujeres embarazadas, hasta la fecha se han enviado 89 personas para recibir tratamiento más especializado en Trinidad, donde el proyecto paga los costos de transporte, y los gastos médicos que no cubre el seguro SUMI.

El año 2012, el Proyecto de Salud y Antropología Tsimane realiza un convenio con el hospital de Clínicas de La Paz para apoyar en el tratamiento de los enfermos Tsimane, donde el Proyecto asume los costos médicos, así como transporte, alimentación y alojamiento y por su parte el hospital se compromete a rebajar los costos de tratamiento. Hasta la fecha ya han viajado 11 personas.

Tabla 4. Detalle de Pacientes Transferidos por año y lugar

Año	Cochabamba	La paz	Trinidad	Total general
2007	7		1	8
2008	9			9
2009	1		1	2
2010	21	2		23
2011	15		20	35
2012	19	9	67	95
Total general	**72**	**11**	**89**	**298**

1.6. GASTOS MÉDICOS PACIENTES TSIMANE

Desde el año 2008, el papel del proyecto en la atención médica es muy grande ya que pagamos casi todos los costos de los pacientes que necesitan enviarse a otros departamentos para una atención especializada y también se provee medicamentos a la gente que llega a San Borja y no tiene dinero para comprar sus propios medicamentos cuando los seguros médicos no están funcionando.

Estos gastos que son aparte de los gastos por la atención en las comunidades han llegado a ser más de 60 mil dólares en los últimos 5 años, gastos que incluyen alojamiento, transporte y alimentación.

Tabla 5. Gastos por transferencia de Pacientes Tsimane desde el 2008 al 2012

Detalle	2008	2009	2010	2011	2012	Total general
Alimentación	181	151	538	1325	2759	4954
Hospedaje				102	54	156
Transporte	804	2297	4980	4751	4290	17120
Gastos médicos	3070	4207	6260	8658	15755	37950
Total general	4055	6654	11778	14835	22857	60180

En la Brigada Médica se han atendido en los últimos 5 años a más de 27 mil quinientas personas, con un costo total por medicamentos de más de 46 mil dólares.

Detalle	2008	2009	2010	2011	2012	Total
Pacientes Atendidos	**3450**	**3552**	**7154**	**7305**	**6011**	**27472**
Costos de medicamentos Brigada en $us	**6588**	**8822**	**12335**	**9470**	**9059**	**46274**

Por esa razón, el año 2011 se realiza un convenio de cooperación entre el gobierno Municipal de San Borja y el Proyecto Tsimane para que asuman parte de los gastos por transporte de la brigada y el salario de los traductores. Aún estamos a la espera del pago y esperamos que no se defraude a la población.

1.7. ACTIVIDADES PARA EL CONOCIMIENTO DE LA ETNIA EN EL MUNDO

Como parte de las actividades del Proyecto están las investigaciones en Salud y Antropología, las cuales han dado información sumamente importante de la forma de vida de los Tsimanes, que entre otras cosas se caracteriza por una gran salud cardiovascular. Esto ha sido presentado a la prensa internacional por medio de varios artículos científicos y reportajes periodísticos, considerándose a la etnia, un espacio protegido de las enfermedades del mundo moderno.

También se hicieron estudios en la leche de las madres Tsimane que mostraron tener mejor calidad que la leche de mujeres de otros países.

AUTORIZACIÓN ACTIVIDADES

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO

SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF ANTHROPOLOGY
SANTA BARBARA, CALIFORNIA 93106-3210

TELEPHONE (805) 893-2257
FAX (805) 893-8707

June 11, 2009

To Whom It May Concern:

Dr. Michael Gurven is a Professor of Anthropology at the University of California. He is Principal Investigator (PI) on a medical and anthropological project, "The Human Life Course and the Biodemography of Aging and Disease among the Tsimane of Bolivia", funded through the National Institutes of Health (NIH). This project operates jointly with the University of New Mexico (co-PI, Hillard Kaplan).

This project is an integrated study of aging, health status and infection, development, resource sharing and social networks across the life course among the Tsimane, a forager-horticultural society with little market involvement and little access to health care. The project started in June 2002 and has now been operating for almost seven years. His project has established itself as an important resource for offering vital health services to under-served indigenous people in remote areas of the Bolivian Amazon. The core of his project is a roving medical team traveling to 26+ Tsimane villages offering health care services to over 3,800 individuals. His base of operations is in San Borja, Beni, Bolivia and all work is conducted in the vicinity of San Borja (TCOs: Maniqui, Isiboro-Secure and Pilon Lajas). There are five Bolivians employed in the office, four Bolivian physicians and two Bolivian biochemists in a roving medical team, and eight Tsimane assistants.

This project has our full support and in Bolivia, this project has the support of the Hospital of San Borja, the Bolivian Ministry of Health, and Gran Consejo Tsimane, and has affiliations with the Medical Schools of UMSA in La Paz and UMSS in Cochabamba, and with CENETROP in Santa Cruz.

We would be most grateful if you could extend your assistance and cooperation to Professor Gurven and the members of his team and allow them appropriate use of your institution's resources or services to pursue their work. U.S. team members include Melanie Martin (UCSB), Jonathan Stieglitz (Univ. of New Mexico), Christopher von Rueden (UCSB), Helen Davis (UNM) and Lisa McAllister (UCSB).

Yours Sincerely,

Professor Katharina Schreiber
Chair, Department of Anthropology
University of California, Santa Barbara

CERTIFICACIÓN

De acuerdo a la solicitud de fecha 20 de Abril del 2007, por el Señor Michael D. Gurven, INVESTIGADOR DE LA UNIVERSIDAD DE CALIFORNIA, Señor Hillard Kaplan, INVESTIGADOR DE LA UNIVERSIDAD DE CALIFORNIA, ambos de nacionalidad norteamericana, con el objetivo de realizar un programa de investigación de salud y antropología en 26 comunidades Tsimané en la región que se encuentra a orillas del Río Maniquí y a lado de la carretera Fátima.

El Programa de investigación enfocado en Salud Publica, epidemiología de enfermedades, analices de sangre, orina, y parasitología, analices de genéticas y estudios antropológicos sobre economía, demografía, alimentación y vida social ha cumplido ya cuatro años de trabajo, brindando además de soporte médico a los comunarios abundante información epidemiológica en beneficio de la Etnia.

En futuros estudios abocaremos en el grupo de ancianos y niños valorando de esta manera el proceso de crecimiento, desarrollo así como el envejecimiento. Cuyos resultados pretendemos sean de utilidad para la justificación de mejores políticas gubernamentales que atiendan a los comunarios de la Etnia.

Para tal efecto, el Gran Consejo Tsimané como Organización máxima del Pueblo Tsimané brinda su total apoyo y autoriza el funcionamiento del proyecto hasta el año 2009 para realizar con normalidad su labor con la Etnia Tsimané en las Investigaciones Medico Antropológicas.

El Consejo Tsimané, además, resalta la autorización para el libre tránsito por la Carretera a Fátima, así como el uso del Puerto de Arenales, para su efectivo traslado a las comunidades.

San Borja, 20 de Abril del 2007.

Jorge Añez Claros
PRESIDENTE
GRAN CONSEJO TSIMANE'

GRAN CONSEJO TSIMANE' G.C.TS. San Borja - Beni - Bolivia

MINISTERIO DE SALUD
Y DEPORTES

C E R T I F I C A D O

EL SUSCRITO VICEMINISTRO DE SALUD, EN CUANTO PUEDE Y EL DERECHO LE PERMITE

CERTIFICA:

Que, el **PROYECTO DE SALUD – ANTROPOLOGÍA TSIMANE,** ha sido presentado en este Despacho en fecha 28 de junio del 2006, posterior a la revisión y análisis del presente documento, este Viceministerio otorga su conformidad al trabajo efectuado.

Es cuanto certifico en honor a la verdad y para fines que convengan a los interesados.

La Paz, Junio 29 del 2.006

Dr. Juan A. Nogales Kocabeño
VICEMINISTRO DE SALUD
MINISTERIO DE SALUD Y DEPORTES

MINISTERIO DE SALUD Y DEPORTES
DESPACHO VICEMINISTRO DE SALUD
La Paz - Bolivia

c.c. Archivo

San Borja, 13 de abril del 2011

Señor

Felipe Mayer Roca

Presidente Gran Consejo Tsimané

San Borja

Ref.: SOLICITUD PARA REALIZACIÓN DE INVESTIGACIONES PSICOLOGICAS EN COMUNIDADES TSIMANÉ

Estimado Felipe, en esta ocasión nos dirigimos a su persona con el objetivo de solicitarle permiso para realizar cuestionarios psicológicos con la gente de la etnia Tsimané. Esto a raíz de la necesidad de entender los efectos que tiene la mente sobre la salud y el cuerpo. Queremos saber que tan estresados vive la gente de la etnia, como manejan sus problemas, etc.

Como primer paso queremos hacer unas entrevistas sobre preocupaciones, nivel de felicidad, tristeza y manejo de problemas; y según sean los resultados se planificaran más investigaciones.

Se mantendrá total confidencialidad de la información y haremos llegar a su institución las copias de los resultados de nuestros estudios a nivel poblacional.

Agradeciéndole de antemano su gentil colaboración, nos despedimos esperando atentos su respuesta.

Atentamente,

Prof. Hillard Kaplan
Co- Director Proyecto Salud y Antropología Tsimané

Prof. Michael Gurven
Co- Director Proyecto Salud y Antropología Tsimané

Felipe Mayer Roca
PRESIDENTE
GRAN CONCEJO TSIMANE

Dr. Daniel Eid R.
Coordinador Salud Proyecto Salud y Antropología Tsimané

CONVENIOS

CONVENIO DE INVESTIGACION EN ANTROPOLOGIA Y MEDICINA CON PRESTACION DE ATENCION MÉDICA A LA ETNIA TSIMANÉ ENTRE EL PROYECTO DE SALUD Y ANTROPOLOGÍA TSIMANÉ Y EL GRAN CONSEJO TSIMANE

1. PRIMERA (PARTES INTERVINIENTES)

Intervienen en la suscripción de éste documento:

1.1. La Etnia Tsimané, representada por su órgano rector el Gran Consejo Tsimané, del cual es presidente el Sr. Felipe Mayer Roca con CI. 10808427 Beni y como responsable de salud del Gran Consejo Tsimane el señor Edgar Nate Roca con C.I. 5584017 Beni.

1.2. PROYECTO SALUD Y ANTROPOLOGÍA TSIMANÉ, bajo la dirección de el Sr. Hillard Kaplan de la Universidad de Nuevo México y el Sr. Michael Gurven de la Universidad de California Santa Bárbara, representado por el Sr. Daniel V. Eid Rodríguez, coordinador del área médica, mayor de edad, hábil por derecho, con CI 3552233 OR.

Ambos en pleno uso de sus facultades legales e intelectuales, concurren a este acto sin que medie ninguno de los vicios del consentimiento como son: el error, el dolo o la violencia.

SEGUNDA (OBJETO DEL CONVENIO)

COMPROMISOS DE PARTE DEL PROYECTO SALUD Y ANTROPOLOGIA TSIMANE:

1. ***Cobertura Médica General*** – Visitas medicas anuales a 80 comunidades, con una población total de aproximadamente 9500 personas. Durante las visitas a las comunidades, cada persona tendrá derecho a recibir atención médica sin costo alguno para el paciente. Su presencia en la consulta es voluntaria.

2. ***Programa para mejorar la salud de los ancianos*** – Todas las personas mayores de 40 años serian invitados a San Borja para recibir un examen médico completo. Los que quieren recibir su examen serán transportado en la movilidad y/o el bote del proyecto a a nuestra clínica en San Borja donde serán hospedados y alimentados mientras se realice su atención médica. Cada paciente será revisado para detectar enfermedades crónicas como el cáncer, y enfermedades cardiacas, vasculares, y del riñón, hígado, ovario, próstata, intestinos, y vesícula. También se realizaran exámenes de sangre para diagnosticar y tratar anemia, enfermedades infecciosas, función renal y hepática, y el estado del sistema inmune. Igual se realizara exámenes de coproparasitologico y orina para detectar y tratar parásitos; así como otras enfermedades. Al finalizar el examen médico cada paciente recibirá un informe de sus resultados y el tratamiento correspondiente en los casos que se requiera.

La parte antropológica consistirá en recolectar información demográfica de los pacientes, sobre mortalidad, parentesco, producción, comportamiento y personalidad, y otros temas relacionados con la cultura, la economía, y la vida social de los Tsimanes. Las entrevistas estarán a cargo de antropólogos Tsimané y estudiantes de Antropología de la Universidad de Nuevo México y California Santa Bárbara. Dicha información contribuirá al entendimiento de la historia de la etnia.

3. ***Colaboración con el Hospital de San Borja y con otros hospitales del tercer nivel*** –El proyecto designa un médico responsable de realizar un seguimiento a los pacientes internados en el hospital, colaborar en decisiones diagnósticas y tratamiento de los pacientes Tsimané, El proyecto también apoyara con transporte de enfermos al hospital de San Borja y cuando sea necesario a hospitales del tercer nivel para una atención médica más compleja.

4. **Apoyo Gran Consejo Tsimané**

   El Proyecto de Salud y Antropología comprometido con el desarrollo de la comunidad indígena apoyara las actividades del Gran Consejo Tsimané en base a los siguientes puntos:

   a. ***Fondo de alimentación para reuniones:*** El proyecto se compromete a la compra de víveres con valor de 1000 Bs. para apoyo en reuniones de la etnia hasta 3 veces por año (Total 3000 Bs. por año)
   b. ***Fondo para traslado***: El Proyecto se compromete a destinar 1000 bs al año, por concepto de costos de transporte que pueden ser descargados como combustible, mantenimiento de vehículos o pasajes para actividades del Gran Consejo Tsimané.
   c. ***Apoyo en elaboración de proyectos de desarrollo:*** El proyecto se compromete en colaborar con su personal capacitado en elaboración de proyectos para financiamiento de iniciativas del Gran Consejo Tsimané, dirigidos a mejorar la calidad de vida de los comunarios.
   d. ***Página Web:*** El proyecto se compromete a diseñar el sitio web para sus actividades de divulgación y socialización de actividades del Gran Consejo Tsimané con información proporcionada por la institución.
   e. ***Devolución de camioneta***: El proyecto hace devolución de la camioneta del Gran Consejo para cubrir sus necesidades de transporte, el mantenimiento del vehículo, reparación y combustible corren a cuenta del Gran Consejo Tsimané.

Todos los gastos realizados por el Gran Consejo en relación a los puntos anteriormente descritos, deben ser descargados con factura al Proyecto Salud y Antropología Tsimané.

La solicitud de dinero debe realizarse con al menos 4 días de anticipación en forma escrita.

El Proyecto se compromete a hacer conocer sobre la entrada y salida de los investigadores, sus propósitos e informe de sus resultados.

COMPROMISOS DE PARTE DEL GRAN CONSEJO TSIMANE:

1. Reconocimiento del Proyecto de Salud y Antropología Tsimané como asesores en Salud del Honorable Consejo Tsimané y a la brigada médica como unidad móvil de salud del Consejo Tsimané.
2. Entrega a concesión un deslizador y un motor fuera de borda para facilitar los viajes a las comunidades por el tiempo de duración del convenio, los gastos de combustible, reparación y mantenimiento corren a cuenta del proyecto.
3. Coordinación con las comunidades para que se colabore a la brigada con ambientes para la atención medica, así como la participación de la comunidad en acudir a las citas para los seguimientos médicos.
4. Coordinación con comunidades para el apoyo, y asistencia de los comunarios al control médico.
5. El Gran Consejo Tsimané se hace responsable del adecuado cumplimiento de los tratamientos médicos de parte de los pacientes hospitalizados y que llegan al centro médico del Proyecto Tsimané en San Borja, haciendo de mediador y consejero, por las atribuciones que como autoridad le corresponden sobre la etnia Tsimané.
6. Difusión de programas radiales informativos para las comunidades, en radio Horeb dirigidas a difundir la noticia del acuerdo, así como explicar el trabajo a realizarse.

TERCERA (DURACION DEL CONVENIO)

La duración de este acuerdo será de 1 año a partir de la firma del presente convenio, con prorroga para 5 años.

CUARTA (GARANTIAS DEL CONVENIO)

Las instituciones aquí representadas se comprometen al fiel y estricto cumplimiento del convenio independientemente de los cambios de autoridades que puedan suceder durante el tiempo de duración del convenio.

San Borja, 15 de Abril del 2011.

Daniel Vladin Eid Rodriguez
COORDINADOR MEDICO PROY. SALUD Y ANTROPOLOGIA TSIMANE

Felipe Mayer Roca
PRESIDENTE GRAN CONSEJO TSIMANE

Edgar Nate Roca
RESP. SALUD GRAN CONSEJO TSIMANE

CONVENIO ENTRE EL GOBIERNO AUTONO MOMUNICIPAL DE SAN BOJA Y EL PROYECTO DE SALUD Y ANTROPOLOGIA TSIMANE PARA LA PRESTACION DE SERVICION MEDICOS A LA ETNIA TSIMANE.

ANTECEDENTES PROYECTO DE SALUD Y ANTROPOLOGÍA TSIMANE

El proyecto de Investigación Salud y Antropología "Tsimané" es una iniciativa de los profesores Hillard Kaplan y Michael Gurven de la carrera de Antropología de las universidades de Nuevo México y Santa Barbara California respectivamente, como un intento de aprender sobre culturas indígenas que se mantienen conservadas y soportan los cambios de la modernidad. Desde el año 2002 hasta la fecha actual, muchos investigadores y profesionales han recolectado información sobre sus costumbres, estilo de vida, relaciones humanas y económicas; el proyecto Tsimane ha censado al 90% de la población Tsimané llegando a los lugares más alejados de las orillas del río maniquí, desde Cuchisama y Acuña río arriba hasta Chaco Brazil por río abajo, también por carretera se llega a todas las comunidades en la carretera del aserradero Fatima hasta Uhisiricansi.

A la par con las investigaciones realizadas, el Proyecto Tsimané ha brindado atención médica gratuita a la gente de la etnia Tsimané inicialmente con una brigada médica que brindaba atención primaria en salud a 26 comunidades cada año y medio, con el paso de los años los alcances de la brigada se fueron ampliando con un sistema de derivación de pacientes multinivel, en un esfuerzo conjunto con otras instituciones de beneficencia, llegando a resolver casos quirúrgicos.

Entre las actividades de la brigada médica móvil cabe destacar el comienzo de la búsqueda de Cancer cervicouterino entres las mujeres Tsimane, desde el 2008 encontramos 29 casos de mujeres con lesiones precancerosas(que se convertirán en cáncer con el tiempo) y dos casos de cáncer in situ, que al ser intervenidos oportunamente recuperan las opciones de supervivencia ante una enfermedad altamente mortal.

El año 2006 y 2008 se impulsaron acuerdos con la Alcaldía de San Borja y el Hospital de San Borja para mejorar la atención de los indígenas Tsimané en el Hospital de San Borja, por su parte el hospital libero los costos de atención médica y por el otro lado la

Alcaldía de San Borja y el Proyecto Tsimané pusieron un fondo de 1000 dólares cada uno por año para cubrir costos de medicamentos.

El año 2008 fue el más productivo por los contactos y acuerdos realizados; gracias a un acuerdo con la ONG Solidaridad Médica Canaria, se han realizado más de 170 operaciones, principalmente de hernias abdominales y enfermedades ginecológicas; con todos los gastos pagados, incluyendo alimentación y alojamiento.

También en un convenio realizado con la ONG "Solidaridad" del Arzobispado de Cochabamba y la ONG Mano a Mano, se pudo realizar el traslado de 27 pacientes graves a Cochabamba con resultados alentadores que salvaron y devolvieron la calidad de vida a los pacientes.

Nuestro equipo móvil en los 7 años atendió a más de 3500 pacientes al año, actualmente atendemos 750 pacientes por mes de manera gratuita, con costos de 1500 doláres mensuales en medicamentos, alojamiento y alimentación 8000 dolares mensuales y personal médico 12000 dolares al mes. La atención de casos graves en los últimos 3 años alcanzo la cifra de 20000 dolares con más de 30 pacientes transferidos.

Actualmente, el proyecto inicia una nueva fase dirigida a los adultos mayores, consistente en visitas de los comunarios a la base de operaciones en San Borja, donde están instalados consultorios, con equipos diagnóstico especializados en enfermedades cardiovasculares, del sistema inmune, detección de cataratas y glaucoma.

PARTES DEL CONVENIO

Conste por el presente convenio de prestación de servicios médicos suscrito entre el **Gobierno Municipal de San Borja y el Proyecto de Salud y Antropología Tsimané ,** bajo los términos y condiciones siguientes el cual dirá:

PRIMERA.- DE LAS PARTES

Suscriben el presente convenio de prestación de servicios médicos; la Honorable Alcaldía Municipal de San Borja por una parte, representado por el Sr. Jorge Añez Claros, Honorable Alcalde del Municipio de San Borja, hábil en toda forma de derecho, que en adelante se denominara Alcaldía Municipal de San Borja y por otra parte el Dr.

Daniel Eid Rodriguez, mayor de edad hábil por derecho, representante del Proyecto de Salud y Antropología Tsimané que en adelante se denominara PROYECTO TSIMANÉ.

SEGUNDA.- OBJETO DEL CONVENIO

El objeto del presente convenio consiste en iniciar un plan efectivo de atención de las comunidades, brindando a los enfermos de la etnia opciones con capacidad de resolución de sus problemas médicos basados en un sistema de atención intercultural, multinivel y adaptado a las características culturales de la etnia.

Es ***intercultural*** porque su trabajo se apoya en traductores capacitados, pertenecientes a la etnia, como mediadores entre el paciente y los servicios médicos.

Es ***multinivel*** porque parte de un nivel inicial que consiste en comunarios capacitados como promotores de salud, pasando a un sistema de brigadas médicas que visitan las comunidades periódicamente y un centro de salud para la atención a los adultos mayores en San Borja. Los casos más complicados se dirigen del centro de salud hacia hospitales de mayor complejidad según corresponda con cada caso.

Es ***adaptado a las características culturales de la etnia***, ya que siendo ellos nómadas, siendo la cacería y la pesca importantes para su supervivencia, su estructura social los organiza en pequeñas comunidades, ampliamente dispersas e internadas en la selva con poco acceso a los caminos, las brigadas son el método más eficiente en relación a costo beneficio, porque se cubrirá una gran cantidad de personas con el mismo costo que tener varias postas médicas.

Para la consecución de este propósito la ALCALDÍA aportara con un presupuesto anual de dieciocho mil bolivianos (18000 bs) para cubrir gastos de combustible para los viajes, además los salarios de los traductores tsimane, para lo cual la ALCALDÍA procederá a la modificación presupuestaria para la viabilización de los fondos para el convenio.

La relación de costos es la siguiente:

El pago de los sueldos vendrá de manera directa de parte de la Alcaldía Municipal de San Borja, y sobre los viveres y combustible el personal de la brigada recogera los mismos directamente de los vendedores y será la alcaldía la responsable de cancelar las cuentas.

Por su parte, el PROYECTO TSIMANÉ aportara un presupuesto mensual de seiscientos veintisiete mil novecientos sesenta bolivianos (627960 Bs), para cubrir gastos de administración, alimentación y transporte de adultos mayores al centro de San Borja, salario de profesionales médicos, de laboratorio y personal administrativo, asi como gastos de atención de pacientes transferidos a otros centros de mayor complejidad bajo la siguiente relación de costos:

Proyecto Tsimané	Bs
Sueldo de médicos(3)	200448
Sueldo de personal de laboratorio(2)	100224
Sueldo personal administrativo centro	48000
Gastos alimentación Pacientes(35 pacientes por semana)	120000
Gastos de transporte de pacientes	105000
Atención pacientes transferidos a centros de 3er nivel	54288
Total	627960

RESOLUCIÓN MUNICIPAL: La brigada y el centro de Salud del PROYECTO TSIMANÉ se convierten en el brazo operativo de la atención médica a la etnia Tsimané de parte de la ALCALDÍA, situación que debe ser avalada por resolución municipal.

COBERTURA DE SEGUROS DE SALUD: El PROYECTO TSIMANÉ viabilizara la mayor cobertura de los seguros de salud a la gente de la etnia Tsimané, carnetizando y descargando los costos de atención médica, principalmente el Seguro Paciente Adulto Mayor SPAM y Seguro Universal Materno Infantil SUMI.

TERCERA.- METAS DEL CONVENIO

Se presentan como metas del convenio para la atención de la etnia Tsimané en San Borja

1. Mejorar la cobertura y acceso de los Tsimanes a los seguros de salud SUMI, SUSA y SPAM.
2. Elaborar informes epidemiológicos de las enfermedades por comunidades y grupos de edad, durante el tiempo de atención del servicio médico.
3. Disminuir la prevalencia de hernias en los varones, prolapsos genitourinarios en las mujeres y ceguera por cataratas en los ancianos mayores a 60 años.

4. Tamizaje de Cancer cervicouterino con papanicolao a las mujeres de la etnia Tsimané.
5. Evaluación cardiológica a los ancianos mayores de 60 años.
6. Atención adecuada a los casos graves y/o de mayor complejidad que requieran traslado a centros médicos especializados.

CUARTA.- TIEMPO DEL CONVENIO

Por convenio y aceptación de partes el presente convenio tendrá una duración de dos años calendario a partir del 18 de abril del 2011 hasta 18 de abril del 2013, con la opción de ampliar los proyectos de salud para la etnia y modificar los montos de cooperación. La continuidad del convenio no se afectara por cambio de autoridades de la ALCALDIA o del PROYECTO TSIMANÉ.

Al terminar dicho periodo, el convenio tendrá la posibilidad de renovar y ampliar la vigencia del acuerdo salvo que existiera un desacuerdo entre las partes.

QUINTA.- DE LA GARANTIA

Las personas que suscriben el presente convenio se comprometen a su fiel y estricto cumplimiento.

SEXTA.- DEL DOCUMENTO DE LA CONFORMIDAD

Al presente documento, las partes en señal de conformidad y aceptación con todas y cada una de las cláusulas precedentemente expuestas, firman el presente documento en triple ejemplar para todos los efectos de ley.

Dr. Daniel V. Eid Rodriguez
COORDINADOR NACIONAL DEL
PROYECTO SALUD Y ANTROPOLOGIA
TSIMANE

Jorge Añes Claros
HONORABLE ALCALDE MUNICIPAL
GOBIERNO AUTONOMO DE
SAN BORJA

CONVENIO DE INVESTIGACION EN ANTROPOLOGIA Y MEDICINA CON PRESTACION DE ATENCION MÉDICA A LA ETNIA TSIMANÉ

1. PRIMERA (PARTES INTERVINIENTES)

Intervienen en la suscripción de éste documento:

1.1. El Consejo Regional Tsimane Mosetén CRTM-PL, representada por su presidente el Sr. Clever Clemente Caimani Josecita con C.I. Nº 1688077 Beni.

1.2. PROYECTO SALUD Y ANTROPOLOGÍA TSIMANÉ, representada por el Dr. Daniel V. Eid Rodríguez, coordinador salud con CI 3552233 OR

Ambos en pleno uso de sus facultades legales e intelectuales, concurren a este acto sin que medie ninguno de los vicios del consentimiento como son: el error, el dolor o la violencia.

SEGUNDA (OBJETO DEL CONVENIO)

El presente acuerdo tiene el objetivo de atender las necesidades de salud de las comunidades indígenas Tsimane Mosetene de la reserva Pilon Lajas, lo que se conseguirá con el cumplimiento de los siguientes compromisos:

COMPROMISOS DE PARTE DEL PROYECTO SALUD Y ANTROPOLOGIA TSIMANÉ:

1. ***Cobertura Médica General*** – Visitas medicas anuales a las comunidades, durante las visitas a las comunidades, cada persona tendrá derecho a recibir atención médica para el paciente. Su presencia en la consulta es voluntaria.
2. ***Programa para mejorar la salud de los ancianos*** – Todas las personas mayores de 40 años serian invitados a San Borja para recibir un examen médico completo. Los que quieren recibir su examen serán transportado en la movilidad y/o el bote del proyecto a a nuestra clínica en San Borja. Ahí serán hospedados y alimentados mientras se realice su atención medica. Cada paciente será revisado para detectar enfermedades crónicas como el cáncer, y enfermedades cardiacas, vasculares, y del riñón, hígado, ovario, próstata, intestinos, y vesícula. También se realizarán exámenes de sangre para diagnosticar y tratar anemia, enfermedades infecciosas, función renal y hepática, y el estado del sistema inmune. Igual se realizará exámenes de heces y orina para detectar y tratar parásitos; así como otras enfermedades. Al finalizar el examen médico cada paciente recibirá un informe de sus resultados y el tratamiento correspondiente en los casos que se requiera.

La parte antropológica consistirá en recolectar información demográfica para saber la edad verdadera de cada persona, sus relaciones de parentesco y la historia de residencia. Igual esa información contribuirá al entendimiento de la historia de la etnia.

3. ***Colaboración con el Hospital de San Borja*** – El proyecto designa un médico responsable de realizar un seguimiento a los pacientes internados en el hospital, colaborar en decisiones diagnósticas y tratamiento de los pacientes Tsimanés.
4. **Transporte de enfermos al hospital de San Borja**– Cuando los médicos del proyecto determinen que un paciente requiere atención hospitalaria, el proyecto ayudará con el transporte de pacientes al hospital de San Borja.
5. **Atención y transporte a hospitales del tercer nivel** –El proyecto colaborará con la logística y gastos relacionados con el traslado y hospitalización de pacientes, en los casos que nuestros médicos consideren necesaria la derivación a niveles más complejos de atención medica.
6. **Entrega de informes y resultados de las visitas a las comunidades y atención a adultos mayores.-** El proyecto se compromete a entregar al finalizar las visitas un informe con los resultados de la revision médica de los pacientes en las distintas comunidades.

COMPROMISOS DE PARTE DEL CONSEJO REGIONAL TSIMANÉ MOSETENE CRTM:

1. Poner a disposición del proyecto dos motores, botes y motoristas para facilitar los viajes a las comunidades por el tiempo de duración del convenio. Los gastos de combustible, reparación y mantenimiento corren a cuenta del proyecto.
2. Poner a disposición los equipos de radiocomunicaciones para coordinación de viajes y logística.
3. Coordinación con las comunidades para que se colabore a la brigada con ambientes para la atención medica, así como la participación de la comunidad en acudir a las citas para los seguimientos médicos.
4. Convocar talleres junto con el proyecto para realizarse en las oficinas del Consejo Tsimané con el fin de presentar resultados del los trabajos realizados, discutir y explicar las metas y los métodos del proyecto.

Ambas partes se comprometen a desarrollar actividades en educación, promoción y prevención en salud a través de programas radiales y visitas a las comunidades.

TERCERA (DURACION DEL CONVENIO)

La duración de este acuerdo será de 5 años a partir de la firma del presente convenio.

CUARTA (GARANTIAS DEL CONVENIO)

Las instituciones aquí representadas se comprometen al fiel y estricto cumplimiento del convenio.

Rurrenabaque, 6 de Abril del 2010.

CONSEJO REGIONAL TSIMNE MOSETENE
LA PAZ - BENI
BOLIVIA
T.C.O. PILON LAJAS

Dr. Daniel V. Eid Rodríguez
Coordinador Médico Proyecto Tsimane´

Sr. Clever Clemente Caimany Josecita
Presidente Consejo Regional Tsimané Mosetene

HOSPITAL MODERNO "SAN BORJA"

San Borja - Beni - Bolivia

San Borja, 06 de Septiembre de 2007

Señor:
Dr. Hillard Kapplan
PROYECTO DE SALUD Y
ANTROPOLOGIA T´SIMANE
SAN BORJA – BENI
Presente.-

Ref.: **Solicitud de Cooperación Interinstitucional en Laboratorio Clínico.**

Distinguido Señor:

Es grato dirigirme a Usted, manifestando mi beneplácito por la acertada labor que desempeña en beneficio de la Salud y por el alto espíritu de servicio a la Etnia T´simane que carece de recursos y a la que apoya constantemente.

El motivo de la presente, es para solicitar a Usted, tenga a bien considerar, la Cooperación Interinstitucional en Salud, en el aspecto de que el Hospital San Borja, cuenta con un Laboratorio instalado que brinda servicios a toda la población, y que bien podría contar con el apoyo de vuestra Institución a fin de fortalecer su capacidad de resolución y brindar los servicios que a bien Ustedes requieran, además de poder integrar a nuestros Profesionales en su funcionamiento.

Seguros de contar con su gentil deferencia, ampliaremos según el requerimiento vuestro, la información adecuada sobre este proyecto.

Atentamente.

Dr. Javier Jiménez V.
DIRECTOR
HOSPITAL SAN BORJA

HOSPITAL "SAN BORJA"
Telf. 3202
SAN BORJA
Beni - Bolivia

CONVENIO DE PRESTACION DE SERVICIOS MÉDICOS A LOS MIEMBROS DE LA ETNIA TSIMANÉ

ANTECEDENTES

El presente Convenio se firma con el objeto de dar una respuesta completa, social y médica, a Los problemas de salud ocular que se producen en la Etnia Tsimané. Esta Etnia no ha tenido, ni tiene acceso a una prestación sanitaria que le permita resolver los problemas de salud ocular, lo que provoca un grave impacto en sus vidas y en la de esta Etnia en su conjunto.

La ceguera es una de las principales causas de muerte en países no desarrollados que no disponen de un sistema universal de salud que cubra este tipo de patología de manera efectiva, y en los que además, las posibilidades de que la población invidente acceda al mercado de trabajo y/o cuente con prestaciones y ayudas económicas y sociales son muy limitadas o inexistentes.

Los indígenas de la Etnia Tsimané, constituyen una población que se ha mantenido internada dentro de los bosques tropicales del Amazonas boliviano, en la provincia Ballivian, del Departamento del Beni. Sus actividades principales son la cacería y la pesca.

La Etnia, por el tipo de actividades en la que basa su sustento y su supervivencia, y por el hábitat en el vive, ha vivido ajena a la influencia y los avances de la vida y la sociedad moderna, y no ha accedido, a los servicios médicos, y ello por diversas razones como las dificultades físicas para ello dado que viven en comunidades muy alejadas de cualquier servicio médico, por las dificultades derivadas de la ausencia de caminos y vías de acceso a tales servicios, y por la falta de recursos económicos. En este sentido, hay que destacar que buena parte de los miembros de esta Etnia están fuera del sistema, y no utilizan ni disponen de dinero de curso legal, basando sus prácticas de comercio en el trueque.

Conocida esta realidad, las Partes que ahora convienen en la formalización de este CONVENIO de COLABORACIÓN, llevaron a cabo este año 2011, una primera experiencia con el objeto de dar una solución de cirugía de catarata y/o pterigium a un total de 15 miembros de la Etnia Tsimané.

Estudiada esa primera experiencia, las Partes han convenido en la necesidad /oportunidad de alcanzar un Acuerdo que permita dar una respuesta permanente y sostenible en salud ocular a los miembros de la Etnia Tsimané, de acuerdo con los objetivos y el alcance que más adelante se incluye en este **Convenio de Colaboración para la Prestación de Servicios de Salud Ocular para la Etnia Tsimané.**

PRIMERA.- DE LAS PARTES

Suscriben el presente convenio las siguientes organizaciones:

CÁRITAS CENTRO DE SALUD NUESTRA SEÑORA DE POMPEYA, con domicilio social en Calle Isidoro S/N, zona Pompeya Trinidad-Beni (Bolivia), y representada por la Hermana Petra López, directora Centro de Salud, en adelante CARITAS NUESTRA SEÑORA DE POMPEYA,

FUNDACIÓN MIRADA SOLIDARIA- BEGIRADA LAGUNKIDEA FUNDAZIOA, en adelante FUNDACIÓN MIRADA SOLIDARIA, con domicilio social en C/ Plaza Gran Vía 4º Bis Nº5, Bilbao-Bizkaia, en adelante, Fundación Mirada Solidaria, representada por D. Iñaki Azua Mendia, mayor de edad hábil por derecho, y Director General de la Fundación, y

PROYECTO DE SALUD Y ANTROPOLOGÍA TSIMANÉ, en adelante, PROYECTO TSIMANÉ, con domicilio en Av. Sucre-San Borja S/N, y representada por el Dr. Daniel Eid Rodríguez, director médico del Proyecto de Salud y Antropología Tsimané,

SEGUNDA.- OBJETO DEL CONVENIO

El objeto de este Convenio es el de promover la salud ocular entre todos los miembros de la Etnia Tsimané, y de manera particular:

- Favorecer las campañas y acciones de promoción de salud ocular que permitan:
    - Realizar acciones de formación, educación, sensibilización y prevención de enfermedades de salud ocular entre la población de la Etnia
    - Realizar campañas de identificación, selección y preparación de pacientes para acceder a consultas y cirugías al amparo de lo dispuesto en este Convenio
    - Realizar cirugías de Pterigium y Cataratas para todos los miembros de la Etnia que hayan sido seleccionados para esas intervenciones según los protocolos de funcionamiento que se aprueben y resulten de aplicación en cada momento
    - Asegurar la prestación universal de estas prácticas médicas a todos los miembros de la Etnia Tsimané en las condiciones que más adelante se dirán. En virtud del objeto de este Convenio, las Partes acuerdan y manifiestan expresamente que durante toda la vigencia de este Convenio, NINGÚN MIEMBRO de la Etnia Tsimané quedará excluido de una cirugía, de su posterior control post operatorio, y/o de una consulta, por motivos económicos.

- Contribuir, por medio de este Convenio, a la supervivencia y el desarrollo humano sostenible de los miembros de la Etnia Tsimané

TERCERA.- COMPROMISOS DE LAS PARTES

En virtud de este Convenio de Colaboración, las partes asumen libremente, y por el tiempo que más adelante se dirá, los siguientes **COMPROMISOS,**

PROYECTO DE SALUD Y ANTROPOLOGÍA TSIMANÉ

a) Evaluación y selección de los pacientes que requieren las cirugías de catarata y de pterigium en la Comunidad Tsimané. A los efectos de este Convenio, se entiende por Comunidad Tsimané, la formada por las comunidades ubicadas a orillas del río Maniqui, las comunidades de la carretera Fátima y de la carretera

a Rurrenabaque, las comunidades del río Quiquibey. En el siguiente cuadro se recoge la relación de Comunidades a las que afecta este Convenio:

Comunidad							
1	Alta Gracia	23	Cachuela	45	Eden	67	Maraca
2	Alto Colorado	24	Campana	46	El Paraiso	68	Monte Rosa
3	Anachere	25	Campo Bello	47	El Triunfo	69	Moseruna
4	Aperecito	26	Cara Cara	48	Emeya	70	Moseruna Bajo
5	Arenales	27	Catumare	49	Fatima	71	Motacusal
6	Asuncion de quiquibey	28	Cedral	50	Gredal	72	Munday
7	Bajo Colorado	29	Cero Ocho	51	Ivasichi	73	Napoles
8	Bajo Tacuaral	30	Chacal	52	Jamanchi Uno	74	Naranjalito
9	Bella Isla	31	Chaco Brasil	53	Jatatal	75	Navidad del Maniqui
10	Bigamia	32	Charaton	54	Jerusalen	76	Nuevo Mundo/Campana
11	Bisal	33	Charque	55	La Cruz	77	Pachene
12	Bolson	34	Chontal	56	Las Maras	78	Pachiual
13	Boreyo	35	Chuchial	57	Las Minas	79	Palmito
14	Cuchisama	36	Comunidades Intermedias	58	Limoncito	80	Pampita
15	Cuverene	37	Corte	59	Majal	81	Puchuya
16	Donoy	38	Cosincho	60	Manguito	82	Puente Yucumo
17	Dos de Agosto	39	San Juan de Napoles	61	Santa Rosita	83	Puerto Gregorio
18	San Miguel del Martirio	40	San Luis Chico	62	Tacuaral del Mato	84	Puerto Mendez
19	San Ramon	41	San Luis Grande	63	Turindi	85	Puerto Triunfo
20	Santa Anita	42	San Antonio	64	Vishiricansi	86	Puerto Yucumo
21	Santa Maria	43	San Bernardo	65	Yacumita	87	Rio Hondo
22	San Jose de Canaan	44	San Joaquin	66	Yaranda		

b) Realizar acciones y campañas de promoción de salud ocular en esas Comunidades

c) Dirigir, coordinar y controlar todas las acciones de carácter logístico que resulten necesarias para asegurar la coordinación de la llegada a la localidad de San Borja de todos los miembros de Etnia que serán trasladado a Trinidad para su atención y cirugía, y la de todas aquellas acciones que resultan necesarias para su posterior traslado desde Trinidad a San Borja.

A modo meramente indicativo, las obligaciones de PROYECTO TSIMANÉ en este punto alcanzan tareas como:

- Asegurar la movilidad de los miembros de la Etnia desde Sn Borja a Trinidad, y coordinar y controlar el traslado

- Coordinar y acordar con el personal de CÁRITAS NUESTRA SEÑORA DE POMPEYA, y con antelación suficiente, la programación de las cirugías y las fechas de los traslados correspondientes

- Contactar y coordinar con el/los médicos locales de San Borja con quien/es los firmantes de este Convenio acuerden en cada momento la prestación de servicios y controlar su actividad para asegurar la realización de las tareas y controles, tanto pre como post operatorios, y que éstos se hacen de acuerdo con los protocolos que se fijen desde la Unidad de Oftalmología del Centro de CÁRITAS NUESTRA SEÑORA DE POMPEYA en Trinidad.

- Atender a los gastos a los que se compromete a tenor de los dispuesto y acordado en este Convenio y que, de modo indicativo, incluyen:

    a. Alimentación y Alojamiento en San Borja durante el pre y postoperatorio.

    b. Compra de gafas y sombreros del postoperatorio.

c. Pago de costos de quirófano y medicamentos correspondientes al procedimiento quirúrgico, así como de los gastos de valoración cardiológica y exámenes de laboratorio. El importe de tales gastos resultará de los precios que en cada momento fije CÁRITAS NUESTRA SEÑORA DE POMPEYA. que es quién tiene esta responsabilidad en el Centro de Nuestra Señora de Pompeya, y a quien las Partes, como más adelante se dirá, reconocen de manera expresa, esta competencia.

d. Los gastos de movilidad (traslado) desde San Borja a Trinidad y de Trinidad a San Borja, así como los gastos derivados del alojamiento y manutención de los pacientes de la Etnia desplazados a Trinidad durante toda su estadía en un 50% (el otro 50% será aportado por la FUNDACIÓN MIRADA SOLIDARIA). En este caso, el alojamiento y la manutención serán los que CÁRITAS NUESTRA SEÑORA DE POMPEYA acuerde en cada momento.

CÁRITAS CENTRO DE SALUD NUESTRA SEÑORA DE POMPEYA

a) Liberar a los pacientes de los costos de uso de quirófano, cancelando 100 bs por concepto de material de quirófano.

b) Disminuir al mínimo los costos de medicamentos siendo 64.22 Bs. para el post operatorio de la cirugía de cataratas, y 108.70 bs de la cirugía de pterigium.

MEDICAMENTOS PARA PACIENTES OPERADOS DE CATARATA

FARMACO	CANTIDAD	PRECIO UNITARIO	COSTO TOTAL
Prednisona 20 mg	3	0,92	2,76
Acetazolamida	3	0,92	2,76
Xolof - D colirio	1	56	56,00
Ibuprofeno 400 mg	9	0,3	2,70
TOTAL Bs.			**64,22**

MEDICAMENTOS PARA PACIENTES OPERADOS DE PTERIGIÓN

FARMACO	CANTIDAD	PRECIO UNITARIO	COSTO TOTAL
Nicotear gel	1	50	50,00
Xolof - D colirio	1	56	56,00
Ibuprofeno 400 mg	9	0,3	2,70
TOTAL Bs.			**108,70**

c) Disminuir al mínimo los costos por valoración cardiológico : 20Bs electrocardiograma y 40 Bs. por consulta con el cardiólogo (para mayores de 60 años y/o antecedente de patología cardíaca o hipertensión arterial)

d) Poner a disposición de los objetivos de este Convenio, la Unidad de Oftalmología del Centro de CÁRITAS NUESTRA SEÑORA DE POMPEYA, su personal médico y auxiliar, y todos los medios técnicos y materiales de aquélla, de forma que se garantice una atención de máxima calidad a todos los miembros de la Etnia Tsimané que se desplacen a Trinidad.

e) Coordinar, junto con FUNDACIÓN MIRADA SOLIDARIA, la dirección médica del proyecto, y de manera especial, el trabajo que el / los médicos de la localidad de San Borja vinculados en cada momento a este Convenio deben realizar en el ejercicio de sus responsabilidades y de los compromisos adquiridos a partir de este Convenio.

f) Hacer el control y seguimiento de todas las actuaciones derivadas de este Convenio, y de manera particular:

   a. Hacer el control y seguimiento de todos los aspectos económicos derivados del Convenio, y realizar la contabilidad de todas las campañas que se realicen

b. Informar a las partes del resultado de cada una de las campañas que se realicen, indicando, al menos, personas beneficiadas por la campaña, número y tipo de cirugía practicada, consultas realizadas, costes e ingresos - por naturaleza de los mismos -, etc. FUNDACIÓN MIRADA SOLIDARIA y CÁRITAS NUESTRA SEÑORA DE POMPEYA acordarán el formato de estos informes de actividad.

g) Asegurar los aspectos de logística que resultan necesarios para los pacientes desplazados a Trinidad, y de manera particular los relacionados con movilidad, alojamiento y manutención, con independencia de que su abono sea realizado por terceros.

FUNDACIÓN MIRADA SOLIDARIA-BEGIRADA LAGUNKIDEA FUNDAZIOA

a) Poner a disposición de este CONVENIO, y extender al mismo, en consecuencia, el compromiso que tiene formalmente pactado con el CÁRITAS NUESTRA SEÑORA DE POMPEYA, para asegurar el funcionamiento de su Unidad de Oftalmología, y de manera particular:
   a. Realizar las inversiones necesarias para asegurar un equipamiento de máxima calidad en la Unidad,
   b. Atender a los gastos de personal médico que permita asegurar un equipo humano suficiente en número y en calidad profesional
   c. Contribuir en el pago de insumos en las campañas en las que participa personal médico especializado de la Fundación,
   d. Participar en la formación del personal de la Unidad de Oftalmología del Centro de CÁRITAS NUESTRA SEÑORA DE POMPEYA

b) Participar en campañas de cirugía organizadas conjuntamente con el Centro de CÁRITAS NUESTRA SEÑORA DE POMPEYA, y en consecuencia, practicar cirugías a los miembros de la Etnia que se incluyan en éstas. El personal

médico de la FUNDACIÓN MIRADA SOLIDARIA desplazado a Trinidad, hace su trabajo de manera totalmente gratuita.

c) La FUNDACIÓN MIRADA SOLIDARIA, además de los compromisos arriba indicados, y en atención al alcance de este Convenio, atenderá de manera particular a los siguientes gastos:

   a. Los correspondientes a los insumos médicos para las cirugías de pterigium y cataratas, tales como: pegamento, bisco elástico y lente intraocular, etc.
   b. Los gastos de movilidad (traslado) desde San Borja a Trinidad y de Trinidad a San Borja, así como los gastos derivados del alojamiento y manutención de los pacientes de la Etnia desplazados a Trinidad durante toda su estadía en un 50% (el otro 50% será aportado por el PROYECTO TSIMANÉ). En este caso, el alojamiento y la manutención serán los que CÁRITAS NUESTRA SEÑORA DE POMPEYA acuerde en cada momento.
   c. El pago al médico(s) de San Borja que quede vinculado a este Proyecto en virtud del presente Convenio, una cantidad de 50Bs por la atención, control y seguimiento de los post operatorios por cada uno de los pacientes de la Etnia que hayan sido operados en Trinidad en virtud de este Convenio. El pago se realizará a partir de la recepción del informe que CÁRITAS NUESTRA SEÑORA DE POMPEYA haga llegar a la FUNDACIÓN MIRADA SOLIDARIA con relación a este concepto.

CUARTA. PRECIOS

Se actualizarán anualmente de acuerdo con el índice interanual de precios del consumo en Bolivia. En caso de que resultase necesario, las tres partes podrán acordar

unos precios distintos que serán firmados y aprobados por la mayoría de las partes firmantes.

QUINTA. DE LAS CAMPAÑAS Y LA ATENCIÓN MÉDICA.

Las campañas y el correspondiente servicio de la Unidad de Oftalmología de CÁRITAS NUESTRA SEÑORA DE POMPEYA, se hará atendiendo de manera estricta los procesos y las condiciones que se acuerden a partir de este Convenio.

CÁRITAS NUESTRA SEÑORA DE POMPEYA será quien definirá, acordando con las partes, los procesos para asegurar el normal funcionamiento del Convenio, para asegurar la coordinación y el control de lo que aquí se acuerda. Algunos de los aspectos que dichos procesos deben contemplar para su buena gestión:

- Planificación anual de las campañas
- Identificación y selección de pacientes
- Información necesaria para cada campaña (número de pacientes, datos de los pacientes a desplazar a Trinidad, patología, informes de control pre operatorio disponibles, etc.)
- Control y seguimiento de post operatorios
- Control y seguimiento de gastos

SEXTA.- DURACIÓN DEL CONVENIO

El presente Convenio tendrá una duración de dos años a partir del mes de abril de 2012.

El Convenio se prorrogará automáticamente, en las mismas condiciones y por el mismo plazo de tiempo que éste, salvo que cualquiera de las partes lo denuncie formalmente con una antelación de tres meses a su finalización.

SÉPTIMA.- DE LA GARANTÍA

Las personas que suscriben el presente convenio se comprometen a su fiel y estricto cumplimiento.

OCTAVA.- DEL DOCUMENTO DE LA CONFORMIDAD

Al presente documento, las partes en señal de conformidad y aceptación con todas y cada una de las cláusulas precedentemente expuestas, firman el presente documento en triple ejemplar para todos los efectos de ley.

En Bolivia, a 28 de Marzo de 2012

CÁRITAS CENTRO DE SALUD NUESTRA SEÑORA DE POMPEYA.
Directora, Hermana Petra López

FUNDACIÓN MIRADA SOLIDARIA-BEGIRADA LAGUNKIDEA FUNDAZIOA
Director General, Iñaki Azua Mendia

PROYECTO DE SALUD Y ANTROPOLOGÍA TSIMANÉ
Director Médico, Daniel Eid Rodríguez

ARTICULOS PRENSA INTERNACIONAL

In Bolivian Amazon, a Yardstick for Modern Health

Michael Gurven

PATIENT: A Tsimane woman, left got a checkup as part of a project studying the indigenous community in Bolivia, which lives in mostly traditional ways.

By JEAN FRIEDMAN-RUDOVSKY
Published: September 24, 2012

SANTA MARÍA, Bolivia — There seems to be little that distinguishes the indigenous Tsimane of northern Bolivia from dozens of other native Amazonian peoples. They still live in small communities, fishing daily, hunting and relying on subsistence farming. They remain relatively isolated from the outside world. They still have large families and fall victim to parasites, worms and infectious diseases. And until a decade ago, few had contact with doctors.

The New York Times

Yet since 2002, when the Tsimane Health and Life History Project was founded, the Tsimane (pronounced chee-MAH-nay) have become arguably the most intensely studied indigenous people in the Western Hemisphere, and perhaps the world.

More than 50 Bolivian and American researchers, doctors and students have participated in the health project, generating an array of landmark studies. The population of 13,000, which stretches along the Maniqui River, has become the scientific community's 21st-century "traditional man."

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Research on the Tsimane led to the finding in 2009 that cardiovascular disease is probably an ill of modern societies. Studies of the group also provided the most conclusive data supporting the idea that high levels of physical activity drastically reduce the risk of diabetes, obesity and hypertension.

Ongoing Tsimane research explores links between testosterone and infection, diet and the nutritional value of breast milk, and DNA and life span.

There have been 42 studies with results published, and at least 33 more are under way. “This is the most productive research site in anthropology today,” Ray Hames, an anthropologist at the University of Nebraska-Lincoln, said.

Samuel Bowles, of the behavioral sciences program at the Santa Fe Institute, said, “The Tsimane will soon become a basic point of reference for everyone studying small-scale societies.”

Michael Gurven, an anthropologist at University of California, Santa Barbara, who is a founder and a director of the project, said the primary focus of the Tsimane studies was aging. “We look at what’s different and what’s similar between the Tsimane and Western populations,” he said.

The Tsimane were chosen because of their numbers; of all Amazonian indigenous groups still living relatively traditionally, the Tsimane are one of the most numerous. “Thirteen thousand is a better data pool than 800,” Dr. Gurven said.

The Tsimane also have the advantage of variety within that population, said Hillard Kaplan, an anthropologist at the University of New Mexico and the project’s other founder and director. A small number of the Tsimane live in or around San Borja, the area’s only town; they own motorcycles and use cellphones. The farther up the Maniqui River from San Borja you go, the more traditional the way of life.

In Puerto Yucumo, a village of thatched huts in plantain groves, women sit in groups at midday, their legs outstretched, attending to babies (the average family has nine children), cooking or weaving. They chatter in their native tongue; few speak Spanish and fewer have finished primary school. Their feet are flat, wide and thick, the sign of a lifetime spent barefoot.

“My people are tied to the land and their way of life,” said Jorge Añez, mayor of San Borja, the highest elected seat a Tsimane has held in Bolivia.

The contrast to the modern world provides a fascinating basis for study, with “real public health significance for us,” said John C. Haaga, a program officer at the National Institutes of Health, which has supported the Tsimane studies for years.

The studies have required time and personnel. Thesis students live in communities for up to a year. A roving medical unit visits almost all 90 Tsimane villages at least once a year.

The infiltration of doctors and anthropologists has had some effect on the culture, the researchers acknowledge, but not as much as might be expected.

“The world is changing around the Tsimane, and they are changing with it, regardless of our presence,” said Dr. Kaplan. He said the Tsimane lifestyle was altered much more by government stipends for the children and the elderly, altering the subsistence economy.

Nevertheless, the researchers had a threshold moment as they began the study. Could they, in good conscience, send doctors into the villages to study the population without also providing the Tsimane with basic medical care?

They decided they could not. “The depth of our science and the depth of our helping are two sides of the same coin,” Dr. Kaplan said. His field team offers basic medical exams for anyone who shows up, provides free medicine for common ailments like stomach parasites, and does on-the-spot analysis of blood, urine and fecal samples.

"It would be unethical not to do this," Jane Lancaster, editor of the journal Human Nature, said. "If you are performing research and bothering these people, the least you can do is provide medical care."

Still, officials at one of the project's supporters, the National Science Foundation, wondered: How can you study health conditions while simultaneously altering them? Dr. Kaplan and Dr. Gurven said they convinced the foundation and others that the kind of medical care they administer — sporadic treatment for parasites, ibuprofen for headaches, stitches for machete wounds — does not taint data on chronic, long-term disease.

Indeed, far along the Maniqui River, it's clear that intermittent medical care goes only so far. "Yesterday we had eight kids, now we have seven," said Damiana Vie Cari, 33, of the village of San Joaquin, whose 3-month-old baby had died after lying out in the field while she worked. "Too much sun," she said.

About 4 to 6 percent of the Tsimane die before age 1, according to the project's unpublished estimates. (That's down from 12 percent in 2002, when Dr. Kaplan and Dr. Gurven began their work; reductions in child and maternal mortality have been the team's most notable public health contribution.) About 15 percent die before age 5.

And they still fall ill from parasites and worms, and infectious diseases like dengue, leishmaniasis and tuberculosis.

Mr. Añez, the mayor, said the Tsimane were appreciative of the free health care. Indeed, as soon as the roving medicos alight in a village, mothers with sickly children slung on their backs converge on the teams.

Families go to the San Borja clinic aboard the project's shuttles, which are meant only to transport Tsimane adults age 40 and older for the full work-ups that are part of the studies, including echocardiograms, lung function tests, white blood cell counts, and lifestyle surveys.

Dr. Gurven said the researchers repeatedly explain what they are doing. Every patient must give oral consent, and all are shown a video about where their blood goes for testing.

Yet helping the Tsimane understand the groundbreaking medical findings they are assisting has not been easy.

Melanie Martin, a doctoral student at the University of California, Santa Barbara, remembers returning excitedly to her research village to report her recent findings: Compared with breast milk produced by Western women, Tsimane women's milk is higher in omega-3 fatty acids, which are critical for brain development. She was met with "a lot of blank stares," she said. "So, do we need medicine?" one villager asked.

The researchers nevertheless believe that they are in a race for time. "The Tsimane are not going to stay this way forever," Dr. Gurven said.

A version of this article appeared in print on September 25, 2012, on page D2 of the New York edition with the headline: In Bolivian Amazon, a Yardstick for Modern Health.

Leche materna de indígenas bolivianas: ¿De mejor calidad?

William Márquez

BBC Mundo, Washington

Viernes, 15 de junio de 2012

Las mujeres en Estados Unidos tienen leche de calidad muy pobre. Esa es la conclusión a la que llegaron antropólogos de la Universidad de California e investigadores de la Universidad de Pittsburgh que compararon muestras con las de mujeres de la etnia tsimane en Bolivia y encontraron estas últimas muchísimo más altas en ácidos grasos Omega-3.

La madres tsimane amamantan a sus hijos durante un promedio de dos años y medio.

El estudio no sólo examinó el contenido de ácidos grasos en la leche materna y dieta de las mujeres sino las costumbres de amamantamiento en ambos lugares y los correlacionó con el desarrollo del cerebro infantil.

Los ácidos grasos Omega-3, en particular el ácido docosahexaenoico (ADH), son considerados fundamentales durante el desarrollo fetal del cerebro y hasta los dos años y medio de vida de los niños. Las deficiencias de este elemento en la dieta del menor pueden resultar en severos retrasos cognitivos y visuales y repercutir también en la salud general de los adultos.

Contenido relacionado

Los niños que toman leche materna se portan mejor

Bolivia, líder en lactancia materna

Reina de las grasas

El cerebro está básicamente compuesto de grasa y cualquier organismo que tenga un cerebro tan grande como el humano (siete veces más grande que cualquier mamífero del mismo tamaño) tiene que proveer el material para mantener este órgano.

El ADH es fundamental en el desarrollo del cerebro infantil.

El codirector de la investigación, doctor Steven Gaulin, profesor de antropología de la Universidad de California en Santa Barbara (UCSB), resaltó la importancia de los ácidos grasos Omega-3, especialmente el ADH que constituye 10% del cerebro.

"El ADH es la reina de las grasas", afirmó a BBC Mundo. Es crucial en el desarrollo del cerebro y su funcionamiento, dijo, contribuyendo a la eficiente transmisión eléctrica de las neuronas. "Un cerebro sin ADH casi ni vale la pena".

Como los cerebros del feto y de los niños en sus primeros años crecen a un ritmo muy rápido, las madres tienen que tener esas sustancias en sus reservas grasas para transferirlas a sus criaturas durante la lactancia.

Melanie Martin, que prepara su tesis de doctorado de antropología de UCSB en base a un proyecto con la cultura tsimane de la amazonia boliviana, tomó muestras de leche materna para analizar el contenido de ácidos grasos.

> **Un cerebro sin ADH casi ni vale la pena"**
>
> Dr, Steven Gaulin, Universidad de California, Santa Barbara

El resultado fueron altos niveles de ADH, colocando a las tsimane por encima del 95% de la población mundial y sólo debajo de culturas como la inuit, de la zona ártica, la japonesa y algunas comunidades caribeñas.

"El ADH se encuentra en el pescado y las poblaciones que más lo

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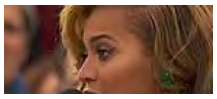

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¿Qué es esto?

consumen tienen más ácidos Omega-3 en sus dietas y leche materna", expresó Martin.

En contraste, las muestras de leche materna tomadas de un grupo de mujeres en Estados Unidos indicaron niveles muy bajos de esta grasa fundamental, colocando al país cerca del fondo de la tabla de contenido de ADH, un resultado que también se repite en países industrializados de Europa Occidental.

"Gemelo malvado"

Lo curioso es que mientras las tsimane sí consumen pescado lo hacen sólo por temporada, cuando los ríos están bajos y la pesca es fácil pero, como es de agua dulce, contiene menos ADH que el pescado de mar.

Melanie Martin (izq.) prepara su tesis de doctorado en base a la dieta y leche materna de las tsimane.

La razón del alto nivel de ADH en el organismo de las tsimane, señaló Melanie Martin, está en lo que no comen.

"Ellas no consumen alimentos procesados que son altos en ácido linoléico u Omega-6", comentó a la BBC. "Pero la dieta estadounidense y occidental tiene altas concentraciones de ácido linoléico presente en el maíz y soja, los aceites derivados de éstos, y las comidas procesadas".

El ácido linoléico (AL) u Omega-6 es considerado el "gemelo malvado" del ácido docosahexaenoico. "Altos niveles de Omega-6 interfieren en la síntesis de los ácidos grasos. La presencia de AL acapara las enzimas que contribuyen a esa síntesis e inhibe la asimilación de ADH en el organismo", explicó.

El doctor Steven Gaulin estudia la correlación entre el bajo contenido de ADH en la leche materna y el desempeño de niños en exámenes cognitivos estandarizados en 25 países de todo el mundo. Estados Unidos figura entre los peores.

La dieta estadounidense y occidental tiene altas concentraciones de ácido linoléico presente en el maíz y soja, los aceites derivados de éstos, y las comidas procesadas"

Melanie Martin, Universidad de California, Santa Barbara

"Estamos cosechando lo que sembramos", afirmó el doctor Gaulin. "Nuestros niños están operando con deficiencia, no solo porque la leche materna es de baja calidad sino porque no es suficiente".

Esta última observación del antropólogo está relacionada al breve tiempo que las madres estadounidenses amamantan a sus hijos, solo hasta los primeros seis meses en promedio, mientras que las mujeres tsimane ofrecen el pecho a sus criaturas permanentemente hasta por lo menos los dos años y medio y no hay tabú en que se haga en público.

Maíz y soja

Es un problema de magnitud social, cultural, comercial, económica y política, aseguró Gaulin. Entre estos factores mencionó que el destete prematuro en EE.UU. sucede porque en dicha sociedad las mujeres están más tiempo por fuera del hogar y es complicado y aún tabú amamantar en público. También buscan regresar rápido al trabajo para mejorar los ingresos de la familia.

El maíz en EE.UU. es subsidiado, barato y omnipresente en la dieta del país.

Desde un punto de vista comercial, "los fabricantes de leche en polvo aplican presión para destetar a los niños" y la industria de alimentos procesados extraen los ácidos grasos Omega-3 -que se degradan muy rápidamente- para prolongar la vigencia de sus comidas en la estantería de las tiendas.

Lo más significativo, sin embargo, es que dos de los principales productos alimenticios de EE.UU. son el maíz y la soja cuyas grasas primordiales son Omega-6, destacó Gaulin.

"No sólo estamos comiendo muchos de estos granos y cocinando con sus aceites, son también el alimento básico de los animales", declaró. "Así que altas concentraciones de

Altas concentraciones de Omega-6

Omega-6 están en nuestra carne, huevos, leche y quesos".

están en nuestra carne, huevos, leche y quesos"

Dr. Steven Gaulin, Universidad de California, Santa Barbara

La situación se complica aún más por la política alimentaria del gobierno, agrega el profesor de UCSB, que subsidia a los agricultores de maíz y soja, bajando los precios de estos productos y haciéndolos más asequibles.

"¿Quién hubiera pensado que es saludable comer sólo dos cosas? pero eso es lo que estamos haciendo", manifestó. "Hay posibilidad de retirar paulatinamente el contenido de Omega-6 en nuestra dieta pero se requiere voluntad política".

Entretanto, la dieta de los tsimane no aparentaría ser muy saludable según algunos estándares. "Son altos en almidones, arroz, mandioca, plátanos", indica Melanie Martin, "pero las tradiciones ancestrales de su dieta y de amamantamiento le provee más ADH para los niños".

No obstante, la etnia boliviana es víctima de parasitismo y luchar contra esta condición requiere muchos recursos calóricos. El doctor Gaulin afirma que mientras la presencia de altos niveles de ADH es positiva, la cantidad de parásitos en un organismo también influye en el desarrollo cognitivo.

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ARTÍCULOS CIENTÍFICOS

Revista: *American Journal of Human Biology* 22:731-740 (2010)

Lípidos de sangre, infección y marcadores inflamatorios en los Tsimane de Bolivia

SARINNAPHAVASUNILASHORN,[1]* EILEEN M. CRIMMINS,[1] JUNG KI KIM,[1] JEFF WINKING,[2] MICHAEL GURVEN,[3], HILLARD KAPLAN,[4] AND CALEB E. FINCH[1]
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Objetivos: Poco es conocido sobre niveles de colesterol (grasa) en sangre en condiciones de infección y limitaciones en la dieta. Este estudio examina grasas, marcadores de infección e inflamación en los Tsimanes de la cuenca amazónica de Bolivia, agricultores-cazadores viviendo en condiciones epidemiológicas como poblaciones Europeas preindustriales debido a la baja expectativa de vida, altos niveles de infecciones, inflamación y limitaciones energéticas.

Métodos: Usamos modelos estadísticos para determinar las relaciones entre niveles de lípidos y marcadores de infección e inflamación. Se analizo los lípidos de sangre, células y marcadores inflamatorios en relación a la carga parasitaria y comunidad de 418 Adultos (entre edades de 20-84 años).

Resultados: La mayoria de los Tsimanes (60%) tenian al menos un especie de parasito, con promedio de 1.3 por persona. Colesterol de suero alta-densidad (HDL-C), colesterol total (total-C), y colesterol de suero bajo-densidad (LDL-C) menores a los niveles en los EEUU y se correlacionan inversamente con marcadores de infección e inflamación. Proteina reactiva-C (CRP), interleukina-6 (IL6), velocidad de sedimentación eritrocito (ESR), imunoglobulina-E (Ig-E) y conteo de eosinofilos. Aunque no había una relación de carga parasitaria con colesterol total, había una asociación entre anemia y prevalencia de parasitos.

Conclusiones: Concluimos que el ambiente infeccioso de los Tsimanes esta relacionado con los niveles bajos de colesterol total, HDL-C y LDL-C. Ese sugiere una posible explicación sobre porque enfermedades arteriales son mayormente ausente en los Tsimanes.

AMERICAN JOURNAL OF HUMAN BIOLOGY 22:731–740 (2010)

Original Research Article

Blood Lipids, Infection, and Inflammatory Markers in the Tsimane of Bolivia

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Objectives: Little is known about blood cholesterol (blood-C) levels under conditions of infection and limited diet. This study examines blood-C and markers of infection and inflammation in the Tsimane of the Bolivian Amazon, indigenous forager farmers living in conditions that model preindustrial European populations by their short life expectancy, high load of infections and inflammation, and limited diets.

Methods: We use multivariate models to determine the relationships between lipid levels and markers of infection and inflammation. Adult Tsimane (N = 418, age 20–84) were characterized for blood lipids, cells, and inflammatory markers in relation to individual loads of parasites and village region.

Results: Most of the Tsimane (60%) carried at least one parasite species, averaging 1.3 species per person. Serum high-density lipoprotein cholesterol (HDL-C), total cholesterol (total-C), and low-density lipoprotein cholesterol (LDL-C) were below the U.S. norms and varied inversely with markers of infection and inflammation: C-reactive protein (CRP), interleukin-6 (IL-6), erythrocyte sedimentation rate (ESR), immunoglobulin (Ig) E and eosinophil count. Although no relationship of parasite load to blood-C was found, there was an association between anemia and parasite prevalence.

Conclusions: We conclude that the highly infected environment of the Tsimane is related to low levels of blood total-C, HDL-C, and LDL-C. This may suggest a potential reason why arterial disease is largely absent in the Tsimane. Am. J. Hum. Biol. 22:731–740, 2010.

The Tsimane, forager farmers of the Bolivian Amazon, are a model for aging in preindustrial human populations because of their short lifespans, high infectious morbidity, variable energy balance with high workloads, natural high fertility (Walker et al., 2008), and limited access to modern medicine. Mortality throughout the lifespan has been high; until recently, their life expectancy at birth of 42.8 years (1950–1989) approximates the demographics of 19th century European populations, Sweden, for example (Gurven et al., 2007, 2008; McDade et al., 2005).

In addition to short life expectancies, the Tsimane also exhibit relatively low levels of blood cholesterol (blood-C) (Vasunilashorn et al., 2010; additional data presented here). Although these low lipid levels may be attributed to their typically modest diets with low saturated fat, the Tsimane also have high levels of infection. We predict that in high-infection environments there would be a potential inverse relationship between markers of infection and inflammation and blood lipid levels.

The Tsimane have a high prevalence of elevated blood C-reactive protein (CRP) at all ages (Gurven et al., 2008; McDade et al., 2007), about 25% having a CRP value greater than 10 mg/dl, a level that indicates acute or chronic infections. In modern industrial nations with longer life expectancy and a lower burden of infection, high levels of CRP ($\geq$3.0 mg/dl) are considered indicators of cardiovascular risk (Danesh et al., 1998; Ridker et al., 2009). Tsimane reaching their 43-year life expectancy have experienced twice the average number of years cumulatively lived with high CRP ($\geq$3.0 mg/dl) above the United States (Gurven et al., 2008).

Blood lipids are important mediators of host defense during the acute phase of innate immunity. Infection and inflammation typically lower blood total cholesterol (total-C) and high density lipoprotein cholesterol (HDL-C), but increase triglycerides (Esteve et al., 2005; Finch, 2007; Jahangiri et al., 2009; Khovidhunkit et al., 2004; McGullicuddy et al., 2009). Several types of infections—viral, bacterial, and parasitic—have been linked to blood lipid levels. Viral infection, as in human immunodeficiency virus (HIV) infections, are associated with lower blood levels of total-C and HDL-C (Anastos et al., 2007; Riddler et al., 2007; Rose et al., 2006), with a greater degree of dyslipidemia associated with greater immune suppression (Constans et al., 1994; Grunfeld et al., 1992; Zangerle et al., 1994). Among those infected with HIV and taking antiviral therapy, total-C, and in some cases, HDL-C was increased (Rimland et al., 2006). Experimental inflammation from bacterial endotoxin (lipopolysaccharide, LPS) induces similar dyslipidemias (McGullicuddy et al., 2009). The hypocholesterolemia and remodeling of lipoproteins during acute phase responses of innate immunity increases clearance of LPS, particularly through increased binding of LPS to HDL particles (Kitchens and Thompson, 2003; Levels et al., 2007), is one example.

Specific parasitic infections also cause dyslipidemias. A study of the Shipibo, another indigenous Amazonian group, showed an inverse correlation of HDL-C with the density of infection by three of five parasitic worm species (N = 32) (Wiedermann et al., 1991). Similar-sized samples

Additional Supporting Information may be found in the online version of this article.

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TABLE 1. Characteristics of Tsimane sample, 20 years of age and older

				Region		
	N	Mean (SD) or %	Range	Forest	River	San Borja
Age	418	39.7 (14.6)	20–84	40.4 (13.4)	38.9 (14.8)	40.6 (15.1)
Males (%)	418	46.7		47.4	47.7	44.3
Regions (%)	418					
Interior forest		18.7				
Upper Maniqui river		52.2				
Near San Borja		29.2				
Anthropometric measures						
Height (cm)	403	155.8 (7.7)	139.6–177.8			
Males	195	162.2 (5.3)	145–177.8	161.6 (5.6)	162.4 (5.6)	162.2 (4.4)
Females	223	150.5 (4.7)	139.6–170.6	149.7 (5.3)	150.9 (4.8)	150.5 (4.2)
Stunted[a]	16	4.0		6.5	4.3	1.7
Body mass index (BMI, kg/m^2)	403	23.2 (2.9)	15.3–39.1			
Underweight (BMI <18.5)	11	2.7		5.2	2.9	0.9
Overweight (BMI ≥ 25)	85	21.1		16.9	19.1	27.4
Obese (BMI ≥ 30)	11	2.7		2.6	1.9	4.3

[a]Males $\leq$155 cm, females $\leq$140 cm (criteria of Centers for Disease Control and Prevention, 1998).
SD, standard deviation.

from a city hospital in Chandigarh, India, showed lower HDL-C for patients with entamoebic and giardia parasites (Bansal et al., 2005). A novel hypothesis linking parasitic infection to cardiovascular disease (CVD) risk is that parasitic worms (helminths) may attenuate atherosclerosis through interactions with host defense systems (Magen et al., 2005). This relationship may involve several mechanisms. First, the helminths can suppress the host immune response through production of antiinflammatory molecules, thereby reducing the risk of CVD. Second, parasitic worms may lower the LDL levels both directly and indirectly: via regulating innate antibodies to cholesterol and interfering with host nutrition (respectively). About one third of LDL turnover is attributed to the effects of these naturally occurring antibodies to cholesterol (Alving and Wassef, 1999; Caspar-Bauguil et al., 1999; Folcik et al., 1997). Moreover, infections potentially elicited by parasites may also regulate host lipid metabolism by stimulating a decrease in total-C levels (Doenhoff et al., 2002).

Nutrition has long been associated with blood-C levels (Clarke et al., 1997). Generally, greater intake of saturated fatty acids has been associated with higher levels of serum cholesterol (C) (Mattson et al., 1972). In subsistence populations, where food containing high saturated fats is less available than in modern societies, C levels are lower. For instance, blood-C was below the U.S. norms in several indigenous African populations and Trobiand Islanders (Expert Panel on Detection Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001; Lindeberg et al., 2003; Pauletto et al., 1996; Pavan et al., 1997), and total-C levels of hunter gatherers were about 125 mg/dl (Eaton et al., 1988).

Another reason for suspecting that inflammatory markers and parasite burden may be associated with lower C among the Tsimane is that in populations with low energy balance and fat reserves, the burden of disease may reduce available energy further, thus affecting circulating C. Considered together, we predict that in high-infection environments there would be inverse relationships between the markers of infection and inflammation and blood lipid levels.

This study extends the previous studies on the separate effects of viral, bacterial, and parasitic infections. We considered that analyzing a combination of these types of infections could further clarify the links to blood lipids. We examined the relationships of blood lipid levels to markers of (1) inflammation [CRP and interleukin-6 (IL-6)], (2) the general burden of infection [erythrocyte sedimentation rate (ESR) and white blood cell count (WBC) and distribution], and (3) specific infections [parasite prevalence and indicators of parasite prevalence, including WBC subtype eosinophil count and immunoglobulin (Ig) E]. We also examine the body mass index (BMI), stunting, and location of village in relation to cultural influences from the nearest town, San Borja.

This article tests the hypothesis that the Tsimane, with a high infectious load, will exhibit relatively low lipid levels; thereby indicating an inverse relationship between infection and cholesterol. We hypothesize that lower levels of blood lipids will be associated with lower levels of past nutrition (i.e., lower BMI) and that blood-C levels will be higher in the more acculturated village regions located near San Borja.

METHODS

Study Sample

This study sample was drawn from the Tsimane Life History and Health Project (Gurven et al., 2008), which has been examining health across the life course since 2002. Interviews, medical examinations, and blood were collected from 17 communities across the traditional Tsimane territories. Blood and feces were sampled in 2004. This forager farmer population, of about 7,000, has low caloric intake relative to energy expenditure and consequently low BMI. The Tsimane provide a model for preindustrial human populations with limited food supply, high energy expenditure, no sanitation systems, no water treatment, and limited medical intervention (Byron, 2003; Reyes-Garcia et al., 2008; Vadez et al., 2004).

Table 1 summarizes the Tsimane adult sample ($N = 418$) for this analysis. The present study was restricted to individuals aged 20 and older (range: 20–84), with blood and fecal samples taken in 2004. Because Tsimane villages have different access to markets and medical care that may affect C and infections, we categorized the Tsimane communities into three geographic regions (Supporting Information Fig. 1) (Gurven et al., 2007): more acculturated villages near the town of San Borja; villages in the interior forest; and remote villages along the upper Maniqui River. These categorizations also reflect the differences in diet; for example, the Maniqui River villagers obtain more food from fish, while those in the forests obtain food from hunting. The Tsi-

TABLE 2. Blood serum lipids and hemoglobin for Tsimane adults

	Tsimane			United States				
	Mean (SD) or %	Range	*N*	Mean (SD) or (SE)[a]	*N*	Clinically normal range	Age	Reference
Lipoproteins								
Total cholesterol	138.0 (29.2)	69–258	415	203.0 (0.8)[a]	8,809	<240	20+	Carroll et al., 2005
% High (>240 mg/dl)	0.2			16.4[b]	1,090			Expert Panel, 2001
HDL	36.8 (8.9)	4–71	356	51.3 (0.4)[a]	8,808	>40	20+	Carroll et al., 2005
% High (<40 mg/dl)	64.0			16.2[b]				Expert Panel, 2001
LDL	70.6 (21.9)	18.4–158.8	231	123.0 (1.0)[a]	3,867	<160	20+	Carroll et al., 2005
% High (>160 mg/dl)	0			11.1[b]				Expert Panel, 2001
Total/HDL cholesterol	3.9 (1.6)	2.2–29.8	353	4.3 (1.4)	3,014	<5.92	20–74	Kannel et al., 2008
% High (>5.92)	2.6			9.9[b]				Seeman et al., 2004
Hemoglobin (g/dl)	12.5 (1.7)	4.3–16.6	414	14.1 (0.03)[a]	15,419		20+	Astor et al., 2002
Males								
Mean	13.2 (1.7)			14.9 (1.3)	8,506	14–18	18+	Hsu et al., 2002; MedicineNet website
% Anemic (<13)	35.8			3.3[b]				
Females								
Mean	11.9 (1.4)			13.1 (1.2)	7,465	12–16	18+	Hsu et al., 2002; MedicineNet website
% Anemic (<12)	47.1			7.2[b]				

HDL, high-density lipoprotein; LDL, low-density lipoprotein.
[a]SE, standard error; SD, standard deviation.
[b]Unpublished analysis using the US NHANES 2003–2006.

mane do not have regular exposure to modern medicines; however, those living closer to San Borja have more access to health care and richer diets, which are indicated by differences in stunting and underweight (Table 1). We include region as a covariate in the analysis to adjust for differences in access to modern medicine and diet.

Cholesterol Measures

Blood serum was analyzed for total-C, HDL-C, and low-density lipoprotein cholesterol (LDL-C). Persons were asked to fast before coming for medical testing, but fasting was not verified. Cholesterol was stratified into high and low levels associated with adverse health outcomes in the United States (Table 2): high-risk cutoffs of HDL-C <40 mg/dl, LDL-C >160 mg/dl, and total-C >240 mg/dl. In ordinary least squares (OLSs) regressions (models described in further detail later), total-C, HDL-C, and LDL-C were used as continuous variables.

Measures of Infection and Inflammation

Blood samples were analyzed for CRP [high sensitivity (hs)-CRP], IL-6, ESR, WBC count and distribution (neutrophils, eosinophils, basophils, monocytes, and lymphocytes), and Igs A, E, G, and M. CRP is an innate immune system response to acute and chronic infections. In the U.S. and other populations with low levels of infection, CRP may also be an indicator of general systemic inflammatory responses due to chronic diseases, including atherosclerosis and diabetes. IL-6 is a cytokine with broad cellular roles in health and disease. Serum hs-CRP and IL-6 were determined from samples collected and frozen in the field, and assayed at 0.1–150.0 mg/l and 2.0–1,000.0 pg/ml (respectively) at the Tricore Reference Laboratories in Albuquerque, New Mexico using Immulite 2000 kits. The mean replicate interassay coefficient variation was 5.6% for hs-CRP and 5.8% for IL-6 (Diagnostics Products Corporation, Siemens, Deerfield, IL). Clinically normal ranges and mean values defined for U.S. populations are shown in Table 3. Using cut points employed in large-scale epidemiological studies to define low and high levels (Ferrucci et al., 2005; Seeman et al., 2004), we created an inflammatory score based on levels of both markers CRP and IL-6 (range, 0–2: 0 = high on neither, high on 1 only, high on both). An alternative score based on the highest Tsimane tertile for CRP (≥5.23 mg/l) and IL-6 (≥3.02 pg/ml) yielded similar results in relation to the blood-C measures; thus, the CRP-IL6 score is based on published cut points.

The ESR (mm/h) gives a nonspecific measure of inflammation (Ingelsson et al., 2005; Sox and Liang, 1986). For a point of reference, we note that the mean ESR in the United States is 15 mm/h (Gillum et al., 1994; Smith and Samadian, 1994) (Table 3). In our OLS regressions, ESR is included as sex-specific quintiles (listed at the bottom of Table 4). Different levels are used for males and females due to gender variations in ESR (Piva et al., 2001).

The WBC (leukocyte) total count includes information on five types that can indicate the type of infection: eosinophils, neutrophils, leukocytes, basophils, and monocytes. The complete blood cell counts were analyzed in the field using fresh samples. Because eosinophils are elevated in some parasitic infections, the level of eosinophils was included as a categorical variable by distributing the percentages into quartiles (Q) in OLS regression.

Four different immunoglobulins (Igs) were measured. IgE levels may be associated with parasitic infection and allergic reactions. IgM is the body's primary response to infection, while IgG is the secondary response. IgA antibodies protect body surfaces exposed to external foreign substances (e.g., ears, eyes, and nose). IgE was included in OLS regressions because of its relationship to parasite prevalence. Because of the varying sensitivity to high levels of the assays used in this project, IgE was categorized into <2,000 and ≥2,000 IU/ml (Barbee et al., 1981), and mean values are not reported (in Table 3) due to the differences in assay sensitivity.

One fresh fecal sample for each person was analyzed in the field by an experienced medical technician, who is a trained biochemist from Universidad Autónoma Gabriel René Moreno. The technician used a microscope to detect

TABLE 3. Measures of infection and inflammation in the Tsimane and United States

	Tsimane			United States			
	Mean (SD) or %	Range	*N*	Clinically normal range	*N*	Age	Reference
C-reactive protein (CRP, mg/l)	9.2 (19.6)	0.19–150	417		3,873	18+	Malik et al., 2005
<3 (%)	52.5			<3			Alley et al., 2006; Ridker, 2003
3.0–9.99 (%)	28.1						
≥10.00 (%)	19.4						
Interleukin-6 (IL-6, pg/ml)	5.2 (9.0)	2–105	394	<4.64	586	65+	Ferrucci et al., 2005; Seeman et al., 2004
<2.68 (%)	67.0				741	65+	
≥2.68 (%)	33.0						
CRP-IL6 score[a]			418				
High on neither	44.0						
High on 1 only	61.6						
High on both	24.4						
White blood cells (WBC)							
WBC count	10,442 (2,960)	2,850–19,500	408	3,800–10,800	3,227	63 (mean)	Horne et al., 2005; International Still's Disease Foundation
% Neutrophils	52.0 (11.5)	0.84		48–73%	3,227	63 (mean)	Horne et al., 2005; International Still's Disease Foundation
% Lymphocytes	27.9 (7.9)	0–53		18–48%	3,227	63 (mean)	Horne et al., 2005; International Still's Disease Foundation
% Eosinophils[b]	20.2 (10.3)	0–49		<5%			International Still's Disease Foundation
% Basophils	0.1 (2.0)	0–33		0–2%			International Still's Disease Foundation
% Monocytes	0.1 (0.9)	0–18		0–9%	3,227	63 (mean)	Horne et al., 2005; International Still's Disease Foundation
ESR (mm/h)	35.8 (24.0)	3–130	413	<50		25–74	Gillum et al., 1994
High ESR (>50) (%)	25.7						Smith and Samadian, 1994
Immunoglobulins (Ig)							
IgA (mg/dl)	322.7 (146.3)	125–2,050	410	80–350			Lymphomation website
High (>385) (%)	23.2						
Low (<85) (%)	0						
IgE (IU/ml)[b]		223–40,000	398	<150 IU/ml	2,743	6+	Barbee et al., 1981; DiaMed EuroGen, 2007; Lymphomation website
High (≥2,000) (%)	94.2						
Low (<2,000) (%)	5.8						
IgG (mg/dl)	1,993.9 (468.9)	210–6,110	411	620–1,400			Lymphomation website
High (>1,765) (%)	69.1						
Low (<565) (%)	0.5						
IgM (mg/dl)	268.0 (262.2)	14–2,460	410	45–250			Lymphomation website
High (>375) (%)	14.9						
Low (<55) (%)	0.2						
Average number of 17 parasites	1.3 (1.1)						
0 (%)	26.5						
1	33.2						
2	26.4						
3 or more	13.9						
Average number of six cholesterol-associated parasites[c]	0.8 (0.8)						
0 (%)	40.2						
1	41.0						
2	15.9						
3 or more	2.9						

ESR, erythrocyte sedimentation rate; SD, standard deviation.
[a]CRP-IL6 index score (where high CRP is ≥3 mg/l; high IL6 is ≥2.68 pg/ml).
[b]Related to parasitic infection.
[c]Entamoeba histolytica, Giardia lamblia, Ascaris lumbricoides, Trichuris trichiura, Uncinaria, Strongiloides

the presence of 17 species of parasites (Supporting Information Table 1): nine species of protozoans (*Balantidium coli, Bastocystis hominis, Chilomastix mesnili, Entamoeba coli, Entamoeba hartmanni, Entamoeba histolytica, Giardia lamblia, Iodamoeba butschilii,* and *Trichomonas hominis*) and seven worm species [roundworms *Ascaris lumbricoides, Strongyloide stercoralis*; whipworm *Trichuris trichiura;* tapeworms *Hymenolepis diminuta* and *Taenia solium* (presumably); pinworm, *Enterobus vermicularis;* hookworm. To determine parasite prevalence, a coverslide with a fecal smear is divided into 30 × 30 boxes. The medical technician scans the coverslide row by row for the presence or absence of any egg, cyst, trophozoite, or larva (depending on the species). Each coverslide is scanned for parasites twice. The first scan occurs at a 10× magnification to search for bigger parasites (e.g., Hookworm, *Ascaris*

TABLE 4. Regression models predicting total and high-density lipoprotein cholesterol levels from markers of infection, inflammation, and parasite burden

	Total-C (N = 345)				HDL-C (N = 318)				LDL-C (N = 218)			
	Model I		Model II		Model I		Model II		Model I		Model II	
	Beta	P value	Beta	P value	Beta	P value	Beta	P value	Beta	P value	Beta	P value
Age	**0.24**	**0.03**	**0.25**	**0.02**	0.03	0.36	0.03	0.45	0.21	0.09	0.23	0.05
Males vs. females	**−7.32**	**0.02**	**−8.02**	**0.01**	0.01	0.99	−0.28	0.78	**−10.37**	**<0.01**	**−11.22**	**<0.01**
Region												
San Borja	Reference		Reference		Reference		Reference		Reference		Reference	
Forest	6.08	0.16	6.5	0.13	**4.11**	**<0.01**	**4.15**	**<0.01**	1.60	0.71	1.00	0.81
River	0.64	0.86	1.52	0.68	0.32	0.80	0.24	0.85	−1.18	0.77	−0.35	0.93
Stunting	0.69	0.92	1.55	0.83	1.65	0.49	1.69	0.48	−2.42	0.71	−1.83	0.78
Body mass index (BMI), quartiles ($Q$1–4)[a]												
$Q$1	−0.39	0.92	−0.01	0.99	**2.68**	**0.02**	**2.71**	**0.02**	0.01	0.99	0.82	0.82
$Q$2	Reference		Reference		Reference		Reference		Reference		Reference	
$Q$3												
$Q$4	**13.13**	**<0.01**	**12.43**	**<0.01**	0.31	0.80	0.41	0.75	**10.02**	**<0.01**	**9.93**	**0.01**
Hemoglobin, quartiles ($Q$1–4)[b]												
$Q$1	**−12.66**	**<0.01**	**−12.67**	**<0.01**	**−2.83**	**0.03**	−2.56	0.05	−2.11	0.60	−1.66	0.68
$Q$2	Reference	Reference	Reference	Reference	Reference	Reference						
$Q$3												
$Q$4												
CRP-IL6 score												
High on neither	Reference		Reference		Reference		Reference		Reference		Reference	
High on 1 only	−3.81	0.28	−3.14	0.37	−1.96	0.09	−1.82	0.11	0.61	0.86	0.65	0.85
High on both	**−9.53**	**0.02**	**−0.90**	**0.02**	**−4.27**	**<0.01**	**−4.54**	**<0.01**	−3.81	0.38	−4.91	0.26
ESR, quintiles ($Q$1–5)[c]												
$Q$1	Reference		Reference		Reference		Reference		Reference		Reference	
$Q$2												
$Q$3												
$Q$4												
$Q$5	1.79	0.66	1.94	0.63	−1.04	0.91	−0.02	0.99	−4.41	0.26	−4.44	0.26
Immunoglobulin E (IgE)	**−18.63**	**<0.01**	**−18.11**	**<0.01**	−2.82	0.25	−2.72	0.27	0.97	0.90	1.18	0.88
Eosinophils, quartiles ($Q$1–4)[d]												
$Q$1	Reference		Reference		Reference		Reference		Reference		Reference	
$Q$2												
$Q$3												
$Q$4	−5.73	0.09	−6.60	0.05	−0.85	0.43	−1.11	0.31	0.25	0.94	−1.38	0.68
Giardia lamblia	−2.51	0.86			7.65	0.05			−3.96	0.76		
Entamoeba histolytica	−5.97	0.34			−2.41	0.27			−4.14	0.52		
Ascaris lumbricoides	5.04	0.22			0.57	0.66			6.74	0.10		
Strongyloides	−6.09	0.33			−2.71	0.22			−11.36	0.12		
Trichiura trichuris	12.12	0.21			5.76	0.06			7.93	0.36		
Hookworm	2.86	0.36			0.16	0.87			0.55	0.86		
Total number of six cholesterol-related parasites												
0			Reference				Reference				Reference	
1			1.33	0.70			0.34	0.77			1.96	0.57
2			3.70	0.43			−0.25	0.87			2.57	0.58
3+			9.33	0.31			3.75	0.25			2.13	0.83

Bold indicates significant effect at $P < 0.05$ level.Total-C, total cholesterol; HDL-C, high-density lipoprotein cholesterol; CRP, C-reactive protein; IL-6, interleukin-6; ESR, erythrocyte sedimentation rate.
Model I: adjusted for age, sex, BMI[a], hemoglobin[b], CRP-IL6 index score (where high CRP is >3; high IL-6 is >2.68), ESR[c], IgE [dummy var: 0 <2,000; 1 ≥2,000], eosinophils[d], stunting, six cholesterol-related parasites.Model II: adjusted for Model I covariates and total number of six cholesterol-related parasites.
[a]Body mass index quartiles
Males—$Q$1: <21.9; $Q$2: 21.9–23.3; $Q$3: 23.3–24.5; $Q$4: ≥24.5; Females—$Q$1: <20.8, $Q$2: 20.8–22.3, $Q$3: 22.3–24.6, $Q$4: ≥24.6.
[b]Hemoglobin quartiles
Males—$Q$1: <12.4; $Q$2: 12.4–13.3; $Q$3: 13.4–14.1; ≥14.2; Females—$Q$1: <11.3; $Q$2: 11.3–12.0; $Q$3: 12.1–12.8; $Q$4: >12.9.
[c]ESR quintiles
Males—$Q$1: <10; $Q$2: 10–18; $Q$3: 19–24; $Q$4: 25–41; $Q$5: >42; Females—$Q$1: <23; $Q$2: 23–33; Q3: 34–42; $Q$4: 43–61; $Q$5: >62.
[d]Eosinophil quartiles
$Q$1: <12, $Q$2: 12–19, $Q$3: 19–26, $Q$4: >27.

lumbricoides, and *Balantidium coli*). The second scan uses a 40× magnification for smaller parasites (e.g., protozoas, *Giardia lamblia*, and Entamoebas). Two slides for each fecal sample are examined: (1) sample is mixed with a 0.9% saline solution to observe movement of certain parasites (e.g., Giardia trophozoites); (2) sample is mixed with an iodine solution to observe the nuclei of amoebas.

Among these parasites, six parasites have been shown to alter blood-C: *Ascaris, Trichuris, Giardia*, Hookworm, *Strongyloides,* and *Entamoeba histolytica* (Bansal et al., 2005; Wiedermann et al., 1991). Dummy variables were constructed for the presence of each of the six parasites; the total number of these six C-related parasites was also examined.

Covariates

Links between blood-C levels and age, sex, and hemoglobin (Hb) levels are also investigated (Au and Schilling, 1986; Crimmins et al., 2008a,b; Inouye et al., 1999; Mjos et al., 1977; Oguntibeju, 2003; Wilson et al., 1994). Because child-

hood infections can stunt growth by reallocating resources for development to combat infection, we include stunted height as an indicator of past exposure to infection (Crimmins and Finch, 2006a,b; Finch, 2007; Finch and Crimmins, 2004; Godoy et al., 2009; McDade et al., 2007, 2008). Stunting is defined using CDC guidelines (Table 1; Center for Disease Control and Prevention, 1998). Current BMI (kg/m^2) is an indicator of both past and present diet and health. In the OLS regressions, BMI is included as population-derived sex-specific *Q*s. Hb, which is related to inflammation and infection as well as with lower lipid levels, was included as a categorical variable based on the sex-specific population *Q*s. Variable-specific *Q* ranges are listed at the bottom of Table 4.

Statistical Analyses

OLS regression was used to determine the associations between blood-C and infection and inflammation. In predicting blood-C levels, two separate models were run for total-C, HDL-C, and LDL-C. The first models include age, sex, region, stunting, sex-specific *Q*s of BMI, sex-specific *Q*s of Hb, CRP-IL6 score, sex-specific quintiles of ESR, IgE, eosinophil *Q*s, and six parasites associated with blood-C. The second models include all the covariates from Model I, except a variable, indicating that the total number of C-related parasites was included instead of the indicators of the six individual, C-related parasites. Analyses used SAS 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS

The sample (Table 1) was restricted to individuals aged 20 and more; the average age was 40 years (range, 20–84). About half resided in the river region (52%); 19% lived in the forest villages; and 29% lived near San Borja. About a fifth (21%) were overweight, but few were underweight or obese (both 3%) or stunted (4%).

Cholesterol

The distribution of total-C, HDL-C, and LDL-C in the Tsimane, compared with the United States, overlaps very little, with the Tsimane exhibiting lower levels for all blood-C levels (Supporting Information Figs. 2–4, respectively). We used data from persons of the same age in the U.S. National Health and Nutrition Examination Survey 2001–2006, a nationally representative study of U.S. residents, to compare the distribution of blood lipids to the Tsimane in a modern and traditional society. Compared with levels of blood-C in the United States, the mean total-C, HDL-C, and LDL-C levels among Tsimane adults are lower (Table 2).

Only one individual, a 35-year-old female, had a high-risk level of total-C (>240 mg/dl). None had elevated LDL-C estimated as >160 mg/dl. Nonetheless, about two thirds had lower HDL-C in the range representing risk for CVD (<40 mg/dl).

Mean Hb levels were normal. Tsimane males and females had an average Hb of 13 and 12 g/dl (respectively), compared with U.S. male and female averages of 15 and 13 g/dl (respectively) (Table 2). Half of the Tsimane women and 37% men were anemic compared with 7% of U.S. women and 3% of U.S. men. Fifty-two percent of Tsimane men and 61% of women with *Ascaris* were anemic. All men infected with *Trichuris* had anemia (Supporting Information Table 1).

Infection and Inflammation

Table 3 lists the means and range for various markers of infection and inflammation in the Tsimane and United States. For many of these indicators, the Tsimane mean levels exceed the U.S. clinical norms. About 48% had elevated levels of CRP (≥3 mg/l), 33% had high IL-6 (≥2.68 pg/ml), and nearly 25% had elevations of both CRP and IL-6. The total WBC averaged 10,442 cells/mm^3, in the upper range of the clinical norm. In contrast, mean WBC for individuals in the United States without coronary heart disease is 7,500 cells/mm^3 (Friedman et al., 1974). Neutrophils, lymphocytes, and eosinophils in the Tsimane constituted 51%, 28%, and 20% of WBC (respectively) (Table 3); mean Tsimane lymphocyte percentage (28%) is above the U.S. mean (19%) (Horne et al., 2005). Relative to U.S. norms, eosinophils were elevated in 97% of Tsimane, with mean values about fourfold above the U.S. mean (International Still's Disease Foundation, 2008). ESR was elevated in about one quarter (>50 mm/h), with Tsimane mean ESR values (35.8 mm/h) twofold above the U.S. mean (15 mm/h) (Gillum et al., 1994; Smith and Samadian, 1994). Means of all Igs exceeded the U.S. range, with a substantial proportion in the high range for IgA (23.2%), IgE (94.2%), IgG (69.1%), and IgM (14.9%).

The majority (60%) of fecal samples had at least one of the six C-related parasites; two or more parasites were carried by 40% and the average number of parasite species per person was 1.3 (Table 3). The prevalence by species was Hookworm (46.2%), *Ascaris lumbricoides* (17.0%), *Entamoeba histolytica* (7.3%), *Strongyloides* (7.1%), *Trichuris* (2.9%), and *Giardia lamblia* (1.6%) (Supporting Information Table 1). These prevalence rates approximated those of other indigenous populations in South America (Baruzzi, 1970; Benefice and Barral, 1991; Chernela and Thatcher, 1989; Kaplan et al., 1980; Miranda et al., 1998; Santos et al., 1995; Tanner et al., 2009).

Associations of Cholesterol with Parasitic Infection, Other Markers of Infection and Blood Inflammatory Markers

In univariate analyses, most blood-C markers vary inversely with levels of infection (Supporting Information Table 2). Moreover, those in the highest ESR quintile had lower total-C levels than the lowest quintile; relative to no parasites, those with one or more parasites had lower total-C levels. However, there was no significant inverse relationship of total-C to eosinophil level (%).

The associations of HDL-C with parasitic infection and other markers of infection and blood inflammatory markers resemble those of total-C (Supporting Information Table 2): lower HDL-C levels were associated with elevated CRP, IL-6, the composite of high CRP and IL-6, and ESR quintiles 4 and 5 (compared to quintiles 1 and 2). Additionally, lower HDL-C was associated with the prevalence of *Entamoeba histolytica* and *Strongyloides*, and having at least one of the six C-related parasites.

For LDL-C, there were no significant relationships between the indicators of infection and inflammatory markers (Supporting Information Table 2). Only elevated levels of IL-6 were significantly associated with lower LDL-C levels.

Multivariate Analysis

Markers of infection and blood inflammatory markers were generally associated with lower total-C, HDL-C, and

LDL-C in multivariate analyses (Table 4). Models I and II showed an inverse relationship of total-C to elevated levels of both CRP and IL-6 ($P = 0.02$ for both models), having high IgE ($P < 0.01$, for both models), being in the highest Q of eosinophils ($P = 0.09$ and $P = 0.05$ for Models I and II, respectively) and in the lowest Q of Hb ($P < 0.01$ for both models).

Relative to Tsimane near San Borja, residents in the more remote forest region had higher total-C ($P = 0.16$ and $P = 0.13$, Models I and II, respectively). Compared to individuals with BMI in $Q2$ and $Q3$, those in $Q4$ had higher total-C ($P < 0.01$ for both models). These multivariate models could underestimate the total effect of parasite prevalence, which presumably affects IgE levels and eosinophils.

Age and sex were associated with total-C ($P = 0.02$ for both models), such that increasing age was related to higher total-C levels ($P = 0.03$ and $P = 0.02$ for Models I and II, respectively) and females had higher total-C than males ($P = 0.02$ and $P = 0.01$, respectively).

Models I and II also showed an inverse relationship between HDL-C and high levels for both CRP and IL-6 ($P < 0.01$ for both models) and being in the lowest Hb Q ($P = 0.03$ and $P = 0.05$ for Models I and II, respectively) (Table 4). Akin to total-C, there were no significant relationships of total-C to parasite prevalence (Model I). Also, similar to the total-C findings, forest residents had higher HDL-C levels compared with those living near San Borja ($P < 0.01$ for both). In comparison to individuals with BMI $Q2$ and $Q3$, those in $Q1$ and $Q4$ had higher HDL-C levels, although this relationship was significant only for $Q1$ ($P = 0.02$ for both models).

Similar to total-C and HDL-C, no relationships of LDL-C to parasite prevalence were significant (Table 4; Model I). Compared to individuals with BMI in $Q2$ and $Q3$, those in $Q4$ had significantly higher LDL-C ($P = 0.01$; Model II); in contrast to females, males had lower LDL-C levels as well ($P < 0.01$). Those residing in the forest area also had higher LDL-C than those living in San Borja ($P < 0.01$; Model II).

Overall, our regression analyses show that, after adjusting for various covariates, there is a significant inverse relationship between blood lipid levels and indicators of infection and inflammation. Of note, however, is the difference in the relationships between control variables and the different lipids. For instance, sex and BMI are significantly associated with total-C and LDL-C, but not to HDL-C. And the village region is only associated with HDL-C and not to total-C and LDL-C.

DISCUSSION

This study documents the high pathogen load and low blood lipids of the Tsimane and is the first to investigate multiple indicators of infection and inflammation to blood-C levels in a highly infected population. The high levels of pathogens are consistent with earlier reports on the Tsimane, in this locale (McDade et al., 2005; Gurven et al., 2007; Tanner, 2005). We found that higher levels of infection and inflammation were associated with lower levels of total-C, HDL-C, and LDL-C. These relationships remained after adjusting for other variables related to blood-C, including age, sex, nutrition (as indicated by village region and BMI), past infection (stunting), and Hb.

The lower total-C, HDL-C, and LDL-C in the Tsimane are suggestive of remodeling of the HDL-C particle during infections. In acute phase responses of innate immunity, HDL is altered ("acute phase HDL"), including a reduction of HDL-C, decreased antioxidant activity, and other structural–compositional changes and interactions with inflammatory proteins (Khovidhunkit et al., 2001, 2004). Experimentally induced inflammation by endotoxin (LPS) impairs multiple aspects of reverse C transport that are antiatherogenic, including efflux of blood-C from macrophages to HDL-C (McGullicuddy et al., 2009). Future studies may characterize the subclasses of HDL-C particles, particularly the remodeled particles associated with serum amyloid (SAA) that arise during acute phase responses (McGullicuddy et al., 2009). The low fat diet of the Tsimane (Byron, 2003; Reyes-Garcia et al., 2008) may also be a factor, because blood-C can be lowered by low caloric diets or fasting; we adjusted for this variability in caloric intake by including village region and BMI in the multivariate analysis. Given the interrelatedness of infection and caloric intake in determining energy balance, it is often difficult to parcel out their independent effects. The lack of fat reserves may also interact with infectious load in producing low levels of blood-C. An adaptive response to high-infectious load may be to divert energy to combat infections.

These results may provide insight into the endogenous adaptive process of energy regulation. Where the infectious burden is high, the body allocates more energy to immune responses, both invoking innate and acquired immunity, thereby reducing the available energy for other activities. The results on HDL-C are particularly interesting in this regard, as is the relationship of Hb to total-C, hence suggesting that energy limitation is probably critical here. Some parasitic infections have been shown to cause anemia (e.g., *Ascaris lumbricoides, Trichuris trichiura, Entamoeba histolytica*) (Oguntibeju, 2003; Walter et al., 1997). This may indicate that infection reduces oxygen transport to muscles, possibly through an adaptive reallocation of energy to immune function. Similarly, presence of *Ascaris* and *Trichuris* in our Tsimane sample was associated with anemia, while the presence of *Entamoeba histolytica* or the total number of prevalent parasites was not.

In addition to considering indicators of infection and inflammatory markers, none of the six C auxotrophic parasites that has been previously associated with lower blood-C was associated with individual differences in blood-C in our study. This indirectly suggests that other types of infection, aside from parasitic infection, are important to the relationship between blood lipid levels and infection. Alternatively, the presence or absence of a specific parasite might be too crude for detecting the effect on blood-C. If most individuals have low-level parasitic infection (as shown in Supporting Information Table 1), egg or worm burden information might more reliably predict blood-C levels. We found that the number of parasites was a better predictor of blood-C, perhaps because individuals carrying a greater number of parasites (or polyparasitism) also may have a greater intensity of infections, which may explain the differences in effect between our measure of the total number of parasites and blood-C compared with the relationship between the presence of each individual parasite and blood-C levels. Moreover, IgE and eosinophil percentage may be a better indicator of parasitism compared with the presence/absence of parasite measure employed here; this may be especially true if parasitism is more chronic. Our study, however, does find a significant inverse relationship between high IgE levels and total-C.

Gender differences in blood-C among the Tsimane are similar to those of other populations, with males exhibiting lower total-C and LDL-C compared to females (Assman and Schulte, 1987; Kastarinen et al., 1997; Mazzarolo-Cruz et al. 1995; O'Meara et al., 2004; Stern et al. 2000). Proposed reasons that account for these sex differences include intrinsic differences in biological risk levels and acquired risks due to differences in work, lifestyle, and health aspects (Waldron, 1983). Increasing blood-C levels with age, as found for total-C in the Tsimane, have also been reported in studies of populations with low-fat diets (e.g., Tarahumara and Guatamalan Indians) (Conner et al., 1978; Mendez et al., 1962; Werner and Sareen, 1978) as well as high-fat diets (e.g., the United States) (Jacobs et al., 1980; Keys et al., 1952). Proposed determinants of this increase with age in total-C include increases in body fatness with age (Berns et al., 1989).

In the present study, modern medications are unlikely to be an important factor, because until recently these Tsimane populations have had almost no access to modern medicine. While it is still very limited, it has increased within the past 10 years. Ethnobotanic knowledge may also be an important variable in these local differences: McDade et al. 2007 showed that the level of maternal ethnobotanic knowledge correlated with Tsimane child growth and health and could have been similarly employed more by those living in the more remote villages of the present study, as suggested by a moderate correlation between mother's ethnobotanic knowledge and village distance to the nearest commercial center ($0.49, P < 0.001$).

This current study has several strengths, particularly the availability of multiple markers of immune activation and inflammation and parasite prevalence, in addition to evaluations on blood-C levels, in a unique population. This study sample gave a unique opportunity to investigate the relationship between living in a high infection environment and blood-C levels within an indigenous population. While several studies have examined the relationship of markers of infection and immune activation to blood-C or the relationship between parasites and blood-C, none has examined the relationships among all of these indicators in a well-defined indigenous population.

We also note some limitations. These cross-sectional observations without a longitudinal component do not allow us to evaluate causal effects. We do not know whether specific infections result in activation of the inflammatory cascade, which in turn may affect blood-C. Another caveat is the uncertainty of fasting in the blood samples. The observed low LDL-C thus might be even lower if fasting were complete. When we categorize the individuals into those with blood samples drawn in the morning (before 12 p.m.—samples likely reflecting fasting conditions) and in the afternoon (at or after 12 p.m.—samples less likely to reflect fasting conditions), we find no significant differences in total-C, HDL-C, nor LDL-C levels ($P = 0.16$, 0.69, and 0.13, respectively). Also, the limited number of cases and the nonsignificant results for LDL-C suggests that the reported relationships of the presence of the three parasites (*Ascaris, Strongyloides*, and Hookworm) to LDL-C reflects a true association (power values of 91, 99, and 97%, respectively), but there does not appear to be enough power to estimate the relationships of LDL-C to other variables. Lastly, our use of fecal smears to determine parasite prevalence may result in an underestimate of the actual parasite load. Depending on the location of the stool from which the slide smear sample was taken, traces of a prevalent parasite may not have been detected. This would alter the observed relationships. Using Percoll gradients to concentrate parasites in a small sample of Tsimane samples, we observed about one additional parasite species per person above the fecal smears. Another limitation of our measure of parasite prevalence is the single fecal sample, which may give an inaccurate parasite prevalence. For a subsample ($N = 56$) with two fecal samples taken on different dates in 2004, the majority (70%) showed no difference in the total number of C-associated parasites.

Variations in blood-C show about 35% heritability in North America, Europe, and Japan (Dahlen et al., 1983; Hegele et al., 1997; Heller et al., 1993; Rao et al., 1982). Genetic heritabilities for Amerindians enrolled in the Strong Heart Study (North et al., 2003) and among Mexican Americans (Mitchell et al., 1996) were also found for HDL-C. Among Yucatan Mayans, polymorphisms in the apolipoprotein AI/CIII/AIV gene cluster were associated with a lowering of total-C (Ahn et al., 1991). Futhermore, in Mexican Americans of the San Antonio Family Heart Study, the additive effects of both shared genes and environments contributed to an inverse relationship between HDL-C and triglycerides (Mahaney et al., 1995), suggesting that gene/environment interactions underscore a substantial amount of the variation in blood lipid levels. Genetic analysis for the Tsimane is planned, and based on previous studies, we expect that accounting for the effects of genetic differences, the variance in blood-C levels due to some factors (e.g., BMI) will be slightly reduced.

In summary, we conclude that the highly infected environment of the Tsimane is related to low levels of blood total-C, HDL-C, and LDL-C. Our recent study examines other vascular risk factors and potentially related health outcomes, which have provided more insight as to the immediate and long-term consequences of living under such highly infected environmental conditions (Gurven et al., 2009). Decreases in ankle brachial index, a measure for peripheral arterial disease (PAD) diagnosis, was associated with higher ESR and diastolic blood pressure, suggesting a relationship between cardiovascular risk factors, PAD, and infection. Moreover, higher ESR is also associated with lower SBP and DBP in the Tsimane. This study indicates that arterial disease is largely absent in the Tsimane, and our present study indicates that one mechanism promoting this would be low levels of blood-C and disease-mediated reductions in blood-C. Moreover, the Tsimane could be an important population for evaluating the hypothesis that parasitic helminths attenuate atherosclerosis and CVD risk through interactions with host-defense systems (Magen et al., 2005). The present samples allow further analysis of a population with limited access to antibiotics that can alter inflammatory processes of atherogenesis. The Tsimane thus represent a unique and fleeting opportunity to study relationships of infection, inflammation, and aging-related conditions under preindustrial conditions similar to those of our ancestral past in the absence of modern medicine.

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Mortalidad de los Tsimanes de Bolivia: Variación entre Regiones del Territorio Indígena y Tendencias en el Tiempo

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RESUMEN

Este articulo examina tendencias regionales y temporales en mortalidad entre los Tsimanes, una población de agricultores-recolectores en las tierras bajas de Bolivia. Comparamos mortalidad por edad en comunidades aisladas de monte y río con las más cercana de San Borja, examinamos cambios en niveles de mortalidad por edad en los últimos 50 años. Usamos un método de estadística (se llama regresión logística) para ver los efectos de región, periodo, sexo y edad sobre mortalidad. Comunidades aisladas muestran tasas de mortalidad en infantes hasta adultos que son 2 a 4 veces más alta que las comunidades cerca del pueblo. Mientras había poco cambio en mortalidad durante los años 1950-1989, la expectancia de la vida ha mejorado 10 años, de 45 a 53, después del año 1990. Mayor de la mitad de los muertos fueron causados por enfermedades infecciosas, especialmente infecciones respiratorias y gastrointestinales. Accidentes y violencia explican un cuarto de los muertos. A diferencia de los patrones típicos descritos por la teoría de la transición epidemiológica, vimos una reducción más alta de las tasas de mortalidad en adultos y ancianos que en los niños e infantes. En las comunidades aisladas, las tasas de mortalidad infantil han cambiado poco, mientras que las tasas de mortalidad entre los adultos mayores se redujo drásticamente. Nuestra hipótesis es que este patrón se debe a una combinación de diferencias de acceso a intervenciones médicas, falta de infraestructura de salud pública y las creencias culturales sobre la enfermedad y la muerte.

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Original Research Article

Mortality Experience of Tsimane Amerindians of Bolivia: Regional Variation and Temporal Trends

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ABSTRACT This paper examines regional and temporal trends in mortality patterns among the Tsimane, a population of small-scale forager-horticulturalists in lowland Bolivia. We compare age-specific mortality in remote forest and riverine regions with that in more acculturated villages and examine mortality changes among all age groups over the past 50 years. Discrete-time logistic regression is used to examine impacts of region, period, sex, and age on mortality hazard. Villages in the remote forest and riverine regions show 2–4 times higher mortality rates from infancy until middle adulthood than in the acculturated region. While there was little change in mortality for most of the life course over the period 1950–1989, overall life expectancy at birth improved by 10 years from 45 to 53 after 1990. In both periods, over half of all deaths were due to infectious disease, especially respiratory and gastrointestinal infections. Accidents and violence accounted for a quarter of all deaths. Unlike typical patterns described by epidemiologic transition theory, we find a much larger period reduction of death rates during middle and late adulthood than during infancy or childhood. In the remote villages, infant death rates changed little, whereas death rates among older adults decreased sharply. We hypothesize that this pattern is due to a combination of differential access to medical interventions, a continued lack of public health infrastructure and Tsimane cultural beliefs concerning sickness and dying. Am. J. Hum. Biol. 19:376–398, 2007.

Analysis of mortality patterns by Neel and Weiss (1975) among the Yanomamo of Venezuela and Brazil was a bugle call to anthropologists to "produce comparable bodies of [demographic] data" of relatively isolated tribal populations. Thirty years later, the number of thorough demographic studies remains few [see for example, Howell (1979) on !Kung, Hill and Hurtado (1996) on Ache, Blurton Jones et al. (2002) on Hadza, Early and Headland (1998) on Agta, Layrisse et al. (1977) on Warao, Pennington and Harpending (1993) on Herero, Early and Peters (2000) on Yanomamo, Hill et al. (in press) on Hiwi]. Our understanding of mortality profiles among remote, relatively unacculturated people living in autarkic societies without the convenience and protection of public health and sanitation programs, modern medicine, access to hospitalization, and predictable resources therefore relies heavily on few well-worn examples. Furthermore, there are even fewer cases for which the mortality experience of middle-aged and older individuals living in remote subsistence-oriented populations is well documented. The lack of focused studies is due in part to problems of age-estimation and small sample sizes of older individuals. Many studies tend to cluster adults into large age categories such as 40+ or 50+. As a result, we know very little about the traditional human aging process and how it varies among societies.

In a recent review of all available demographic data on mortality patterns among hunter-gatherers and forager horticulturalists, Gurven and Kaplan (2006) showed that

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prior to significant exposure to western medicine and public health, humans exhibit a characteristic mortality profile that differs dramatically from that of other nonhuman primates, including our closest relative, the chimpanzee. We found that: (1) Postreproductive longevity is a robust feature of hunter-gatherers and forager-horticulturalists, appearing to be a fundamental feature of the life-cycle of Homo sapiens. Survivorship to grandparental age is achieved by over two-thirds of people who reach sexual maturity, and lasts for two decades, on average; (2) life expectancies for modern foraging, and presumably ancestral populations, are typically low due to high infant and child mortality but adult mortality rates remain low through the fifth decade of life; (3) much of the variation across foraging and forager-horticultural populations in mortality hazards and life expectancy at birth is due to differences in infant and childhood mortality rates; (4) mortality rates across populations tend to converge during adulthood, especially during and after late middle age; (5) all populations show a modal age of adult deaths for hunter-gatherers in the range of 65–75 years, which we interpret as the closest functional equivalent of an "adaptive" human lifespan.

Departures from this general pattern in published estimates of life expectancy in historical and past populations are likely due to a combination of high levels of contact-related infectious disease, excessive violence or homicide, methodological problems that result in poor age estimates of older individuals, and inappropriate use of model life tables (ibid). On average, we found that illnesses accounted for 70%, violence and accidents 20%, and degenerative diseases 9% of all deaths in the cross-cultural sample. Illnesses largely include infectious and gastrointestinal disease, although less than half of all deaths in our sample were contact-related disease.

Today, however, most of these and other small-scale subsistence-oriented groups have undergone or are undergoing dramatic change due to their increasing incorporation into modern state societies. While increased sedentism, intensive farming, and greater market access are often clearly associated with higher fertility (Bentley et al., 1993; Sellen and Mace, 1997), the effects on health and mortality are more ambiguous (Godoy et al., 2005b). A lack of micro- and macro-nutrient diversity and increased susceptibility to infectious disease are two pathways by which morbidity and mortality can increase in transitional and acculturated populations (Cohen, 1989; Eaton et al., 1988). While the former may be due to a heavier reliance on carbohydrate-rich and protein-poor farm staples, the latter is usually attributed to increased sedentism and higher population densities that are typical of groups heavily reliant upon agriculture. On the other hand, however, access to vaccinations, improved hygiene, antibiotics, and medical services may reduce morbidity and mortality. The total effects of these two processes remain largely unexplored. Furthermore, acculturation need not impact mortality on each age class in the same way. For example, immunizations can substantially reduce infant and child mortality, but might impact adult mortality mainly among the immunized cohort (Crimmins and Finch, 2006).

Over the last four decades, demographers and epidemiologists have developed a body of theory and empirical data to explain patterns of change in mortality and morbidity rates that accompany modernization (Frederiksen, 1969; Gribble and Preston, 1993; McKeown, 1976; Omran, 1971; Preston, 1976; Salomon and Murray, 2002). Those changes have been termed the 'epidemiologic transition' and were first described by Omran (1971). Omran (1971) defines the epidemiological transition as "the complex change in patterns of health and disease and on the interactions between these patterns and their demographic, economic, and sociologic determinants and consequences". Omran's theory of the epidemiologic transition is based on five principles. First, mortality is the fundamental factor underlying population dynamics. Second, during the transition, pandemics of infection are replaced by chronic, degenerative diseases as the primary causes of morbidity and mortality. Third, the most profound changes in health and disease patterns are found among children and young women. Fourth, changes in disease patterns are associated with demographic and socioeconomic changes that accompany modernization. Fifth, three models of the historical transition have been defined according to the pace and timing of changes in disease patterns and mortality—the classical or western model (England/Wales, Sweden), the accelerated model (Japan), and the contemporary or delayed model (Chile, Ceylon).

Omran's most significant findings are that during the first phases of the epidemiological transition, infectious diseases are gradually replaced by chronic, degenerative diseases as

the leading causes of death and that changes in public health and socioeconomic conditions had massive effects on reducing infant and early childhood mortality due to the lowered exposure to infectious disease (see also Preston, 1976). Only minor effects on older age mortality were found early in the transition, and major changes in adult lifespan were only achieved after 1960 in subsequent epidemiological transitions (Crimmins, 1981). However, Gage (2005) shows that some declines in adult mortality occurred in several European countries during the early part of the 19th century, prior to dramatic drops in mortality at the end of the 19th century and first part of the 20th century.

In this paper, we argue that the mortality experience of small-scale indigenous populations in response to exposure to modern states today may be very different from that which occurred a century ago with the rise of public health. In the specific case of the Tsimane, we find exceptionally large reductions in adult and old age mortality, and no declines in infant mortality. High infant mortality given lower adult mortality has been described as a fairly widespread phenomenon in Latin America and perhaps other parts of the developing world (Palloni, 1981).

Against this background, this paper has four principal goals. First, it contributes to the pool of demographic studies on small-scale societies by exploring mortality patterns among the Tsimane, a population of forager-horticultarists living in the Bolivian Amazon (Fig. 1). The Tsimane diet is a mix of wild game, fish, plantains, and rice. Although agriculture provides approximately three fourth of the caloric contribution to the diet, the relative abundance of protein and lipid sources varies depending on proximity to rivers, where fish is plentiful and primary forest where wild game is abundant. The mix of farming and foraging presents viable options for obtaining benefits of a diet rich in proteins, lipids, and carbohydrates. If diet quality deteriorates with the shift to agriculture then a population with a mixed subsistence strategy should show improvements in health indicators in comparison to pure foragers or pure horticulturalists. By examining mortality at all ages, we hope to document and situate the Tsimane case in the larger body of Amazonian and other anthropological populations.

A second goal is to provide more precise estimates of mortality patterns among middle- and old age individuals. The Tsimane demographic sample contains the largest sample size of risk-years for older adults that we are aware of for a small-scale indigenous population, and therefore allows for a more thorough depiction of mortality in late adulthood.

Third, and most importantly, our goal is to examine regional and temporal variation in mortality rates in different Tsimane communities. The Tsimane are rapidly acculturating to national society and acculturation is an uneven process. The attraction of markets and other features of national society has been and will continue to impact indigenous groups all over Amazonia and the rest of the world (see Godoy, 2001). One enticement of acculturation may be the positive impact on health status. On the other hand, increased population density and food stress also appears to accompany acculturation among the Tsimane and other Amazonian populations. Increased population size and density is often associated with increased waste accumulation, macroparasites, gastrointestinal disease, and higher rates of acute infections (Ewald, 1994). If health worsens and morbidity increases, the question of why acculturate is even more salient (Godoy et al., 2005a).

Teasing apart the separate effects of dietary shifts and population size or density effects can therefore be difficult. Tsimane currently reside in both dispersed, small settlements and larger, more densely populated villages. Tsimane villages that are more acculturated and closer to town tend to be larger. Thus, the Tsimane case is useful for distilling mortality variation that might be due to broad differences in both diet and population density. Health care, immunizations, and hospitalization are beneficial byproducts of increased access to market towns, whereas loss of traditional culture, alcoholism, sexually transmitted diseases, infectious disease, stress, and depression are often unfortunate concomitants of acculturation. One key factor affecting the level of acculturation and exposure to modern medicine is the nearness and ease of access of different villages to markets by way of roads or rivers. Variation in acculturation by geographical area is therefore a natural experiment for investigating the effects of integration on mortality. By focusing attention on the distance of different villages to the nearest market town, San Borja, and on temporal changes in mortality, we can begin to understand the differential effects of modernization on overall and age-specific Tsimane' mortality. In addition, there have been changes in mortality rates over time, and those changes interact with both age and community location.

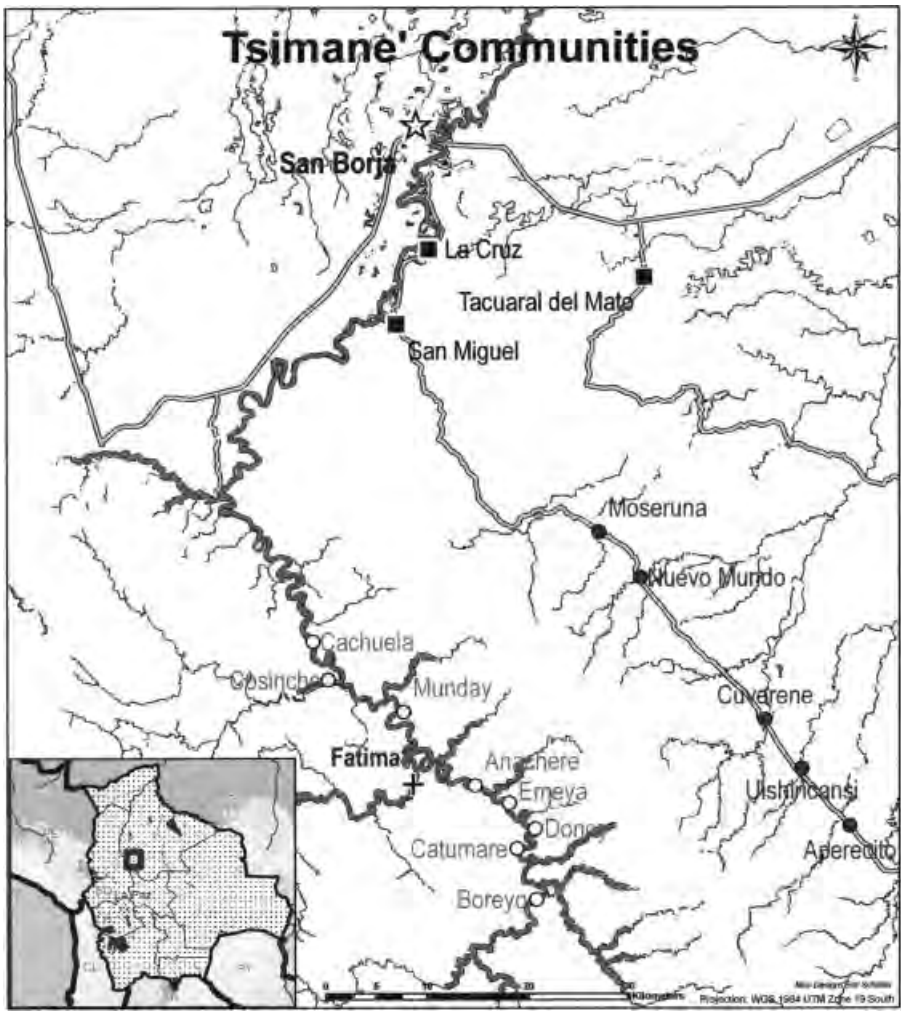

Fig. 1. Map of Tsimane study area and sample communities.

We will show that the Tsimane display a different pattern of mortality change that has previously been described for the epidemiologic transition.

Finally, a fourth goal is to describe and contrast the causes of mortality in older versus younger adults. An appreciation of mortality patterns is crucial for understanding aspects of Tsimane life history, such as growth, production, reproduction, and aging. This paper thus lays the demographic groundwork for future studies of physical growth and maturation, age-related changes in economic production, intergenerational resource transfers, and senescence.

The paper is organized as follows. We begin with a description of the Tsimane and their current situation, and discuss methods of data collection and analysis. The results are then presented, discussing first infancy, childhood, and adolescence, and then early adulthood, middle-adulthood, and old age. In each case, we examine the effects of proximity to town (comparing the more acculturated villages close to the town of San Borja, with a distant but missionized settlement, and then to the much more isolated communities living in riverine and forest environments, respectively). We also compare the early time period 1950–1989 with the more recent period, 1990–2002

to examine both secular trends in mortality and its interaction with proximity to San Borja. The results section concludes with a discussion of how the causes of mortality change with each of the six age groups mentioned above. The paper concludes with a discussion of the results and their implications for epidemiologic transition theory, particularly in Amazonia and among rural societies throughout the developing world.

MATERIALS AND METHODS

Study population

The Tsimane are lowland forager-horticulturalists living in small villages composed of extended family clusters, located primarily in the Maniqui river system in the Ballivián and Yacuma Provinces of the Beni region of Bolivia (14° 35′ S-15° 30′ S, 66° 23′ W-67° 10′ W). Approximately 8,000 Tsimane inhabit 80 villages in the forest and savanna regions between San Borja, the foothills of the Andes and San Ignacio de Mojos (VAIPO, 1998). Almost all of the food the Tsimane consume derives from slash and burn agriculture, fishing, hunting, and gathering. They cultivate plantains, rice, corn, and sweet manioc in small swiddens and regularly fish and hunt for meat. Subsistence tasks are primarily performed by all adults within a group of kin-related households, although group fishing, cooperative hunting, and field clearance are not uncommon.

Denevan (1966) estimated a population size of roughly 350,000 natives in the Beni region shortly after contact and a low population density of 2 per km^2. Although the Tsimane' were exposed to Jesuit missionaries before the 17th century, they were never successfully settled in missions and remain relatively unacculturated (Chicchón, 1992). Rice and various citrus fruits were likely introduced by the Jesuits at this time. Other neighboring lowland groups such as the Mojeño and Yuracaré engaged in more intensive agriculture and were more easily concentrated in centralized missions. Some degree of the Tsimanes' isolation is suggested by the fact that their language is an isolate, even within Bolivia, sharing a similar vocabulary and grammar only with the Mosetene, who inhabit the southern and northern stretches of Tsimane territory. Tsimane share distant genetic affiliation with the Yuracare, Trinitario, and Quechua ethnic populations, and little affiliation with the nearby Aymara who inhabit the highlands (Bert et al., 2001). However, there is some evidence that Tsimane likely interacted with Incas (Saignes, 1985).

New mission posts in several villages began in the 1950s. The greatest influence of the 35-year-old New Tribes Mission was to create a system of bilingual schools with the goal of training Tsimane' as teachers, and organizing the election of chiefs in each village located downstream from the Catholic mission, Fátima. In 1989, a central representative organization, the Gran Consejo Tsimane was founded with assistance of the New Tribes Mission. The New Tribes Mission also organized a small health clinic on the outskirts of San Borja, and has provided intermittent access to medicines in exchange for labor since 1990.

Tsimane villages vary in their degree of market access and interaction with Bolivian nationals. Acculturation takes several principal forms: visits to the main market town, San Borja (pop'n $\sim$ 18,000), and the selling of agricultural produce, wage labor with loggers or colonists, debt peonage with river merchants, and formal schooling. Portable radios that transmit messages and music from the New Tribes radio tower outside of San Borja are also available in many villages. The Tsimane came into greater contact with outsiders as new roads were built in the 1970s, inviting a burst of logging and trading interests, as well as encroachment by lowland and highland colonists (Chicchón, 1992; Ellis, 1996). Market items that are highly valued by the Tsimane include clothing, aluminum pots, utensils, salt, sugar, kerosene, and school supplies. Schools exist in over two third of all Tsimane villages, having been established anywhere from 2 to 20 years ago.

Tsimane make occasional visits to San Borja during town festivals, and some sell agricultural produce or handicrafts. Near San Borja, some Tsimane work as farm hands for local ranchers. Along the upper Maniqui River, Tsimane sometimes collect jatata palm leaves and weave them into roofing panels. These panels are then traded with itinerant merchants who provide market goods and alcohol. The exchange rates vary among merchants, but most are unfavorably low. Goods are usually given in advance of payment, and Tsimane rarely refuse these 'gift' advances, which positions many households in a cycle of debt with the merchants.

Chicchón (1992) and Reyes-Garcia (2001) report a lack of any serious epidemics in Tsimane history, based partially on historical estimates

TABLE 1. Tsimane demographic sample characteristics

Village	No. of interviews	No. of repro histories	No. of complete repro histories	No. of deaths	Census 2003	Location	Dates sampled
Anachere	17	67	38	52	37	Upper Maniqui	May 2003
Aperecito	41	116	82	108	71	Forest	Oct 2002, Feb 2003
Boreyo	24	59	45	41	48	Upper Maniqui	May 2003
Cachuela	17	44	33	27	34	Upper Maniqui	Dec 2003
Campana	19	40	34	39	45	Forest	Feb 2003
Catumare	5	27	18	20	29	Upper Maniqui	May 2003
Cosincho	76	198	161	178	219	Upper Maniqui	Oct–Dec 2003
Cuverene	47	165	114	116	80	Forest	Sept–Oct 2002, Jan–Feb 2003
Donoy	9	46	25	49	19	Upper Maniqui	May 2003
Emeya	20	95	60	96	50	Upper Maniqui	May 2003
Jamanchi 1	39	132	79	87	111	Forest	Jul 2005
La Cruz	116	382	298	n/a	307	Near San Borja	Jul–Sept 2003
Mision Fatima	161	405	286	279	460	Upper Maniqui	June 2003, Aug 2004
Moseruna	30	67	52	61	91	Forest	Mar 2003
Munday	26	73	63	54	66	Upper Maniqui	Nov 2002
Nuevo Mundo	12	33	25	50	35	Forest	Feb 2003
San Miguel	118	348	188	129	325	Near San Borja	Mar–May, Sept 2003
Tacuaral del Mato	91	229	143	160	313	Near San Borja	Sept–Oct 2003
Uishiricansi	15	33	25	26	38	Forest	Feb 2003
Total	883	2,559	1,769	1,572	2,378		

Deaths only include people with known years of birth and known or estimated ages at death.

of Tsimane population growth over the past two hundred years. Nonetheless there is some evidence of a smallpox epidemic in the mid 1800's shortly after two missions, San Pedro and San Pablo, were formed along the Maniqui River. San Pablo was subsequently abandoned shortly after the murder of a Catholic priest who worked there (Cardús, 1886, cited in Chicchon, 1992). Demographic interviews revealed several waves of measles or rubeola that killed a large number of small children over the past 60 years. However, it is unlikely that any epidemic would have globally impacted all Tsimane due to the highly dispersed character of Tsimane settlements.

Study villages

Demographic data were collected in 18 villages that span traditional Tsimane territory (Fig. 1). These include distant villages on the upper Maniqui River (Cachuela, Cosincho, Munday, Fatima, Anachere, Donoy, Emeya, Catumare, Boreyo), villages situated along a private logging road in the interior forest (Aperecito, Uishiricansi, Cuverene, Nuevo Mundo, Campana, Moseruna), and two acculturated villages located near San Borja (Tacuaral de Mato, San Miguel). We separate Fatima from the rest of the riverine sample because of its unique association with a Catholic Redemptorist mission that has provided some medical assistance since its inception in 1952. Table 1 reports the numbers of interviewed adults, reproductive histories, deaths, and risk-years resulting from interviews with members of each village.

The source study population, constituting about 31% of all Tsimane, has a very young age structure, as shown in the age-sex pyramid in Figure 2. Approximately 51% of the current population is under age 15 and only 10% over the age of 45. The sex ratio is male-biased during early childhood, and most of adulthood, with a slight female-bias present during adolescence and early adulthood (15–24) and after age 70.

Demographic interviews

Demographic interviews were conducted in the Tsimane language among all available adults over age 18 by Gurven during 14 months from July 2002 to August 2005 with the assistant of a bilingual Tsimane (Zelada) as a central component of a project focused on Tsimane life history and health. Deaths were elicited from retrospective reproductive histories of interviewees and their parents and siblings, whether alive or dead. This process yields redundant

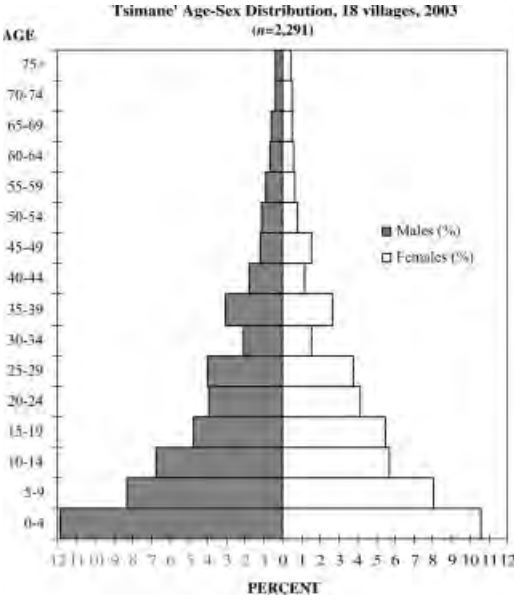

Fig. 2. Tsimane age-sex pyramid based on censuses in 18 study village censuses during 2002–2003 (n = 2,291 individuals).

reproductive histories (e.g., if more than one sibling is interviewed), allowing for cross-validation of information. On the basis of these interviews, all living and deceased Tsimane' in the sample were assigned estimated ages. The Tsimane' have no taboos against speaking the names of deceased relatives, including small children. In consultation with a team physician (Dr. Daniel Eid Rodriguez), causes of death were assigned using a system based on the International Classification of Disease version 10 (ICD-10) (WHO, 1990). No cause could be determined for 13% of the 1,442 deaths in our complete sample, due more to a lack of information by informants than inexplicable symptoms. The number of cases of undiagnosed deaths is distributed proportionally among 1950–1989 and 1990–2002 time periods. Our estimates of the percentages of deaths due to specific causes, and of cause-specific death rates, are underestimates of their true values because deaths with unknown causes are included in the denominator but never in the numerator. Cause-specific death rates were calculated by dividing the number of deaths due to specific causes by the appropriate number of risk-years.

Years of birth and death were assigned based on a combination of methodologies employed by researchers among the !Kung (Howell, 1979), Ache (Hill and Hurtado, 1996) and Hadza (Blurton Jones et al., 2002). These include using known ages from written records, relative age lists, dated events, photo comparisons of people with known ages and cross-checking of information from independent interviews of kin. Catholic missionaries have recorded the dates of 1,110 births among the Tsimane since 1952, many of the deaths occurring during the same period, and age estimates for an additional 120 individuals who were baptized as small children or as young adults during the early 1950s. These records are invaluable because they include many residents of Fatima, three additional study villages, Cachuela, Munday, and Cosincho, and other migrants now dispersed in other communities. We have also obtained birth records for an additional 310 individuals associated with the Evangelical Mission, La Cruz.

For individuals born prior to record keeping, four procedures were used to ascribe ages to individuals from the reproductive histories. For children, age at death was estimated using developmental stages (e.g., just born, still breastfeeding, crawling, walking), comparisons to living children of known ages, and seasons of birth and death. For each pair of consecutive siblings, the birth interval was estimated. For pairs in which the older sibling was alive when the younger one was born, the elder's age at birth was estimated, using the above methods for assigning age at death. For pairs in which the older sibling died before the birth, the time interval between death and birth was estimated using information on the ages of other living children in the family and seasonality.

The second method ranked all individuals, both living and deceased, in the sample of reproductive histories by relative age, beginning first with 5-year estimated age classes for relative age rankings. Multiple informants were used for each age class and inconsistencies were investigated and resolved. In addition, significant age-related relationships were investigated to augment the relative age lists. These include 'hip-child', hunting mentor, and playgroup companions.

Third, ages were also estimated using historical information and known historical events. A Catholic missionary, Father Marcelino, began working with the Tsimane' in 1952, and Father Martin Bauer in 1958. Both missionaries are widely known among most Tsimane in the Maniqui region. Another missionary was

murdered in 1848, and many Tsimane scattered to other regions downstream and in the interior forest back in the late 1920s. The first dirt highway was cleared in the interior forest in 1970 and then refurbished again in 1985. The Tsimane government organization started in 1989. We investigate which people were born and approximate ages of other individuals, such as younger siblings, or smallest child, with respect to these events. When interbirth intervals are short, as is common among the Tsimane, the use of sibling comparisons and dated events can be an effective tool in age estimation.

A final method used a sample of seventy photos of individuals with known ages. For older individuals, fifty photos of men and women from ages 50 through 75 were used. These photos were used as a means of aging dead individuals at the time of their death, and for aging old interviewees. This method worked in conjunction with comparisons of dead individuals to known individuals in the community and surrounding region.

Each of the above methods provides a roughly independent estimate of age. When all estimates yield a date of birth within a 3-year range, the average was used unless one or two estimates were judged to be superior to the others. Individuals for whom confident ages could not be ascertained are not included in this analysis. These individuals are mostly people whose name appeared only once in the interviews, distant siblings without other interviewed kin in the sample, and estranged individuals not seen or heard from in many years.

All research was conducted with the approval of the Institutional Review Boards of the University of California-Santa Barbara and University of New Mexico, and with approval by the Tsimane government in San Borja (*Gran Consejo Tsimane*). Approval by village leaders and members was given in community meetings and before each interview.

Data analysis

Period life tables stratified by sex, region, or time period are calculated by considering the total number of deaths within a specific category (e.g., females living near San Borja in the 1950s) with respect to the total number of person-years at risk of death in that same category. Age-specific probabilities of death (q_x) are computed directly from these raw data of deaths and person-years of exposure, while cumulative probability of living from birth to age x (l_x), and the yearly mortality hazard (h_x) are derived from q_x in the life tables. We estimate infant (IMR) and child mortality rates using a restricted dataset that includes only births or risk-years from directly interviewed individuals.

We smooth l_x and h_x functions using a Siler competing hazards model (Gage, 1989; Siler, 1979). The Siler model includes three components: a negative Gompertz exponential function to capture infant and juvenile mortality, a Makeham constant hazard, and a positive Gompertz function to capture late age mortality. The hazard has the following functional form:

$$h(x) = a_1 \exp(-b_1 x) + a_2 + a_3 \exp(b_3 t)$$

We produce Siler-based l_x and h_x curves using the nonlinear regression procedure (NLIN) in SAS version 9.1.

The statistical comparison of mortality rates is facilitated by the use of discrete-time logistic regression models (Allison, 1995). We use fixed effects models for examining temporal trends from the 1950s through 1990s and geographical variation in age-specific mortality in forest, riverine, and acculturated regions. Due to the similarity in mortality rates from 1950 to 1989, we primarily compare temporal trends between 1950–1989 and 1990–2002 time periods [There are no significant differences in overall mortality by decade from 1950 to 1989 ($\chi^2 = 0.92$, $P < 0.82$, poisson regression)]. These regressions are implemented with the LOGISTIC procedure in SAS v. 9.1 and applied separately for six life stages: infancy (<1-year-old), early childhood (1–4), late childhood (5–15), early adulthood (16–39), middle adulthood (40–59), and late adulthood (60+). All regressions produce partial estimates that examine the effects of age, sex, region, and period simultaneously. We test for interactions and report these effects when statistically significant at the 5% level.

RESULTS

Infancy (age < 1)

Figure 3 shows infant mortality rates (IMR) grouped in 5 year intervals from 1950 through 2000, and makes comparisons with national Bolivian IMR (UN Common Database, UNICEF). While, at the national level, Bolivia experienced a significant decline in infant mortality of 2.41/1,000 per year ($P < 0.0001$) during the 50 year period, Tsimane infant mortality did not decrease significantly (0.91/1,000 per year, $P = 0.14$).

Using the most reliable data derived from focal-person reproductive histories, the IMR

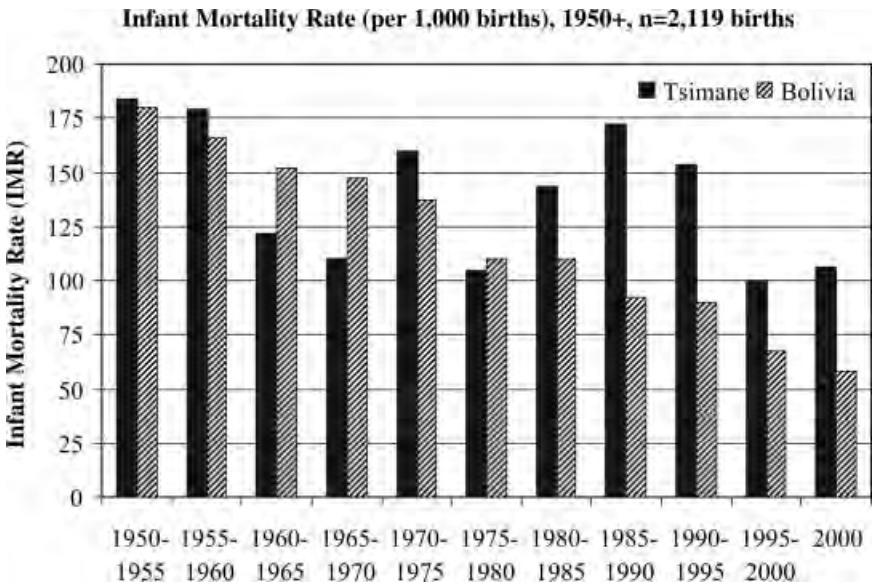

Fig. 3. Infant mortality rate (IMR), per 1,000 births, from 1950 to 2000 in 5 year intervals ($n = 2{,}119$ births).

for the Tsimane population as a whole is 137/1,000 for the period 1950–1989 (Including reproductive histories of siblings who were not directly interviewed reduces this estimate to 112/1,000, revealing the tendancy for relatives to forget infants who died shortly after birth). This estimate is derived from live births only, and does not include reported cases of abortions or miscarriages. Overall, 2.9% of pregnancies were reported as miscarriages or abortions. However, ethnographic experience and informant reports suggest that some of these reported miscarriages are probably premature births or babies killed by infanticide, which would lead to a slight underestimate of IMR. If we assume that a conservative 20% of reported abortions are legitimate births, then the IMR increases from 137 to 144. Moreover, from 1990 to 1999, 4.8% of all pregnancies from directly interviewed adults were reported as miscarriages, suggesting that some miscarriages in the past were forgotten as well.

Table 3 (part A) reports the IMR among Tsimane regions and by period. The more isolated communities located along the upper Maniqui River and in the interior forest show the highest rate of infant deaths (177 and 178, respectively). Although Fatima is located along the upper Maniqui River, it shows a lower IMR of 142. The lowest IMR occurs among acculturated communities living in close proximity to San Borja (100). Thus we find an almost 2-fold difference in infant mortality rates among Tsimane communities.

Logistic regression analysis of infant mortality confirms a significant main effect only for region, where infants born in remote communities experience about 1.5 times the risk of dying than those born near San Borja (Table 3, part A). IMR does not significantly vary between females and males, although we do find that female infants die at slightly higher rate (14.8% versus 13.7% dying during the first year of life, respectively). IMR does not change significantly over time and there are also no significant two-way or three-way interactions between sex, geographical region, and period of birth. The mean rates reported in Table 2 show that IMR actually increased somewhat in the least acculturated villages in the riverine and forest ecologies, whereas rates tended to decrease somewhat in the Fatima mission and even more so near San Borja.

Early childhood (ages 1–4)

Average survivorship to age five (l_5) is 79.3% (80.8% for males, 77.7% for females—Fig. 4). The total probability of dying from ages 1 to 5 is 9.8%, 8.7%, 7.5%, and 3.6%, for forest, riverine, Fatima, and near San Borja samples, respectively, with average rates per year shown in Table 2. Logistic regression

TABLE 2. Mortality rates (per 1,000 individuals) by abridged age groups, geographical region, and time period

Time frame	Fatima	Forest	Riverine	Near San Borja	Overall	Mortality ratio
Age <1						
1950–1989	157	160	179	112	153	1.22
1990–2002	111	171	147	85	126	
Ages 1–4						
1950–1989	20	23	26	9	20	1.60
1990–2002	8	17	18	8	12	
Ages 5–14						
1950–1989	6	7	8	6	7	1.89
1990–2002	5	4	5	1	4	
Ages 15–39						
1950–1989	7	8	12	5	8	1.79
1990–2002	4	7	6	2	5	
Ages 40–59						
1950–1989	12	17	19	25	19	2.59
1990–2002	4	7	8	10	7	
Age 60+						
1950–1989	94	80	87	34	77	2.25
1990–2002	42	33	30	36	34	

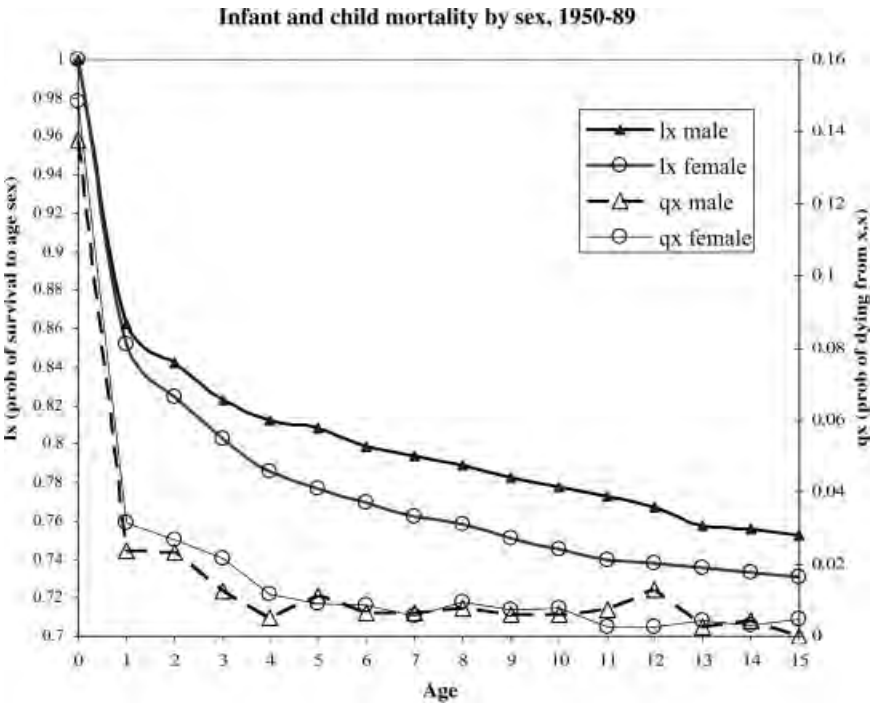

Fig. 4. Probability of survival to age × (l_x) and age-specific mortality rates (h_x) for males and females under age 15, 1950–1989.

analysis shows that expected mortality decreases by about 30% with each advancing year over the age range 1–4 as children grow and their immune systems develop.

Again, there are no significant effects of sex. Mortality appears to have improved over time, with mortality prior to 1990 being 1.6 times higher than after 1990 (Table 2). However, there is a stronger effect of region. Controlling for sex and time period, mortality is 2.4 times greater in the remote villages than in the villages near San Borja (Table 3, part B).

TABLE 3. Logistic regression of infant and child mortality

					95% C.I.			Model fit		
Variable	Comparison	Estimate	Sig	Odds ratio	Lower	Upper	*n*	−2LogL	Chi^2 Wald	*P*-value
(A) Infant mortality rate, <1										
Sex	Female vs. male	−0.008	0.914	0.985	0.743	1.305	1,938	1,361	10.2	0.0687
Region	Forest vs. near San Borja	0.113	0.354	1.474	1.005	2.161				
	River vs. near San Borja	0.229	0.051	1.712	1.181	2.482				
	Fatima vs. near San Borja	−0.030	0.815	1.335	0.894	1.993				
Period	Pre-1990 vs. 1990+	0.114	0.124	1.255	0.940	1.675				
(B) Early child mortality, ages 1–4										
Age	1 year	−0.310	0.001	0.733	0.607	0.887	6,018	966	32.4	0.0001
Sex	Female vs. male	0.252	0.016	1.393	1.099	2.490				
Region	Forest vs. near San Borja	0.266	0.116	2.445	1.271	4.703				
	River vs. near San Borja	0.389	0.018	2.765	1.451	5.267				
	Fatima vs. near San Borja	−0.028	0.887	1.823	0.902	3.685				
Period	Pre-1990 vs. 1990+	0.243	0.025	1.627	1.064	2.486				
(C) Child mortality, ages 5–15										
Age	1 year	−0.091	0.001	0.913	0.866	0.963	26,818	1,830	23.9	0.0005
Sex	Female vs. male	−0.028	0.735	0.946	0.686	1.305				
Region	Forest vs. near San Borja	0.037	0.792	1.434	0.885	2.323				
	River vs. near San Borja	0.225	0.081	1.730	1.098	2.725				
	Fatima vs. near San Borja	0.061	0.699	1.467	0.876	2.459				
Period	Pre-1990 vs. 1990+	0.244	0.011	1.629	1.118	2.373				

Late childhood (ages 5–15)

Survivorship to age fifteen (l_{15}) is 74.2% (75.2% for males, 73.1% for females—Fig. 4), indicating that one-fourth of children ever born die before the age of fifteen. Mortality rate continues to decrease by about 7% each advancing year from ages 6 to 15 (Table 3, part C). By age 15, mortality rate is below 1% per year (Fig. 4).

There are significant and similar effects of period and region on mortality, with odds ratios of about 1.63. This suggests a smaller regional effect than at the earlier ages. There is a marginally significant region by period effect ($P = 0.066$), as can be seen in Table 2, where the gains in survivorship seem to be greater in the more acculturated communities near San Borja. The highest mortality rates in late childhood appear to be in the riverine communities.

Early adulthood (ages 15–39)

Survivorship to age 39 is 60.9% (57.8% for females, 63.8% for males—Fig. 5). Mortality rates for both men and women during early adulthood are low and fairly flat, at about 1%, with increases beginning at around age 30 (Fig. 5). In a multiple logistic regression, the mortality rate increases by less than 3% per year (Table 4, part A). During these critical reproductive years, women show a 35% higher mortality rate than men, with most of the difference being in the age range of 26–39, where the odds ratio is 1.5. Presumably much of this difference is due to death in childbirth and related complications.

The multiple logistic regression also reveals large regional differences, where the odds ratio is 2.5 in remote riverine and forest villages, and smaller but significant for period differences, with an odds ratio of 1.63 (Table 2, Table 4, part A). Further analysis reveals that almost all the regional effect is due to the 15–25 year age bracket (odds ratio = 4.0).

Middle adulthood (ages 40–59)

Survivorship to age 59 is about 41.0% (40.5% for women, 41.4% for men—Fig. 5). During middle adulthood, the mortality rate increases by about 6% per year (Table 4, part B, Fig. 5).

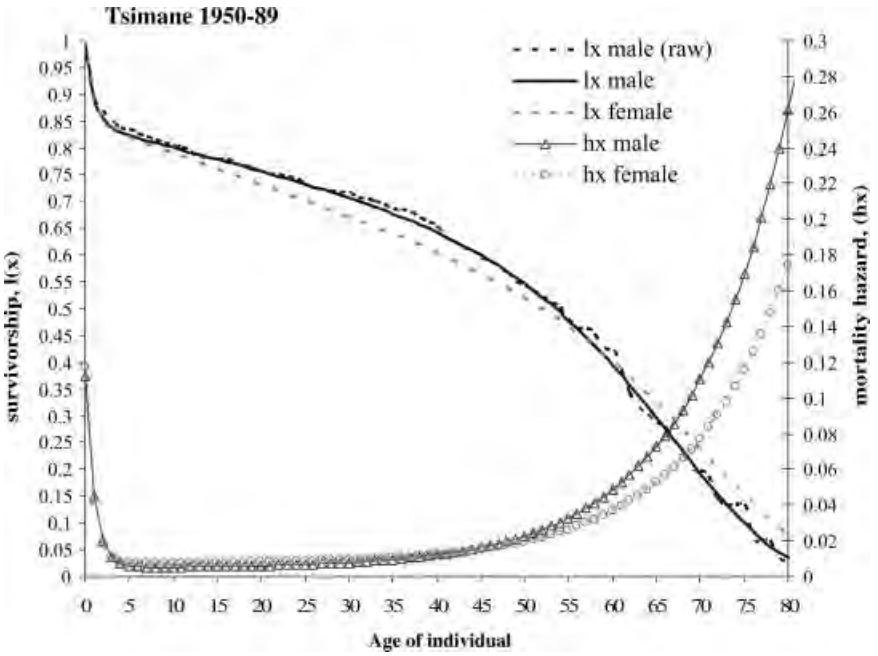

Fig. 5. Siler-estimated survival curves (l_x) and age-specific mortality rates (h_x) for males and females across the lifecourse, 1950–1989. Dashed bold line shows raw male l_x curve.

TABLE 4. Logistic regression of adult mortality

Variable	Comparison	Estimate	Sig	Odds ratio	95% C.I. Lower	95% C.I. Upper	*N*	Model fit −2LogL	Model fit Chi^2 Wald	Model fit *P* value
(A) Early adult mortality, ages 16–39										
Age	1 year	0.027	0.009	1.028	1.007	1.049	30,027	2,476	41.6	<0.0001
Sex	Female vs. male	0.146	0.035	1.340	1.021	1.759				
Region	Forest vs. near San Borja	0.257	0.024	2.399	1.538	3.741				
	River vs. near San Borja	0.335	0.002	2.593	1.673	4.018				
	Fatima vs. near San Borja	0.026	0.855	1.904	1.151	3.150				
Decade	Pre-1990 vs. 1990+	0.244	0.002	1.629	1.197	2.218				
(B) Middle Adult mortality, ages 40–59										
Age	1 year	0.057	0.0002	1.058	1.027	1.090	9,477	1,381	40.3	<0.0001
Sex	Female vs. male	−0.130	0.142	0.772	0.546	1.091				
Region	Forest vs. near San Borja	0.005	0.972	0.704	0.453	1.094				
	River vs. near San Borja	0.055	0.707	0.740	0.475	1.153				
	Fatima vs. near San Borja	−0.417	0.044	0.461	0.254	0.839				
Decade	Pre-1990 vs. 1990+	0.459	0.0001	2.506	1.680	3.738				
(C) Late adult mortality, ages 60+										
Age	1 year	0.080	0.0001	1.083	1.043	1.125	1,878	750	40.5	<0.0001
Sex	Female vs. male	−0.189	0.075	0.685	0.451	1.039				
Region	Forest vs. near San Borja	−0.076	0.657	1.454	0.754	2.804				
	River vs. near San Borja	0.061	0.723	1.668	0.861	3.231				
	Fatima vs. near San Borja	0.465	0.010	2.498	1.271	4.910				
Decade	Pre-1990 vs. 1990+	0.451	0.0001	2.467	1.599	3.805				

There are no significant differences between the sexes during this period, although the point estimates in Table 2 show a slightly lower mortality rate for women.

Interestingly, the overall regional effect is in the opposite direction from the common pattern encountered among other age groups, with the more remote communities exhibiting lower mor-

tality than those near San Borja, with an odds ratio of 0.66. Mortality of middle aged adults at Fatima is about half that in the acculturated region (Table 4, part E). There is a very strong period effect, however. Mortality is much higher prior to 1990 than after, with an odds ratio of 2.5. This can be seen especially in the more remote villages (Tables 2 and 4).

Late adulthood (ages 60+)

About 40% of men and women survive to age 60 (Fig. 5). Late adulthood shows a 9% increase with each advancing year from age 60. For late ages, men are about 50% more likely to die than women. Upon reaching age 60, women and men show a mean of 12.3 and 9.9 years remaining, respectively (Table 5). There are no reliable cases of individuals surviving past the age of 80.

As in middle adulthood, the period effect is stronger than the region effect. Only Fatima shows a significantly higher mortality rate in late adulthood than in other regions, with an odds ratio of 2.5. When region is dichotomized as those villages located far versus those near San Borja, the region effect is borderline significant ($P = 0.06$ with an odds-ratio of 1.76). The odds ratio for the period effect is 2.47, $P < 0.0001$. Thus, as in middle adulthood, there are large significant gains in survivorship in recent years. There are no significant sex, period or region interactions, but from Table 2, it is clear that the large absolute effects are in the more remote communities.

Mortality and its causes across the life course

Table 5 presents an annual life-table for males and females, covering the early period from 1950 to 1989, based on all deaths and risk-years from this forty year period. Life expectancy at birth for males and females is 44.2 and 42.8, respectively. Siler-based mortality hazard and survivorship curves are shown in Figure 6. The mortality hazard curves illustrate the cross-over whereby older males are more likely to die than older females, whereas female mortality is modestly higher than male mortality for the rest of the life course.

During the 1990s, life expectancy at birth for males and females increased to 54.3 and 54.0, respectively. Table 6 shows the abridged life table for 1990–2002 and Figure 6 compares the Siler-smoothed mortality hazard from the combined 1950–1989 sample with that from the 1990s. The regional differences in mortality mirror, to a large extent, the period differences in mortality, with the villages closer to San Borja exhibiting lower mortality than the more distant ones. The distant Fatima mission village falls somewhere in between the more acculturated villages and the unattended forest and remote riverine villages. Despite Fatima's remote location, some medical support has been provided by the Mission staff, and on occasion, there have been emergency departures to San Borja by small propeller plane through use of an airstrip. The general pattern, however, is that the regional effects are stronger at younger ages, whereas the period effects are stronger in adulthood and old age.

Causes of death over the lifespan reflect the importance of infectious disease at all ages, but also reveal some important differences across the life course. Beginning with pregnancy, an analysis of reported ('emic') causes of miscarriages shows that over a third (36.5%) were induced by an abrupt and rough traumatic fall, 16% from over-working and carrying too much weight (usually firewood, agricultural produce or large bundles of palm thatch), and 15% from maternal sickness. An additional 7% were self-induced as a means of spacing births or because of doubts concerning paternity.

Less than half of all infant deaths in our sample are due to infectious disease (38%), for a total rate of 55.0 deaths per thousand infant risk years (Table 7). Respiratory infections, such as whooping cough, pneumonia, measles, and tuberculosis account for half of these diseases of infectious origin. The largest community, Fatima, had the highest rate of respiratory infectious disease (33.1/1,000). There is also a 6-fold difference in measles rates across regions, confirming our suspicion that certain disease outbreaks were likely localized in space and time in the Tsimane region. Diarrhea, extreme parasitism, other gastrointestinal disease and perinatal complications together account for about a third of infant deaths. Complications at birth and perinatal infection accounted for over one fourth of infant deaths with a total rate of 23.6/1,000. The forest communities showed a much higher rate when abortions were included, 27.8 + 64.2 (abortions)/1,000. Perhaps some of those cases were cryptic forms of infanticide. Of the 11% of deaths reported to be due to accidents or violence, over one third of these are from infanticide, and one-fourth from falls out of hammocks or baby slings. Infanticide was most frequent in the forest region (5.3% of infant deaths). The rate of infanticide is low, compared with re-

TABLE 5. Period life table, 1950–1989, 648 deaths, 47,854 person-years

	Female					Male				
Age	d_x	P_x	q_x	l_x	e_x	d_x	P_x	q_x	l_x	e_x
0	73	491	0.148	1.000	42.8	68	498	0.137	1.000	44.2
1	14	442	0.032	0.852	49.2	11	461	0.024	0.863	50.2
2	11	411	0.027	0.825	49.8	10	433	0.023	0.842	50.4
3	8	373	0.021	0.803	50.1	5	401	0.012	0.823	50.5
4	4	349	0.011	0.786	50.2	2	378	0.005	0.812	50.1
5	3	327	0.009	0.777	49.8	4	350	0.011	0.808	49.4
6	8	907	0.009	0.769	49.2	6	954	0.006	0.799	49.0
7	5	874	0.006	0.763	48.6	6	925	0.006	0.794	48.3
8	8	848	0.009	0.758	47.9	7	889	0.008	0.789	47.6
9	6	816	0.007	0.751	47.4	5	857	0.006	0.782	46.9
10	6	793	0.008	0.746	46.7	5	825	0.006	0.778	46.2
11	2	760	0.003	0.740	46.1	6	806	0.007	0.773	45.5
12	2	722	0.003	0.738	45.2	10	780	0.013	0.767	44.8
13	3	694	0.004	0.736	44.3	2	741	0.003	0.758	44.4
14	2	664	0.003	0.733	43.5	3	706	0.004	0.755	43.5
15	3	644	0.005	0.731	42.6	0	682	0.000	0.752	42.7
16	5	622	0.008	0.727	41.8	6	666	0.009	0.752	41.7
17	4	606	0.007	0.721	41.1	3	647	0.005	0.745	41.1
18	3	588	0.005	0.717	40.4	5	621	0.008	0.742	40.2
19	2	569	0.004	0.713	39.6	3	601	0.005	0.736	39.6
20	4	551	0.007	0.710	38.7	5	580	0.009	0.732	38.8
21	5	539	0.009	0.705	38.0	1	556	0.002	0.726	38.1
22	6	523	0.011	0.699	37.4	3	538	0.006	0.725	37.2
23	6	485	0.012	0.691	36.8	2	521	0.004	0.721	36.4
24	4	461	0.009	0.682	36.2	7	502	0.014	0.718	35.5
25	5	430	0.012	0.676	35.5	4	481	0.008	0.708	35.0
26	3	410	0.007	0.668	35.0	3	455	0.007	0.702	34.3
27	4	396	0.010	0.663	34.2	1	434	0.002	0.697	33.5
28	3	384	0.008	0.657	33.5	2	421	0.005	0.696	32.6
29	4	377	0.011	0.652	32.8	0	408	0.000	0.693	31.7
30	2	355	0.006	0.645	32.1	6	395	0.015	0.693	30.7
31	3	343	0.009	0.641	31.3	0	377	0.000	0.682	30.2
32	3	332	0.009	0.635	30.6	3	358	0.008	0.682	29.2
33	3	313	0.010	0.630	29.9	3	342	0.009	0.676	28.4
34	5	297	0.017	0.624	29.1	4	333	0.012	0.670	27.7
35	3	282	0.011	0.613	28.6	1	321	0.003	0.662	27.0
36	3	268	0.011	0.607	27.9	1	311	0.003	0.660	26.1
37	4	257	0.016	0.600	27.2	5	301	0.017	0.658	25.1
38	5	240	0.021	0.591	26.6	4	292	0.014	0.647	24.5
39	4	229	0.017	0.578	26.2	3	277	0.011	0.638	23.9
40	2	221	0.009	0.568	25.6	8	266	0.030	0.631	23.1
41	1	207	0.005	0.563	24.8	3	247	0.012	0.612	22.8
42	5	197	0.025	0.560	24.0	4	233	0.017	0.605	22.1
43	0	187	0.000	0.546	23.6	2	222	0.009	0.595	21.4
44	2	172	0.012	0.546	22.6	5	207	0.024	0.589	20.6
45	4	159	0.025	0.540	21.8	2	187	0.011	0.575	20.1
46	2	147	0.014	0.526	21.4	3	174	0.017	0.569	19.3
47	3	138	0.022	0.519	20.6	3	161	0.019	0.559	18.6
48	1	132	0.008	0.508	20.1	5	153	0.033	0.549	18.0
49	1	122	0.008	0.504	19.2	1	141	0.007	0.531	17.6
50	4	116	0.034	0.500	18.4	3	138	0.022	0.527	16.7
51	2	106	0.019	0.482	18.0	3	128	0.023	0.515	16.0
52	3	103	0.029	0.473	17.3	2	120	0.017	0.503	15.4
53	1	97	0.010	0.460	16.8	2	114	0.018	0.495	14.6
54	4	95	0.042	0.455	16.0	5	106	0.047	0.486	13.9
55	4	88	0.045	0.436	15.6	3	95	0.032	0.463	13.5
56	2	79	0.025	0.416	15.3	0	85	0.000	0.449	12.9
57	0	72	0.000	0.405	14.7	2	81	0.025	0.449	11.9
58	0	66	0.000	0.405	13.7	4	74	0.054	0.438	11.2
59	3	62	0.048	0.405	12.7	1	68	0.015	0.414	10.8
60	5	55	0.091	0.386	12.3	5	64	0.078	0.408	9.9
61	1	45	0.022	0.351	12.4	7	60	0.117	0.376	9.7
62	0	39	0.000	0.343	11.7	4	49	0.082	0.332	9.8
63	0	37	0.000	0.343	10.7	2	45	0.044	0.305	9.6

(Continued)

TABLE 5. (Continued)

	Female					Male				
Age	d_x	P_x	q_x	l_x	e_x	d_x	P_x	q_x	l_x	e_x
64	1	35	0.029	0.343	9.7	2	41	0.049	0.292	9.0
65	2	32	0.063	0.333	8.9	1	37	0.027	0.277	8.4
66	3	26	0.115	0.312	8.5	3	35	0.086	0.270	7.6
67	0	21	0.000	0.276	8.4	3	32	0.094	0.247	7.2
68	2	20	0.100	0.276	7.4	4	27	0.148	0.224	6.9
69	3	17	0.176	0.249	7.1	0	22	0.000	0.190	6.9
70	0	14	0.000	0.205	7.5	1	19	0.053	0.190	5.9
71	0	11	0.000	0.205	6.5	4	18	0.222	0.180	5.2
72	0	9	0.000	0.205	5.5	1	13	0.077	0.140	5.4
73	1	8	0.125	0.205	4.5	0	9	0.000	0.130	4.8
74	2	7	0.286	0.179	4.0	0	9	0.000	0.130	3.8
75	0	5	0.000	0.128	4.1	4	8	0.500	0.130	2.8
76	1	5	0.200	0.128	3.1	0	3	0.000	0.065	3.5
77	0	3	0.000	0.102	2.7	0	2	0.000	0.065	2.5
78	1	3	0.333	0.102	1.7	1	2	0.500	0.065	1.5
79	1	2	0.500	0.068	1.0	0	1	0.000	0.032	1.0
80	1	1	1.000	0.034	0.0	1	1	1.000	0.032	0.0
	318.8	22,933.2				329.4	24,920.8			

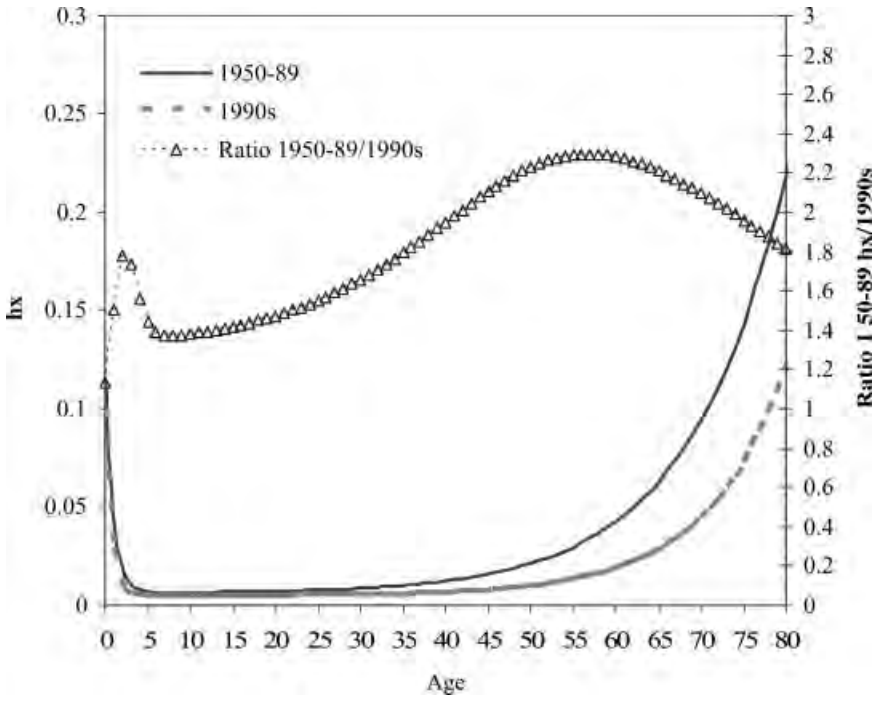

Fig. 6. Siler-estimated mortality rates (h_x) for 1950–1989 and 1990–2002 time periods. Triangles indicate the ratio of mortality hazards from 1950–1989 to 1990–2002.

ported estimates for other Amerindian populations (see Table 19.9 in Early and Peters, 2001; see Table 14.1 in Hill and Hurtado, 1996).

About two-thirds of all early childhood deaths are due to infectious disease (67.7%), with forest and riverine regions showing the highest rates due mainly to respiratory disease (6.0 and 8.1/1,000, respectively). While infectious disease accounts for a greater percentage of deaths during early childhood than

TABLE 6. Abridged period life table, 1990–2000, 361 deaths, 31,589 person-years

Age group	Female					Male				
	d_x	P_x	q_x	l_x	e_x	d_x	P_x	q_x	l_x	e_x
<1	65.4	639	0.102	1.000	54.0	73.2	699	0.105	1.000	54.3
1–5	32	2,149	0.057	0.898	59.1	27	2,377	0.044	0.895	59.6
5–10	10	2,179	0.023	0.846	58.6	13	2,301	0.028	0.856	58.3
10–15	7	1,964	0.018	0.827	54.9	7	1,949	0.018	0.832	54.9
15–20	8	1,662	0.024	0.812	50.8	7	1,782	0.019	0.817	50.8
20–25	6	1,381	0.021	0.793	47.0	8	1,509	0.026	0.801	46.8
25–30	7	1,200	0.029	0.776	43.0	7	1,216	0.028	0.780	42.9
30–35	5	994	0.025	0.754	39.2	2	1,065	0.009	0.758	39.1
35–40	7	742	0.046	0.735	35.1	6	848	0.035	0.751	34.5
40–45	1	641	0.008	0.701	31.7	0	667	0.000	0.725	30.6
45–50	3	544	0.027	0.696	26.9	10	608	0.079	0.725	25.6
50–55	3	422	0.035	0.677	22.6	5	465	0.052	0.668	22.6
55–60	4	273	0.071	0.653	18.3	5	333	0.072	0.633	18.7
60–65	8	204	0.179	0.607	14.5	5	229	0.104	0.587	15.0
65–70	2	170	0.057	0.499	12.2	3	134	0.106	0.526	11.4
70–75	4	85	0.211	0.470	7.7	4	67	0.260	0.470	7.5
75+	3	36	0.345	0.371	4.1	4	55	0.308	0.348	4.2
	175.4	15,285				186.2	16,304			

TABLE 7. Cause-specific death rates (per 1,000 individuals), n = *1,473 deaths (197 with unknown causes) covering the period from 1950–2002*

Category of illness	Geographical region				Age group						Total
	Forest	River	Fatima	San Borja	<1	1–5	6–15	16–39	40–55	60+	
I. Infectious and parasitic disease	7.8	9.3	6.4	5.0	55.0	10.8	3.4	2.6	6.5	22.8	7.2
A. Gastrointestinal	2.3	1.9	1.4	1.1	17.8	3.8	0.8	0.2	0.4	0.5	1.7
B. Respiratory	4.0	5.9	3.5	2.7	26.2	6.1	2.1	1.8	4.2	14.4	4.1
1. Whooping cough	0.3	0.4	0.5	0.2	4.7	0.6	0.1	0.0	0.1	0.0	0.3
2. Pneumonia	0.9	0.9	1.1	0.6	10.6	1.5	0.3	0.1	0.5	0.9	0.9
3. Measles	1.3	1.6	0.2	0.8	3.0	1.8	1.2	0.4	0.9	2.3	1.1
4. Tuberculosis	0.4	1.3	0.5	0.5	0.0	0.3	0.1	0.7	1.7	6.5	0.7
C. Cutaneas	1.1	0.8	0.8	0.4	8.4	0.4	0.3	0.3	1.0	3.7	0.8
D. Nervous system	0.1	0.3	0.1	0.0	0.5	0.1	0.0	0.1	0.5	0.0	0.1
E. Sepsis	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.5	0.0
II. Malignant neoplasms	0.3	0.0	0.2	0.2	0.0	0.0	0.0	0.2	0.2	3.3	0.2
III. Blood disorders/Immune system	0.2	0.0	0.1	0.2	0.2	0.1	0.1	0.0	0.3	0.0	0.1
IV. Endocrine system	0.2	0.4	0.2	0.1	4.5	0.1	0.0	0.0	0.0	0.9	0.2
VI. Nervous system	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
VIII. Cardiovascular	0.1	0.3	0.1	0.1	0.5	0.0	0.1	0.1	0.4	1.9	0.2
IX. Respiratory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
X. Digestive	0.5	0.6	0.4	0.4	1.0	0.0	0.3	0.4	0.8	5.1	0.5
A. Stomach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B. Appendix	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.4	0.1
C. Intestinal	0.2	0.4	0.2	0.2	0.5	0.0	0.2	0.3	0.2	2.8	0.3

in infancy, the actual rate of death due to infectious disease is only about a quarter (6.1/1,000) as high as in infancy. The lower percentage in infancy is due to the greater relative importance of perinatal birth complications and accidents and violence in infancy. The large drop in death rates due to infectious disease during early childhood reflects the increase in immunocompetence as children grow.

A similar percentage (64.9%) of late childhood deaths are due to infectious disease, but the death rate (2.1/1,000) is only about one third as high as in early childhood and less than one tenth the rate of infancy. One-fourth of deaths are due to measles and 10% due to accidents or violence. The riverine sample shows the highest infectious disease rate (4.9/1,000), twice that in the acculturated region where infectious disease is the lowest (2.3/1,000).

By early adulthood, infectious disease drops to less than one-half of all causes of death (39.5%), although death rates, especially for

respiratory illnesses, remain at a similar level as in late childhood (1.8/1,000). Overall, tuberculosis is responsible for 11% of deaths, with higher prevalence evident in forest and riverine regions. Violent and accidental deaths show a comparable rate of occurrence as respiratory disease (1.8/1,000), and these are largely due to homicides. Violence and accidents account for 24.5% of all early adulthood deaths. Common accidental deaths are due to trees falling in fields during clearing activities, drowning in rivers, snake bites and suicide. For women, death in childbirth accounts for a large fraction of deaths, especially during the prime reproductive years.

Half of deaths in middle adulthood are due to infectious disease (50.0%) and this life stage witnessed a doubling of the incidence of death from infectious disease (6.5/1,000). The incidence of death from infectious respiratory disease (e.g., tuberculosis) and digestive illnesses (e.g., appendicitis, obstructed gut, gallbladder disease) also doubled. Accidents and violence continue to explain about a fifth of all middle aged adult deaths and show an increase in the death rate (2.6/1,000, Table 7). Over one third of these deaths (total of 8%) are due to homicide (incidence 1.1/1,000).

Tuberculosis is a cause of 12.5% of late age deaths with a 4-fold increase in death rate compared with that in middle adulthood (6.5/1,000). The rate of pneumonia deaths doubled (0.9/1,000) and that of respiratory infectious disease in general tripled (14.4/1,000). The riverine sample shows the highest incidence of respiratory infectious disease (23.4/1,000), almost six times that of those villages near San Borja where the death rate is lowest (4.0/1,000). Immune function appears to be increasingly compromised in old age. Accidents and violence are the next largest macro-cause of death, accounting for 10% of deaths and with prevalence of 5.1/1,000. The acculturated sample shows the highest rates of deaths due to intestinal disease and the Fatima sample shows the highest rates of death due to accidents and violence. The death rates from cancer and cardiovascular deaths are not trivial (3.3 and 1.9/1,000, respectively), even if these two categories only explain 6.3 and 3.6% of late age deaths, respectively. It is relevant to note that 26% of the 58 older adults dying of unknown causes were said to have died of "old age". Old age is said to occur when there are no obvious symptoms and the person is usually reported to have been feeble, blind and/or unable to walk. It is possible that a large percentage of deaths in old age are actually the sequalae of cancer, given the frequent occurrence of intestinal disease and respiratory diseases, and this large unknown category.

Summary of results

1. Prior to 1990, 14% of Tsimane died in their first year of life, 26% before age 15 and 44% before age 45. Life expectancy at birth was 44 years. Upon reaching age 15, Tsimane could expect to live until age 58. Those reaching age 45 could expect to live until age 66. Those reaching age 65 live an average of 9 additional years.
2. Sex differences in mortality are evident during reproductive adult years and late adulthood. Women show 35% higher mortality from 16 to 39 and men show 50% higher mortality after age 60.
3. Villages in the remote forest and riverine regions show highest overall mortality, with 2–4 times higher mortality until middle adulthood.
4. There was little change in mortality over most of the life course throughout the period 1950–1989. Overall life expectancy at birth improved by 10 years from 45 to 53 after 1990. There was a larger absolute and relative period effect on death rates during middle and late adulthood than during infancy and childhood. In the remote villages, infant death rates changed little, whereas death rates among older adults decreased sharply.
5. Half of all deaths are due to infectious disease, especially respiratory and gastrointestinal infections. Accidents and violence account for about 14% of all deaths. Cancer and cardiovascular disease are relatively rare causes of death, but in old age, it is possible that their rates may be as high as those in developed countries.

DISCUSSION

There is substantial regional and temporal variability among mortality profiles in Tsimane communities. Overall, those living closest to town suffered lower mortality, and all regions witnessed improvements in survivorship during the 1990s. However, the pattern of change and regional variation is complex, and differentially distributed across the life course. Regional effects were strongest at younger ages, and period effects were stronger at older ages. This pattern is partially consistent with the overall framework of epidemiologic transi-

tion, but also in some ways, highly inconsistent with the historical transitions in developed and developing countries upon which the theory was built (Omran, 1971). Even the accelerated, delayed and transitional models of epidemiologic change (Olshansky and Ault, 1986) do not adequately capture the Tsimane experience. The patterns presented here are consistent in the sense that diseases of infectious origin are, in large part, responsible for the high mortality rates of the Tsimane, and because modernization has had a substantial effect on lowering the risk of death due to infectious disease. They are inconsistent in the sense that although our data show an overall decrease in mortality in the past decade, there has been little change in the proportion of deaths due to infectious origins between the 1950–1989 and 1990–2002 time periods (49% vs. 44%). Furthermore, we have observed a modest or no effect of period on infant mortality rates in remote Tsimane communities. When western countries historically underwent epidemiologic transitions, reductions in infant and child mortality rates showed the greatest initial improvements (Omran, 1971).

We would like to offer briefly an elaboration of epidemiologic transition theory to help explain this pattern of results, and to provide a broader framework for examining mortality transitions worldwide. Our basic proposal is that mortality transitions can be decomposed into changes in three factors that may operate somewhat independently: (1) exposure to morbidity and mortality risks; (2) host vitality and immune defenses; and (3) modalities for treatment and prevention of morbidity and mortality risks (the first two factors are discussed by Omran, whereas the third is not extensively treated). Exposure to morbidity and mortality risks can change in response to (a) public investments, such as in the water supply and sewage treatment; (b) population movements, density and distribution, which affect the introduction and rate of spread of new and old diseases (Ewald, 1994); (c) host behavior, such as hand washing, risk taking, diet and exercise and (d) a variety of other factors, including the emergence of new diseases, and incomplete antibiotic treatment. Host vitality refers to phenotypic condition and the ability of the host to combat assaults of infectious diseases and other forms of morbidity through biological defenses. Presumably, host vitality is improved with better nutrition and sufficient antibody responses due to prior disease history. Treatment modalities can change in response to (a) public investments and technological change, such as the availability of vaccinations, antibiotics, clinics and hospital services, (b) cultural change, such as loss or gain in knowledge of traditional or modern healing practices, and (c) host behavior, including the knowledge, capability and choice to utilize different treatment options ranging from traditional healers, public and private clinics, to purchased or collected natural and commercial pharmacopeias.

In the case of western countries in the late nineteenth and early twentieth centuries, most of the change in mortality appears to be due to the first factor, exposure to morbidity risks, and perhaps some smaller contributions of the second and third factors (Barrett et al., 1998). At the turn of the century, most major cities had cleaned up their water supply and developed more adequate systems of sewage. There were also changes made in crowding and housing. These changes greatly reduced exposure to infectious disease. Since infants and children under age 5 are most susceptible to dying from such infections, these changes in public health had major effects on the mortality rates of young children (Schofield et al., 1991). While there were continual improvements in treatment modalities, the major gains in treatment and prevention due to the advent of antibiotics and effective vaccines did not come until later in the century (McKeown, 1976).

The Tsimane case is quite different. Disease exposure probably has not decreased at all, and may even have increased. Although there have been a few attempts to provide clean water in Tsimane villages near San Borja, these attempts have been largely unsuccessful and the vast majority of Tsimane people obtain their water from untreated surface water sources. Attempts to create ground wells in more distant communities have also been largely unsuccessful. Due to increasing population in the region as a whole, increased livestock near San Borja, and increased use of motorized transport and toxic detergents, water quality may perhaps be substantially worse now than in the past few centuries. Based on the results of fecal analyses, we have found that members of all communities in our sample present high rates of parasitism, with prevalences near 100% in many communities, and frequent gastrointestinal infections. Common parasites include *Uncinaria* (hookworm), *Ascaris lumbricoides* (roundworm), *Strongyloides stercoralis*, *Giardia lambia*, and *E. histolyica*. Moreover, behavioral practices that increase disease exposure remain intact. Very little handwashing is prac-

ticed, and soap is frequently unavailable or not used regularly. Infection and re-infection is possible through several routes. Unwashed hands prepare and handle foods that are only rinsed with potentially contaminated water. Children's waste products are wiped cleaned with rags or leaves, and such cleaning is not usually followed by washing. Finally, communal drinking of homemade beer (*chicha* or *shocdye*), generally not prepared using hygienic practices, is an important component of daily social life in every Tsimane community.

On the other hand, there have been significant changes in the third factor, treatment modalities. During the 1990s, there was an increase in immunization campaigns that even sporadically entered remote regions. In 1990 the mission-organized health clinic, Horeb, was established outside of San Borja to provide medical assistance for Tsimane. An evangelical mission-affiliated nurse also helped with numerous cases of hospital care of gravely sick individuals during this time, in coordination with personnel at Horeb. Analysis of inpatient records for the year 2000 shows a large number of people receiving treatment, primarily for infant and child diarrhea, fevers, pneumonia, influenza, skin and eye infections. The majority of patients came from nearby communities due to excessive travel time for members of distant communities and lack of sufficient food for patients and family members while awaiting recovery. There is also a municipal hospital in San Borja to which Tsimane sometimes travel when they are gravely ill. Some have received surgeries there. Moreover, there are itinerant merchants that travel to Tsimane communities, both distant and far, to trade forest products and food for clothes, cooking utensils, alcohol, and, importantly, antibiotics and treatments for Leishmaniasis.

With these factors in mind, we offer the following set of hypotheses to explain the pattern of mortality change among the Tsimane. The life expectancy of the Tsimane had already begun to change by 1950, and this is why we find a life expectancy of about 44, instead of the usual 35 for other premodern populations. The first set of changes was due largely to host factors, as a result of nutritional improvements with the introduction of rice horticulture, citrus fruits and some market exchange. From 1950 to 1990, large regional differences in mortality rates developed, because members of the closer villages could travel to receive medical treatment. Members of close villages were also more likely to be involved in patron-client relations with Bolivian *patrones*, who sometimes helped provide medical assistance. In communities with missionaries, people also received direct help and were also assisted in traveling to receive medical treatment in San Borja. Communities closer to San Borja also experienced greater nutritional and health status, because of increased participation in wage labor and market exchange, enabling them to buy shoes, clothes, soap, and food. Even though villages near San Borja tend to be large and residents may therefore be at a greater risk of exposure to disease vectors requiring sufficient host density, the longer history of interaction with outsiders, and easier access to money and medicines seem to outweigh any potential cost of increased morbidity. Access to the market and domesticated animals also seems to outweigh any potential change in diet quality due to reduced access to meat and fish in these acculturated villages.

Preliminary analysis of children's heights and weights from 18 study communities shows a higher prevalence of stunting in forest and riverine villages than in acculturated villages and Fatima. Among adults, we found higher weights-for-age for those living in the acculturated communities and Fatima, and lowest for adults living in remote interior forest and riverine communities, suggesting caloric shortage, greater energy expenditure or greater complications due to infections. We found no differences in adult height by region. Godoy et al. (2006) also show no evidence for any secular change in adult heights from 1920 to 1980 birth cohorts, in contrast to other reported increases in height among other indigenous populations with increasing market exposure and healthcare access (Barrett and Brown, 1971; Laure, 1991; Leonard et al., 1996). Investments in human capital (i.e., schooling, literacy, Spanish speaking ability) showed no relationship with differences in men's height, and only slight positive impact on women's height during this time period. They explain the lack of any secular trend by the lack of any substantial intensification of market integration, and the continual presence of infectious disease. To the extent that increases in adult height tend to track improvements in nutrition, parasitism and infectious disease and mortality (Crimmins and Finch, 2006; Eveleth and Tanner, 1990), these data are consistent with our argument that the sources of morbidity and mortality have remained roughly the same in recent history.

The period improvements in health due to greater access to medical care did not benefit

all age groups equally. One hypothesis is that infants and young children in remote villages often die before they receive treatment. Because of their increased vulnerability, infants and toddlers frequently die within days of becoming sick. The travel time of two or more days from remote communities to San Borja can be long and difficult, especially for sick young children. Moreover, it frequently rains torrentially, and no travel is possible during those times. One tragic case occurred recently. We received an emergency message from a remote, forest community for whom we provided a radio. The log bridges along the dirt road leading to their community had been washed away by recent rain storms. They asked if we could send a motorcycle out to retrieve the sick infant. As we were preparing the emergency evacuation that same day, the villagers called again to say that it was too late and the baby had died. In addition, because infant death is so frequent, there appears to be some resignation to its occurrence. As is commonly the case in Amazonian societies, newborns are often not given names until they are over 1 year old, and have passed the high mortality period. Additionally, sicknesses are rarely viewed as caused by microscopic pathogens that respond to medical treatment, especially in more remote villages. Instead, sickness and disease is due to sorcery by forest or river guardians, or by suspicious, jealous or angry individuals. Attitudes of resignation and the native understanding of causes of sickness often result in delays for receiving proper treatment, with death as an unfortunate result. In our experience, we have found that it is not uncommon for Tsimane to seek out medical attention when it is too late. While these same problems sometimes occur in the communities nearby San Borja, they are less frequent because of the reduced travel time, greater access to money and increased familiarity with medical treatments and personnel. This may perhaps explain the very large differences in infant and child mortality across regions.

In contrast, in the case of adults and older people, there is more time and motivation to travel and obtain treatment. We hypothesize that the large period effects on adult mortality in the remote communities is due largely to increased access to the clinic and hospital, and the purchase of antibiotics. Prior to 1990, the access was much more limited. The reduction in mortality among adults over age 40 is due to fewer tuberculosis and respiratory-related deaths. Increased resistance to tuberculosis and other infectious illness may also have contributed to reductions in adult deaths, as observed in the historical epidemiologic transition pattern. Digestive illnesses such as appendicitis and intestinal infections, and accidents are also greatly reduced in the 1990s among older adults. Emergency medical attention for older adults may be partly responsible for lower mortality at Fatima. Greater mobilization of effort to treat older adults with chronic and acute illnesses, rather than any decrease in the incidence of illnesses, may be responsible for improvements in adult survivorship over the last decade. In a provocative reanalysis of age-specific changes in mortality throughout the epidemiologic transition, Gage (2005) found for some European countries in the early 19th century, changes in adult mortality occur without major improvements in treatment modalities, a notion contrary to our argument for the Tsimane. However, none of those historical changes are of nearly the magnitude experienced by the Tsimane. For example, whereas Swedish and English mortality decreases absolutely by 1% for older adults during early parts of the epidemiologic transition, we find an absolute decline of 5% in old age mortality, representing a relative reduction of close to 50% in remote Tsimane villages.

Some of these hypotheses may prove incorrect. We are currently collecting data to test them. However, we hope that this framework will prove useful for analyzing epidemiologic transitions in traditional aboriginal groups and in developing societies. It has already been recognized that standard epidemiologic transition theory, as developed by focusing on trends among nations, may require revision when focused more narrowly on distinctions based on ethnicity, sex, socioeconomic status and ecology (Gaylin and Kates, 1997). Lack of a clean water supply and sanitation hurt many people throughout the developing world, especially in rural areas but sometimes in urban areas as well (Gribble and Preston, 1993). Differential access to medical attention is likely to affect the character of mortality transitions by age and sex. Host factors are also likely to play a role in areas of high food insecurity.

There are clear applied implications here. Programs that assess host factors, exposure and treatment modalities as separate factors may be able to more efficiently direct personnel, resources and funds to areas of greatest potential impact. In the case of the Tsimane, it is clear that improved water supply and sanitation could make a large difference in disease exposure and transmission. In the more remote

communities, it will be necessary to train community health workers and provide them with the materials for primary care treatment. At the present, almost all of the medical resources are provided to the more acculturated communities nearby San Borja, because of their greater political influence and because of logistical ease. Our data clearly show that infants and young children are dying at higher rates in remote communities.

Compared with other documented Amazonian groups, Tsimane survivorship ranks as moderately favorable. Mortality among Amazonian Indians varies widely over space and time, ranging from the initial Neel and Weiss Yanomamo study reporting an average life expectancy at birth of 21 years to a recent Ache life expectancy in 1996 of 51 years. Infant mortality among a sample of small-scale populations varies from 10 to 34% (Salzano and Callegari-Jacques, 1988). Survivorship to age 15 ranges from 38% among Xingu to 86% among Kaxuyana, with a mean of 69%, based on a survey of forager- horticultarists reported in Salzano and Callegari-Jacques (1988). Very low survivorship is likely due to contact-related epidemics (Coimbra et al., 2002). Tsimane child survivorship and life expectancy at birth are higher than those for South American hunter-gatherers such as the Ache (Hill and Hurtado, 1996), Hiwi (Hill et al., in press) and Warao (Layrisse et al., 1977). However, as found among most indigenous groups with respect to the national standard, Tsimane life expectancy still lags far behind that of Bolivia ($e_0 = 64$ in 2,000), which already carries the lowest life expectancy in South America.

Despite living in a similar tropical macroenvironment and engaging in a similar set of subsistence activities, Amazonian populations differ in terms of endemic parasitism, experience with infectious disease, tuberculosis and measles (Black, 1975; Hurtado et al., 2005). Increasing integration of Amazonian populations into national society is likely to improve health and increase survivorship, although outcomes will vary depending on the combination of prior history of infectious disease exposure, public health infrastructure, shifting diets and access to medical treatments. The census of indigenous Amazonia is estimated to be only a tiny fraction of precontact estimates (e.g., 4–6 million in precontact Brazil vs. 100,000 in 1950—Ribeiro (1967)). The future livelihood of indigenous Amazonian populations, especially in regards to decision-making about resource use, fertility and family planning depends critically on recent mortality patterns and expected mortality in current and future generations.

Finally, we conclude with some remarks about the human life course and its evolution. As we have shown elsewhere for other groups (Gurven and Kaplan, 2006; Kaplan and Robson, 2002), adult mortality among the Tsimane does not conform to traditional expectations of the Gompertz model that assumes mortality rates increase at a constant exponential rate after its nadir at the end of childhood. Instead, mortality rates increase very slowly during prime adulthood, and even in middle age. Gompertz-like mortality increase does not occur until after age 30, and the proportional rate of mortality increase grows sharply after age 60. Immunocompetence drops dramatically, and death rates from infectious disease increase sharply as a result. A range of chronic illnesses, including heart disease, cancer and gastrointestinal illnesses also occur at relatively high frequencies. It is possible that chronic disease actually occurs at higher frequencies among people who have been exposed to infection throughout their lives, as hypothesized by Costa (2000) and Finch and Crimmins (2004). Preliminary analysis of our economic data shows that very few people remain productive after age 70. Our hypothesis is that natural selection in the context of the traditional human lifestyle resulted in an effective lifespan of about 65–70 years (Gurven and Kaplan, 2006). The data presented in this paper show that medical interventions can greatly reduce mortality rates in old age, but we do not see evidence of significant increases in the productive lifespan upon which natural selection acts. We have shown elsewhere, as have others (e.g., Lee, 2003), that intergenerational transfers, rather than direct reproduction, are a good candidate for the extension of human longevity. However, after about 15 years of postreproductive investment in children and grandchildren, there may have been little evolutionary advantage to living longer. A quantitative understanding of the human life course remains a challenge, but we may now be closer to an adequate understanding of its determinants.

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Envejecimiento y Inflamación en Dos Mundos Epidemiológicos

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Resumen

Los seres humanos han evolucionado en un mundo con altas niveles de infección resultando en alta mortalidad a través de la vida, con pocos sobrevivientes en las edades avanzadas. Bajo tales condiciones, una fuerte respuesta de fase aguda inflamatoria se requiere para la supervivencia, sin embargo, las respuestas inflamatorias también pueden promover enfermedades crónicas del envejecimiento. Nuestra hipótesis es que los aumentos globales e históricos en expectativas de vida a edades más avanzadas se explican en parte por la exposición reducida a la infección y la inflamación. Para empezar una prueba de esta hipótesis, se compara la proteína reactiva-C(CRP); niveles en dos poblaciones con diferentes entornos epidemiológicos: los Tsimane de Bolivia y de las personasen los Estados Unidos. Alto CRP es significativamente más frecuente entre los Tsimane a través de la mediana edad, a los 35 años los Tsimanes han pasado más años con PCR alta comparado a los niveles que tienen los estadounidenses a los 55 años. Otras pruebas de los vínculos entre la infección, inflamación y enfermedades crónicas del envejecimiento entre los Tsimane requieren la recopilación de indicadores específicos de la aterosclerosis y la función cardiaca.

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Special Article

Aging and Inflammation in Two Epidemiological Worlds

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Humans evolved in a world with high levels of infection resulting in high mortality across the life span and few survivors to advanced ages. Under such conditions, a strong acute-phase inflammatory response was required for survival; however, inflammatory responses can also promote chronic diseases of aging. We hypothesize that global historical increases in life span at older ages are partly explained by reduced lifetime exposure to infection and subsequent inflammation. To begin a test of this hypothesis, we compare C-reactive protein (CRP); levels in two populations with different epidemiological environments: the Tsimane of Bolivia and persons in the United States. High CRP is significantly more prevalent among the Tsimane up through middle age; by age 35, the Tsimane have spent more years with high CRP than have Americans at age 55. Further testing of the links among infection, inflammation, and chronic diseases of aging among the Tsimane requires collection of age-specific indicators of atherosclerosis and cardiac function.

Key Words: Inflammation—Infection—C-reactive protein.

EXPLANATIONS of increases in life expectancy at older ages often focus on the role of relatively recent medical advances and behavioral changes. The historical reduction of infections is recognized as a major factor in the decline of early age mortality in the past two centuries: We and others have noted that cohorts who experienced lower mortality when young also experienced reduced mortality among survivors in old age (1–4). It is further hypothesized that population levels of inflammation have decreased over time in parallel with the reduction in mortality from infectious diseases (1,2). A reduction in the prevalence and duration of time spent with infectious conditions should lower the levels of lifetime inflammation. Because chronically elevated blood levels of inflammatory cells and proteins are independent factors in the atherosclerotic process, reductions in lifetime levels of inflammation should slow deterioration in the cardiovascular system with aging, as well as delay the onset of chronic cardiovascular diseases of old age (5–9). Cohort reductions in inflammation should result in increased ages at mortality, heart attack, stroke, and cognitive loss (8,9). The hypothesis that lifetime inflammation has decreased in modern populations and that aging processes are consequently delayed relative to historical populations cannot be directly tested because of the lack of tissue samples from these earlier eras. As an approach to testing the inflammation–aging hypothesis in modern populations, we compare C-reactive protein (CRP) levels in two populations with different epidemiological environments: the Tsimane of the Bolivian Amazon versus Americans.

Methods

Lacking statistically valid blood or tissue samples from historical populations, we sought a contemporary population that had limited exposure to modern medicine with a high level of mortality that would provide a useful calibration for understanding past populations and modern epidemiologic transitions. The Tsimane are indigenous foragers in the Bolivian Amazon with limited access to modern medicine, low life expectancy, and high mortality from infection. We examined CRP, a serum marker of inflammation, across the age range in this population for comparison with age-specific CRP and mortality levels in the United States. These two populations represent extremes in contemporary levels of infectious mortality, exposure to inflammation, and life expectancy.

In July 2002, Kaplan and Gurven initiated long-term research on Tsimane life history. Data were collected on demographic, economic, social, and health characteristics of >2200 Tsimane living in 17 study villages (9). These forager-horticulturalists live in about 60 small villages of extended family clusters located in a forested lowland tropical area. Despite their exposure to Jesuit missionaries in the late 17th century, the Tsimane were never successfully settled in missions and are relatively unacculturated. Their isolation will not last much longer because of increasing access to market towns, especially as supplies of forest game and fish diminish with increased encroachment by loggers and colonists. The life history data provide the basis for estimating life expectancy over the past 15 years in this population (10).

Inflammation is indicated in both countries by levels of serum CRP. Elevation of CRP is an acute phase response to infection that mediates bacterial clearance and is widely used to indicate systemic inflammation. However, chronic exposure to even moderately high CRP is associated with increased risk of cardiovascular events and other disabilities of aging in long-lived populations (9,11). We examined age-

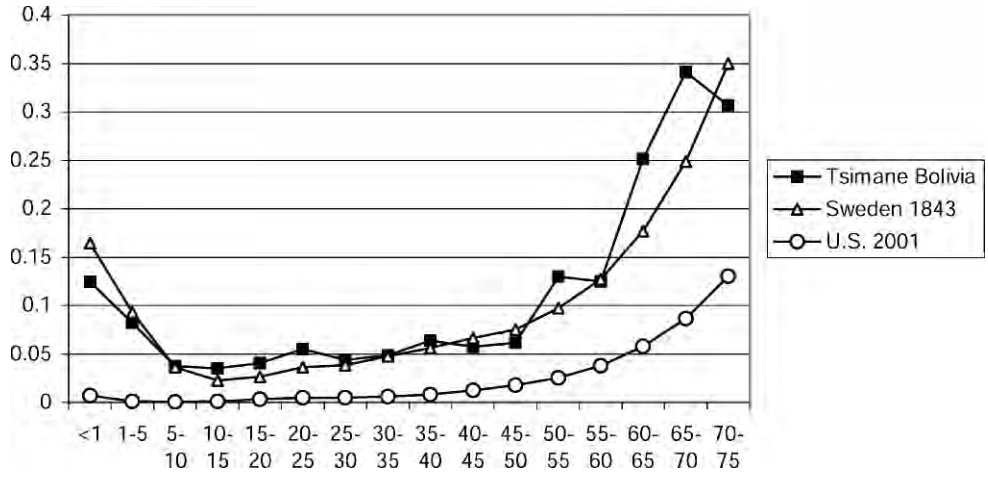

Figure 1. Probability of dying among Tsimane (1950–1989), Swedes (1843), and Americans (2001).

specific prevalence of high CRP and estimated the average number of years spent with high CRP for survivors up to specified ages.

For the Tsimane, CRP was assayed in whole blood collected by venipuncture from 607 people over the age of 4 during medical examinations in four villages during the summers of 2004 and 2005. Whole blood was hand-centrifuged on site at an ambient temperature and then frozen and stored in liquid nitrogen pending transport to the United States for assay. Assays were done using the Immulite 2000, high-sensitivity CRP assay, a solid-phase, chemiluminescent immunometric assay with a mean replicate coefficient of variation of 5.6% (Diagnostics Products Corporation, Siemens, Deerfield, IL). An indication of the reliability of this assay is that the percentages of high serum CRP reported for Tsimane children resemble those reported for Tsimane children of the same age from assays of dried blood spots after using the conversion formula (12).

The U.S. data on CRP are from the National Health and Examination Study (NHANES); 1999–2002, a nationally representative sample from noninstitutionalized persons collected from 1999 through 2002. Values of serum CRP were determined from samples analyzed by high-sensitivity latex-enhanced nephelometry on a BN II Nephelometer (Dade Behring, Siemens) (13). The assay used monoclonal anti-CRP antibodies and a calibrator that was traceable to the World Health Organization (WHO) reference material. The mean replicate coefficient of variation for the assay is 6.4% (13). Values of CRP for the Tsimane based on the Immulite 2000 assay were standardized to the Dade Behring assay used in NHANES (14).

This analysis defined CRP $>$ 3.0 mg/L as the cutoff for high CRP, which indicates high cardiovascular risk (15). Because we are interested in lifetime exposure to high inflammation, we use the age-specific prevalence of high CRP to estimate the number of years lived with high CRP by specified ages for both the Tsimane and U.S. data. The calculation assumes that the prevalence of high CRP observed in an age interval represents the proportion of life lived with high CRP for persons who survive through the interval. We also assume that the prevalence of high CRP below the age of measurement (4 years for the Tsimane and 2 years for the Americans) is equal to that in the 5–9 age range.

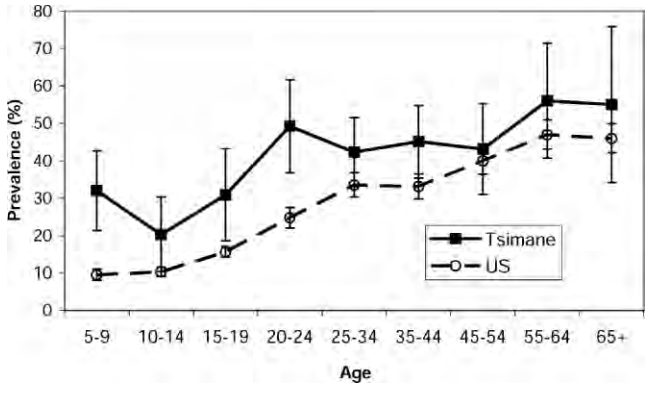

Figure 2. Prevalence of high-risk C-reactive protein (CRP) (>3 mg/L) in Tsimane and Americans.

Results

A Tsimane life table was constructed by Gurven from recent interviews representing the period from 1950–1989 (29,464 person-years of life) (10). Recent life expectancy, 42.8 years, is very close to that in 19th century Western Europe, for example, Sweden in 1843 (42.6 years) (Figure 1). In contrast to the Tsimane, the current U.S. life expectancy is almost twice as high (77.2 years) with infections responsible for only a small percentage of deaths.

The age-specific proportions with serum CRP $>$ 3.0 mg/L differ strikingly between the U.S. and Tsimane data (Figure 2). The Tsimane have significantly higher age-specific proportions with high serum CRP up to age 45–54 years than do the Americans. The proportion with high CRP among young Tsimane adults exceeds U.S. values for ages 65 and older. These remarkable elevations of CRP can be attributed to endemic infections in the Tsimane, as documented above. Few U.S. children have high CRP at any time relative to the Tsimane because childhood infections are less prevalent

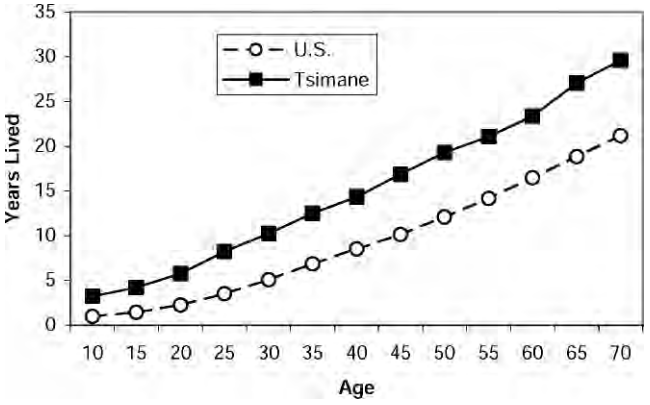

Figure 3. Years lived with high C-reactive protein (CRP) for those who survive to a specified age.

Table 1. Years Lived with High C-Reactive Protein (CRP) for Those Who Survive to Specified Age; Proportion of Life Lived With High CRP Up to Specified Age

	Tsimane		United States	
Age	Years With High CRP	Proportion of Life Lived With High CRP	Years With High CRP	Proportion of Life Lived With High CRP
10	3.6	0.36	1.0	0.10
15	6.1	0.41	1.5	0.10
25	10.3	0.41	3.5	0.14
35	15.0	0.43	6.8	0.19
55	24.5	0.45	14.1	0.26
65	30.1	0.46	18.8	0.29

in the United States. Nonetheless, in both samples, the percentage with high CRP increases after childhood. Factors associated with chronically high CRP in low-mortality countries include obesity, smoking, and the onset of cardiovascular conditions and other chronic degenerative diseases of aging (16,17). At the older ages, the Tsimane and U.S. populations have similar serum CRP.

Lifetime exposure to high levels of CRP is implicated in the development of atherosclerosis. Longer exposure to high inflammation early in life results in the Tsimane having lived more years with high inflammation by the time they reach adulthood. Years lived with high inflammation estimated from the prevalence is shown in Figure 3 and Table 1. By age 15, the average Tsimane has lived 6.1 years with high CRP, whereas the average time with high CRP for an American 15-year-old is only 1.5 years. By age 35, the Tsimane have spent more years with high CRP than have Americans at age 55. Over their entire life history up to age 70, the Tsimane spend more years and a greater proportion of life with high CRP than do people in the United States.

Discussion and Conclusion

The Tsimane population provides a unique opportunity to evaluate the role of CRP in an epidemiologic setting with current mortality as high as that in 19th century Europe. The similarity of the levels and the age-specific pattern of mortality for the Tsimane and Swedish suggests that both the Tsimane and those living in Northern Europe 150 years ago suffered from high levels of infectious mortality and morbidity (18,19). Medical examinations of 2800 Tsimane in 2004 and 2005 document the high levels of endemic parasitism and infection. More than two thirds (69%); were infected with at least one species of intestinal parasite at the time of the examination, and >60% had symptoms of either a gastrointestinal or respiratory illness.

Our evidence shows that persons in a high-mortality, highly infectious environment have higher CRP in the first four decades of life than persons in a low-mortality, low-infection environment have. Based on the association of CRP elevations with future cardiovascular events in populations with lower mortality and infections, we hypothesize that premature cardiovascular disease is a factor in the higher adult mortality of Tsimane. Studies of young persons in the United States have linked high CRP to vascular deterioration beginning in childhood (20,21). In the United States and other generally healthy populations, individual exposure to common infections has been associated with both CRP levels and risk of cardiovascular events (6). Thus, the greater exposure of Tsimane to inflammation could promote earlier vascular disease and other dysfunctions of aging. Conversely, the reductions in inflammatory exposure in countries like the United States may have been a significant factor in delaying aging and mortality in the past.

It is not straightforward to compare levels of CRP among the Tsimane to those in other populations. Most reports on CRP in populations come from those with low mortality and of European extraction; most do not show an age pattern of change in CRP, but report on one age group or do not differentiate by age. However, growing evidence suggests that CRP levels vary widely around the world. Tsimane children have higher levels of CRP than children in Kenya and Samoa; this finding would be consistent with relative levels of infection (12). Tsimane adults also have higher CRP than adults in the indigenous North Asian Yakut population, a group with relatively high, but recently decreasing, life expectancy due to rapid social change in the area that was once the Soviet Union (22). In fact, CRP levels among the Yakut are almost as low as levels in Japan which has much lower levels of CRP than the United States, the U.K., and Germany (22,23). In contrast, Tsimane adults 45 years old and older have a median CRP level (3.0 mg/L) close to that of the adult American Indian population (3.2 mg/L), with low levels of infection but high levels of diabetes and other cardiovascular risk factors (24).

In populations with low levels of infection and mortality, high inflammation has been strongly implicated in the pathophysiology of arterial degeneration and immunosenescence, as well as in a wide variety of chronic diseases including diabetes (25), metabolic syndrome (26), congestive heart failure (27), Alzheimer's disease (28,29), and disability (30). These links between inflammation and most major health problems support the hypothesis that inflammation is a common mechanism of many degenerative conditions linked to aging (28,31,32). There are many links between life circumstances and inflammation in addition to the infection emphasized among the Tsimane: The importance of various

paths depends on the population circumstances. Currently, in the United States, levels of inflammation among children and young adults are predicted by weight and obesity, exposure to cigarette smoke, and air pollution (33).

Further testing of our hypothesis requires new information on the role of arterial disease in adult mortality among the Tsimane. We must also test competing hypotheses about mortality from immune dysfunctions caused by high levels of lifetime infection and inflammation. CRP, for example, can impair the differentiation of antigen-presenting monocytes (dendritic cells) (34). While the Tsimane are rapidly gaining access to medicine and immunizations, we may be able to glean critical insights about the nature of mortality in a highly infectious environment that will more fully explain the doubling of life expectancy during the last 200 years and the potential for further increases in many parts of the world. In addition, a link between inflammation and late life health would provide evidence of antagonistic pleiotropy, that is, a process that enhances survival and reproductive success in the young, but with delayed adverse consequences at older ages (6,28).

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Inflamación e Infección No Causan Envejecimiento Arterial, ni son Factores de Riesgo de Enfermedades Cardiovasculares entre Agricultores-Cazadores-Pescadores

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Antecedentes: El envejecimiento de las arterias es bien caracterizada en poblaciones industriales del mundo, pero casi nada es conocido en poblaciones con poco acceso a la medicina moderna. En este artículo, describimos la salud y envejecimiento de los Tsimanes, una población con baja expectancia de vida, una carga parasitaria alta, pero poca grasa y fuerte condición física. La inflamación debido a las infecciones está implicada en todas etapa del envejecimiento arterial, inicio de aterosclerosis (enfermedad de las arterias que causa los infartos cardiacos) e hipertensión (alta presión sanguínea), entonces averiguamos si mayor nivel de inflamación esta correlacionado con riesgo cardiovascular. Al contrario, actividades diarias que son entre moderados y vigorosos, poca obesidad, y poca grasa en la dieta predicen un muy bajo riesgo en ancianos Tsimanes.

Métodos y Resultados: Enfermedad de las arterias periféricos (brazos y piernas) (PAD), basado en el índice tobillo-brazo (una medida se llama ABI que mide la diferencia en presión sanguínea en los tobillos y los brazos) e hipertensión fueron medidos en adultos Tsimanes, y comparados con niveles de poblaciones industrializadas. No había ningún caso de PAD en los Tsimanes, y nivel de hipertensión era muy bajo (3,5% de los adultos mayor de 40 años; 23% de los mayor de 70 años). Marcadores de infección e inflamación fueron más altas en los Tsimanes en comparación con adultos de EEUU, mientras HDL fue más bajo en los Tsimanes. Modelos estadísticas examinan relaciones entre ABP y presión sanguínea con biomarcadores del estatus energético, metabolismo, de inflamación e infección. En los Tsimanes, la obesidad, lípidos en la sangre, e historia de enfermedades no fueron asociados con ABI. A diferencia de los Tsimanes, el mayor nivel de colesterol, proteína reactiva-C, leucocitos (células blancas), tabaquismo y presión sistólica en los norteramericanos están asociados fuertemente con menor nivel de ABI.

Conclusiones: Inflamación no siempre es un factor de riesgo de degeneración de las arterias y de las enfermedades cardiovasculares, sino que puede ser compensado por otros factores como metabolismo saludable, estilo de vida muy activa, poco obesidad, una dieta con poca grasa, bajo nivel de lípidos en la sangre y salud cardio-respiratoria. Otras posibilidades incluyen la susceptibilidad genéticay el papel delas infecciones por helmintos. La ausencia de PAD y las enfermedades cardiovasculares entre los Tsimane son similares con informes anecdóticos de otras poblaciones de agricultores-cazadores-pescadores y sugiere que las enfermedades vasculares crónicas han tenido poco impacto enla mortalidad de adultos en la mayor parte de la historia de la evolución humana.

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Inflammation and Infection Do Not Promote Arterial Aging and Cardiovascular Disease Risk Factors among Lean Horticulturalists

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Abstract

Background: Arterial aging is well characterized in industrial populations, but scantly described in populations with little access to modern medicine. Here we characterize health and aging among the Tsimane, Amazonian forager-horticulturalists with short life expectancy, high infectious loads and inflammation, but low adiposity and robust physical fitness. Inflammation has been implicated in all stages of arterial aging, atherogenesis and hypertension, and so we test whether greater inflammation associates with atherosclerosis and CVD risk. In contrast, moderate to vigorous daily activity, minimal obesity, and low fat intake predict minimal CVD risk among older Tsimane.

Methods and Findings: Peripheral arterial disease (PAD), based on the Ankle-Brachial Index (ABI), and hypertension were measured in Tsimane adults, and compared with rates from industrialized populations. No cases of PAD were found among Tsimane and hypertension was comparatively low (prevalence: 3.5%, 40+; 23%, 70+). Markers of infection and inflammation were much higher among Tsimane than among U.S. adults, whereas HDL was substantially lower. Regression models examine associations of ABI and BP with biomarkers of energy balance and metabolism and of inflammation and infection. Among Tsimane, obesity, blood lipids, and disease history were not significantly associated with ABI. Unlike the Tsimane case, higher cholesterol, C-reactive protein, leukocytes, cigarette smoking and systolic pressure among North Americans are all significantly associated with lower ABI.

Conclusions: Inflammation may not always be a risk factor for arterial degeneration and CVD, but instead may be offset by other factors: healthy metabolism, active lifestyle, favorable body mass, lean diet, low blood lipids and cardiorespiratory health. Other possibilities, including genetic susceptibility and the role of helminth infections, are discussed. The absence of PAD and CVD among Tsimane parallels anecdotal reports from other small-scale subsistence populations and suggests that chronic vascular disease had little impact on adult mortality throughout most of human evolutionary history.

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Introduction

We report the first systematic study of peripheral arterial disease (PAD), hypertension and cardiovascular risk factors in a population with both high infectious and parasitic burden but low adiposity and robust physical fitness. The Tsimane are a population of 9,000 forager-horticulturalists in the Bolivian Amazon. Their recent life expectancy at birth of 43 years resembles much of Europe in the mid-nineteenth century, with half of documented deaths by infectious and parasitic disease [1]. The Tsimane have only in the past decade begun an epidemiological transition to increased life expectancy. Public health infrastructure and medical services remain minimal for most Tsimane and they continue to incur high rates of infection. Immunization was only regularly administered in the past decade and is still sporadic in many areas. Medical surveys show that about one-third suffer from respiratory illness, one-fourth from gastrointestinal illness, and over three-fourths from intestinal helminths or pathogenic protozoa. Anemia is highly prevalent and physical growth is stunted. Their history of infection and chronic low-grade inflammation lead us to predict greater PAD and hypertension.

Prevalence of PAD and hypertension was measured in Tsimane adults and compared with representative samples from seven countries spanning the Americas, Asia, Africa and Europe. PAD was assessed with the Ankle-Brachial Pressure Index (ABI), a simple, non-invasive and recommended form of PAD diagnosis [2] and risk indicator of coronary heart disease, stroke and mortality

[3,4,5,6]. We use regression models to examine associations of ABI and blood pressure with cholesterol, triglycerides, and body mass index (BMI) (measures of energy balance) and with biomarkers of inflammation [C-reactive protein (CRP)] and infection [erythrocyte sedimentation rate (ESR), leukocytes (WBC)]. We present comparative analyses among U.S. adults using a large, nationally representative sample (NHANES) in order to highlight the distinctions between Tsimane and members of a sedentary, well-fed and low infection population.

Background and Significance

Cardiovascular disease (CVD) and stroke account for the majority of adult deaths in the industrialized world, and are now major causes of morbidity and mortality in the developing world [7]. In the U.S., atherosclerosis is the main cause of CVD-related heart attacks and strokes [8]. PAD, affecting limb circulation in 10 million Americans, is primarily caused by atherosclerosis and is a risk indicator for coronary and carotid arterial disease, aneurysm, diabetes, and hypertension [9]. Diagnosis of PAD increases risk of CVD mortality 4–6 times over healthy age-matched individuals, though PAD is often asymptomatic [6]. The prevalence of PAD is 10–25% in men and women over 55 in developed countries.

Recent research considers chronic inflammation in the onset and progression of CVD. Many studies associate inflammatory markers and CVD morbidity and mortality after controlling for risk factors [8,10,11]. Bacterial, viral and parasitic infections are common among traditional human and primate populations both now and throughout our evolutionary past [12]. As a consequence, inflammation and adaptive immune responses have evolved under intense selection against pathogens. However, in modern societies with immunizations, public sanitation, adequate nutrition and medical services, and where hypertensive people live sedentary lives and frequently smoke, inflammatory processes have been implicated in all stages of arterial aging and atherogenesis [10,11], beginning early in life [10,13], and in the critical CVD risk factor, hypertension [14].

Atherosclerosis and CVD are caused by a complex interaction of lifestyle factors (diet, energy balance, smoking, exercise) and inflammatory pathways. Elevated cholesterol and other risk factors predict less than half of heart attacks annually [15]. The acute phase inflammatory marker, C-reactive protein (CRP), often predicts future vascular events better than other risk factors [16,17]. Indeed, individuals with lower than average cholesterol but high CRP have fewer heart attacks when given statins [18]. An estimated 25–30 million Americans fall into this category of low cholesterol but high CRP. Although CRP's role either as inflammatory marker or causal agent of vascular disease continues to be a subject of lively debate [19,20,21], it is increasingly used in clinical settings to help evaluate CVD risk.

Understanding the interaction of diet, energy balance, physical activity and inflammation is hampered by the populations studied: mainly well-fed in developed nations, or experimental animals fed *ad libidum* on diets that promote rapid growth. Both biomes contain few infectious pathogens and environmental inflammogens. In contrast, past human populations faced environments with strenuous physical demands, greater pathogen burden and low caloric diets. These environments characterize the lives of extant indigenous peoples with traditional lifestyles. Much of total mortality in those environments is by infections and parasites, rather than by the causes common in industrial populations, like chronic heart disease, diabetes and cancer [15,22]. Thus, opposing risk conditions characterize such populations. On one hand, high infection rates over the life course should associate with greater lifetime inflammation exposure, and hence greater risk of atherosclerosis and CVD. On the other hand, high work effort, minimal obesity, and low fat intake should lower CVD risk.

Though arterial aging in the form of elastin fragmentation and medial fibrosis may be an inevitable outcome of aging, the role of atherosclerosis in adult morbidity before the 20th century remains unclear. Studying arterial disease and CVD in indigenous populations is illuminating for three reasons. First, new light is shed on the roles and interactions of diet, exercise and inflammation on disease etiology. Second, subsistence populations with minimal medical access are characteristic of our evolutionary past, and may be informative about the role of vascular disease in the biology of aging during the long course of human evolution. Third, infectious disease is most prevalent in tropical regions of the developing world where the synergistic mix of risk factors and infectious causes are expected to bring a "gigantic epidemic of heart disease" in the coming decades [23].

Existing research provides contradictory findings and lacks important information on relevant variables. Traditional populations often show negligible CVD prior to acculturation to western diets and sedentary lifestyles [22,24,25]. Recently, however, Australian Aborigines and Pima Indians have acquired the highest prevalence of obesity and Type 2 diabetes in the world [26]. Higher rates of atherosclerosis, heart murmurs and other cardiac conditions among US soldiers in early 20th century were linked to higher lifetime burden of infectious disease, particularly respiratory infections and rheumatic fever [27]. In one of the few non-western populations assessed for PAD, high prevalence was found among black South Africans [28], consistent with their extensive CVD mortality and morbidity. To date, no studies have measured the prevalence of PAD and other cardiovascular risk factors, such as hypertension, in an environmental context with chronically low energy status and high rates of infection.

Results

Prevalence of CVD: PAD and BP

Peripheral arterial disease (PAD). PAD is absent (ABI$<$0.9) among all 258 Tsimane in our sample (see Methods). Mean$\pm$SD ABI is 1.10$\pm$0.07 for Tsimane women and 1.16$\pm$0.07 for men over age 40 (Fig. 1a). There is little evidence that ABI changes by age among Tsimane.

The absence of PAD among Tsimane contrasts with patterns observed in national samples, especially South African blacks (Fig. 2a). PAD increases with age in every investigated population except the Tsimane, ranging from 5–25% for adults over age 70. The comparison includes people in developed and developing countries, in urban and rural settings, but none live in the relatively isolated and infected conditions of the Tsimane.

Blood pressure (BP). Systolic BP was low among Tsimane young adults and climbed to moderately higher values among older adults (Fig. 1b). From age 20 to 70, the mean increases by 16% for women and 3% for men. Average diastolic BP is 9% higher for women in their 70s (65$\pm$8 mm) than for those in their 20 s, and 6% higher for older men than the average 66$\pm$10 for men in their 20 s (Table 1). Overall prevalence of hypertension among adults $\geq$20 years is 3.5% (SBP$\geq$140 and/or DBP$\geq$90), and increases with age. Hypertension peaks at 23.5% (12/51) for adults $>$70 years, much lower than that of the US and other countries (Fig. 2b).

CVD risk factors: inflammatory markers, infectious disease and blood lipids

Inflammatory markers and disease risk. Blood indicators suggest high levels of inflammation and infection among Tsimane (Fig. 3, Tables 1 and 2). For adults aged 40+, mean$\pm$SD CRP is

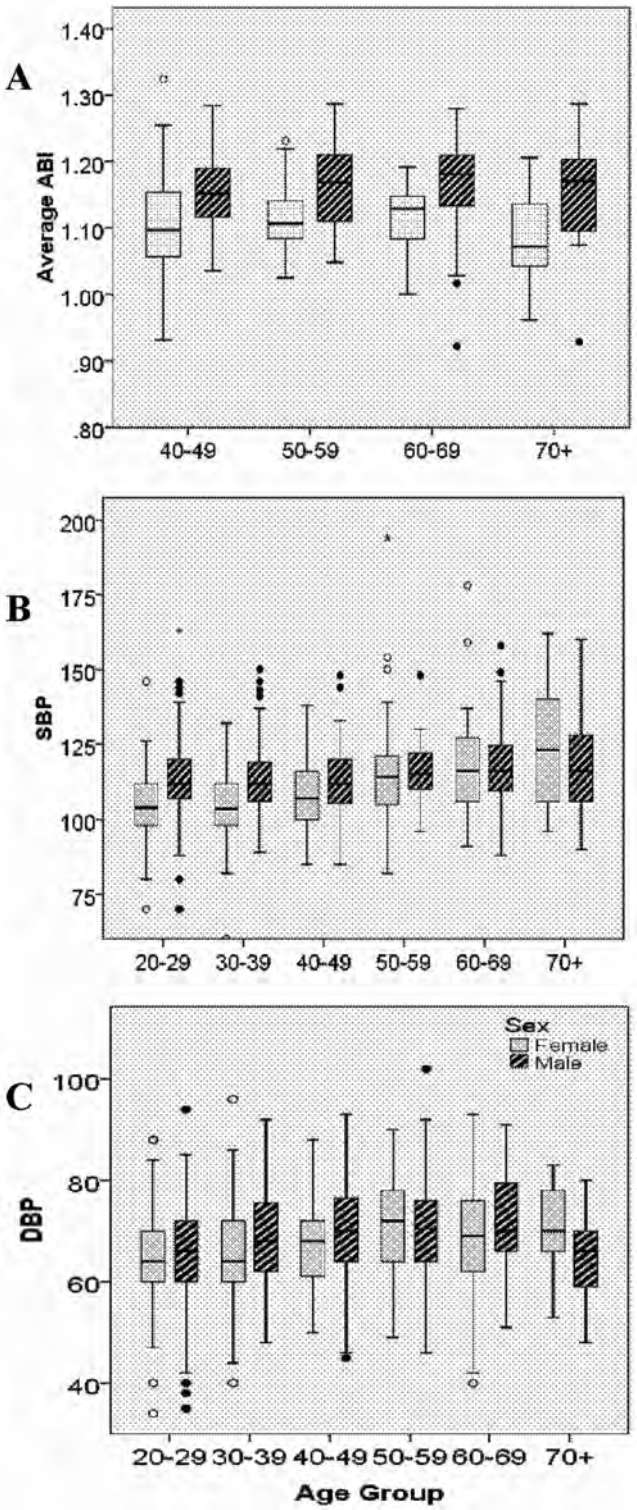

Figure 1. Median and interquartile values of (A) ABI (averaged across left and right sides), (B) systolic BP and (C) diastolic BP, for Tsimane by age group and sex.
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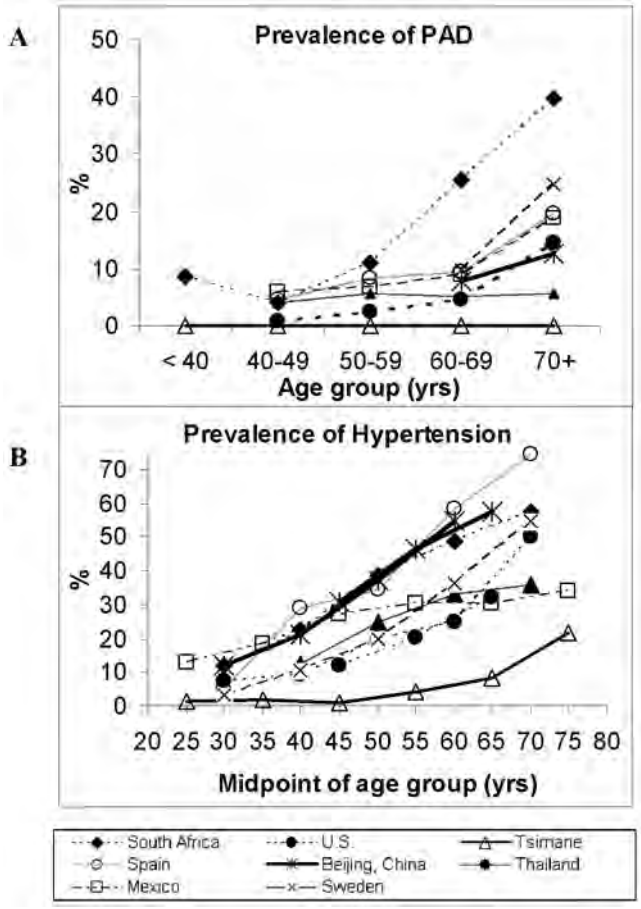

Figure 2. Prevalence of (A) Peripheral Arterial Disease (ABI<0.9) and (B) Hypertension (SBP≥140 and/or/ DBP>−90), among Tsimane and other populations. Data sources for ABI: urban China [67], urban Mexico [68], South Africa [28], southeast Spain [69], Sweden (Sigvant Birgitta pers comm), Thailand [70], United States [9]. Hypertension data for the same countries come from the World Health Organization Global Infobase, http://www.who.int/infobase/report.aspx. Note: x-axis represents mid-points of age intervals because of the different age intervals reported among studies (e.g. 30–39 vs. 35–44); Hypertension defined as SBP≥140 and/or DBP≥90 except for Sweden where SBP≥160 and/or DBP≥95.
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8.5±17.8 mg/L. About 50% of adults 40+ have CRP levels indicating CVD risk (CRP≥3.0 mg/dL) and 23% have CRP levels ≥10.0 mg/dL, which is usually indicative of acute infection [mean±SD CRP (<10.0 mg/dL) is 2.7±2.4] Tsimane white blood cell counts are elevated by US norms: with an average 9,461±2,824 units/mm^3, 17% over 40 are elevated. The prevalence of elevated ESR is 82% (see Table 1).

Tsimane clinical history is consistent with high cumulative exposure to acute infection. About 55% of those 40+ had at least one gastrointestinal illness in two prior medical exams and one third had respiratory illnesses. Two-thirds carried helminthic parasites. Infection and concomitant high inflammation are prevalent [29].

Blood lipids. Other CVD risk factors are low: mean±SD total cholesterol, 138±29 mg/dL and LDL, 75±22 mg/dL. However, high density lipoprotein (HDL) and triglycerides are exceptions: HDL is low at 37±9 mg/dL and trigylcerides moderately high at 130±73 mg/dL. Over half of Tsimane adults show unfavorable HDL levels by American Heart Association standards (<40 for men, <45 for women). Whereas no Tsimane show high risk levels of total cholesterol and LDL, 20% of U.S. adults have elevated levels of each blood lipid, even though many Americans use lipid-lowering medications. The prevalence of high triglycerides for most age groups in the U.S. is

Table 1. CVD risk factors for Tsimane population, presented as prevalence (%) of high risk, and mean absolute level, for metabolic and cardiovascular risk factors and indicators of infection and inflammation.

	Body size / lipids / lifestyle						**Inflammation**			**Pressure**	
	Prevalence of High Risk (%) + (standard error)										
Age group	BMI	Trig	Chol	HDL	LDL	Cig. Pack Yrs	CRP	WBC	ESR	Hyper- tension (%)	
	≥30	≥200	>240	<40	≥160	≥25	≥3	≥10800	>20 or 13	(Stage I/II)	
40–49	3.1	15.5	0.0	59.7	0.0	0.0	49.0	21.5	74.9	1.3	0.0
	(0.2)	(0.4)	(0.0)	(0.5)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)
50–59	8.3	12.0	0.0	68.1	0.0	0.0	45.1	15.0	87.6	3.7	1.9
	(0.3)	(0.3)	(0.0)	(0.5)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)
60–69	2.3	13.3	0.0	57.7	0.0	0.0	60.0	11.9	88.5	6.8	1.1
	(0.1)	(0.3)	(0.0)	(0.5)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)
70+	1.9	3.8	0.0	68.2	0.0	0.0	53.8	11.5	92.0	15.7	7.8
	(0.1)	(0.2)	(0.0)	(0.5)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.1)	(0.0)
	Mean level + (standard error)										
Age group	BMI	Trig	Chol	HDL	LDL	Cig. Pack Yrs	CRP Mean/ median	WBC	ESR	SBP	DBP
40–49	23.9	137	144	37	80	0.4	9.9/2.7	8,968	30.1	111	68
	(0.2)	(8)	(3)	(1)	(2)	(0.1)	(2.0)	(177)	(1.4)	(1)	(1)
50–59	24.4	142	144	37	79	0.4	6.8/2.7	8,244	38.1	115	71
	(0.4)	(11)	(4)	(1)	(4)	(0.1)	(1.7)	(251)	(2.3)	(1)	(1)
60–69	23.2	116	136	37	76	0.7	7.2/4.0	8,218	38.6	118	70
	(0.3)	(15)	(4)	(1)	(3)	(0.2)	(1.5)	(241)	(2.7)	(2)	(1)
70+	22.1	121	134	35	72	0.5	15.1/3.4	8,074	47.1	121	70
	(0.4)	(8)	(5)	(2)	(3)	(0.2)	(6.1)	(296)	(3.9)	(3)	(2)
N =	477	203	203	172	170	463	205	480	436	472	

Note: Triglycerides and LDL are based on non-fasting samples for Tsimane (a 6+ hours fasting sample was used for US). Units for variables are the following: triglycerides, cholesterol, HDL and LDL (mg/dL), BMI (kg/m^2), cigarette pack years (# cigarette packs smoked per day, where 1 pack-year is equal to smoking 1 pack per day for 1 year), CRP (mg/L), WBC (cells/mm^3), ESR (mm/hr), SBP and DBP (mm Hg). For ESR, 20 is cutoff for women and 13 for men. Hypertension prevalence refers to 140≤SBP<160 and/or 90≤DBP<100 (Stage I) and SBP≥160 and/or DBP≥100.

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double that of the Tsimane. There is little indication of age increases in these measures among Tsimane. Values are similar across ages after 40 and do not show increased CVD risk at older ages in any parameter (Fig. 3, Table 1).

Lifestyle risk factors: obesity and smoking

Obesity is 8–10 times more common in the US than among Tsimane (Tables 1 and 2). The average BMI for Tsimane adults is 24, but 29 for US adults. Among Tsimane tobacco consumption is minimal, about 0.77±1.85 pack years for men and 0.14±0.78 for women. While 72% of Tsimane men and 14% of women reported occasional use of unfiltered cigarettes or tobacco from home gardens, most Tsimane even in their sixties have smoked less than 2 pack-years. By contrast, U.S. adults aged 60+ have smoked 24 (men) and 11 (women) years.

Summary

The main CVD risk factors greater among Tsimane than U.S. adults are markers of infection. Low HDL prevalence is also common, being about 3-fold greater among Tsimane, although the clinical significance of low HDL in energy-limited populations has not been established. Inflammatory markers (CRP, ESR, and WBC counts) were significantly higher among Tsimane (Tables 1 and 2).

Regressions of ABI and BP on risk factors. The links between CVD risk factors and ABI, SBP and DBP were examined in multiple regressions controlling for age, age^2 and gender in both Tsimane and U.S. populations to explore whether risk factors show similar associations in both populations.

ABI. Regression results indicate that Tsimane men have higher ABI than women (Table 3), in contrast to the patterns for U.S. men and women. Obesity (BMI≥30), blood lipids, disease history, and cardiovascular indicators were not significantly associated with Tsimane ABI after controlling for age and sex (Table 3). Higher ESR predicted lower ABI (increase by 10 mm/hr associated with decrease in ABI of 0.05). Those with higher brachial diastolic BP display lower ABI. In U.S. adults, unlike the Tsimane case, higher cholesterol, CRP, WBC count, cigarette smoking and systolic pressure are all significantly associated with lower ABI, or more PAD (Table 3). Combining BMI, CRP, cholesterol and cigarette smoking in the same regression (Table 4) does not change these results. Restricting CRP analyses to cases where CRP<10 mg/L, as recommended by the American Heart Association and Centers for Disease Control [30], does not change the Tsimane results, although in the U.S. the magnitude of the effect increases five-fold ($\beta = -0.005$, $p<0.001$).

SBP and DBP

Aside from sex, the strongest predictor of both SBP and DBP among Tsimane is BMI (standardized estimate = 0.178, 0.170, respectively). The magnitude of the effect, however, is not very

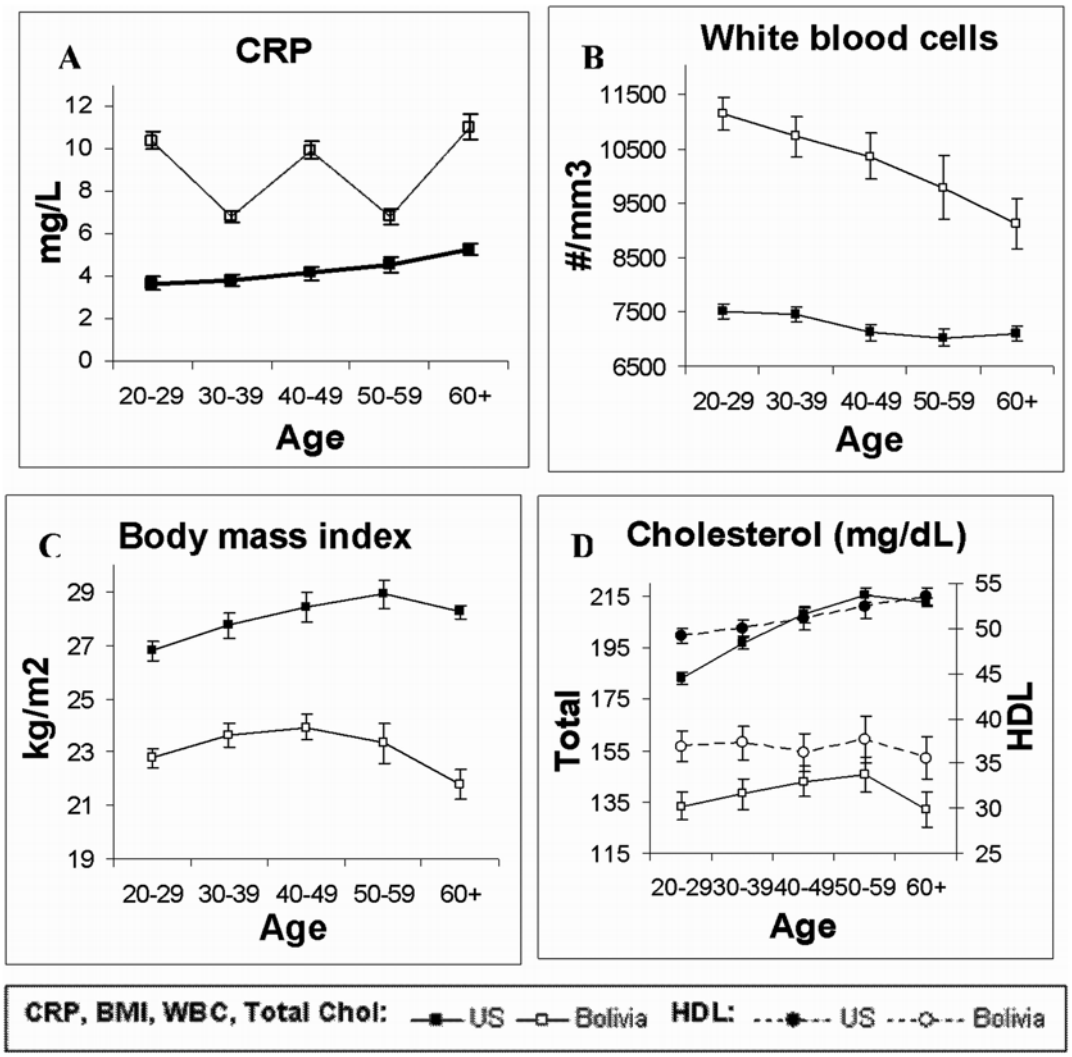

Figure 3. Comparison of cardiovascular disease risk factors among Tsimane and United States adults. Mean levels of (A) C-reactive protein (CRP, mg/L), (B) white blood cell (WBC) count (cells/mm^3), (C) body mass index (BMI,kg/m^2), (D) total and HDL cholesterol (mg/dL). Total cholesterol correlates strongly with low-density lipoprotein (LDL) among both Tsimane ($r = .82$, $p < .0001$) and US ($r = .91$, $p < .0001$), and with triglycerides (Tsimane: $r = .48$, $p < .0001$; US: $r = .43$, $p < .0001$), and so are not illustrated here. See Table 6 for further details.
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large: an increase in BMI by 5 kg/m^2 increases SBP by 4 mm and DBP by 3 mm (Table 5). High total cholesterol and triglycerides are associated with high SBP and DBP, and LDL marginally predicts higher DBP. Similar patterns for these variables are found in the U.S., with smaller BMI and triglyceride effects. In the U.S., CRP significantly associates with higher SBP, and DBP when CRP values $\geq$10 mg/L are eliminated ($\beta = 0.026$, $p < 0.001$).

Contrary to expectations, higher WBC and ESR associate with *lower* SBP and DBP among Tsimane, and CRP is not significant in the analyses. Restricting CRP<10 mg/L in the multiple regressions in Table 5, however, makes CRP a significant *negative* predictor of systolic pressure among Tsimane ($\beta = -0.728$, $p = 0.026$, $n = 210$), while in the U.S., CRP is a positive predictor of SBP ($\beta = 0.579$, $p < 0.001$). Cigarette smoking among Tsimane and U.S. shows results contrary to standard prediction: higher tobacco consumption is associated with *lower* SBP and DBP (Table 5), but smoking loses significance among Tsimane in the multiple regression in Table 4.

Discussion

Despite their high levels of inflammation, we find no evidence of advanced atherosclerosis among Tsimane adults. This is consistent with subjective clinical evaluation of arterial hardening: only 3 out of 570 individuals aged 40+ showed signs of augmented tension in the radial and humeral arteries. The presence of mild hypertension in older adults is, however, consistent with some age-related arterial stiffening. Tsimane show several clinical indicators for CVD: high blood CRP, low HDL and moderately elevated triglycerides, which are established risk factors in well-nourished populations. Tsimane diet includes salt in acculturated villages, and Tsimane consume moderate amounts of alcohol in the form of fermented manioc and maize. Nevertheless, we found little evidence for the most common risk conditions of atherosclerosis and CVD: no PAD and little hypertension. These results are consistent with reports of low CVD among traditional foraging and small-scale farming populations [22,25]. Hypertension and CVD increase upon greater adoption of a western lifestyle [31].

Table 2. CVD risk factors for US population (based on NHANES 1999–2004), presented as prevalence (%) of high risk, and mean absolute level, for metabolic and cardiovascular risk factors and indicators of infection and inflammation.

	Body size / lipids / lifestyle						**Inflammation**		**Pressure**	
	Prevalence of High Risk (%) + (standard error)									
Age group	BMI	Trig	Chol	HDL	LDL	Cig. Pack Yrs	CRP	WBC≥	Hyper- Tension (%)	
	≥30	≥200	>240	<40	≥160	≥25	≥3	10800	(Stage I/II)	
40–49	33.9	17.8	19.1	21.4	15.2	16.3	36.3	5.7	12.7	3.0
	(1.3)	(1.6)	(1.1)	(1.0)	(1.6)	(1.1)	(1.2)	(0.5)	(1.0)	(0.5)
50–59	35.1	23.4	22.5	19.9	17.5	24.7	41.2	5.5	17.1	5.8
	(1.6)	(2.0)	(1.2)	(1.3)	(1.6)	(1.0)	(1.5)	(0.6)	(1.1)	(0.7)
60–69	38.2	26.3	22.7	19.5	16.8	32.0	45.6	4.7	23.6	11.7
	(1.0)	(1.7)	(1.0)	(1.0)	(1.4)	(1.1)	(1.5)	(0.6)	(1.2)	(1.0)
70+	25.7	19.0	18.9	17.0	12.4	25.3	43.3	4.3	29.3	23.7
	(1.2)	(1.5)	(0.8)	(0.9)	(1.1)	(0.8)	(1.2)	(0.4)	(1.0)	(1.3)
	Mean level + (standard error)									
Age group	BMI	Trig	Chol	HDL	LDL	Cig. Pack Yrs	CRP	WBC	SBP	DBP
40–49	29	159 (7.1)	208	52	125	9.6	4.1/2.0	7196	121	76
	(0.2)		(1.3)	(0.5)	(1.4)	(0.5)	(0.2)	(60.7)	(0.5)	(0.3)
50–59	29	174	214	53	128	15.1	4.6/2.4	7082	127	76
	(0.2)	(8.3)	(1.2)	(0.5)	(1.6)	(0.6)	(0.2)	(76.9)	(0.6)	(0.4)
60–69	29	162	214	53	128	20.3	5.2/2.7	7032	135	72
	(0.1)	(3.5)	(1.1)	(0.5)	(1.7)	(0.8)	(0.2)	(64.3)	(0.6)	(0.4)
70+	27	151	208	55	120	17.1	5.52.6	7227	144	65
	(0.1)	(2.4)	(0.9)	(0.5)	(1.1)	(0.6)	(0.2)	(57.1)	(0.8)	(0.5)
N =	8761	3871	8564	8562	3818	8641	8620	8744	8619	

Note: Triglycerides and LDL are based on 6+ hours fasting sample for US (a non-fasting sample was used for Tsimane). Units for variables are the following: triglycerides, cholesterol, HDL and LDL (mg/dL), BMI (kg/m^2), cigarette pack years (# cigarette packs smoked per day, where 1 pack-year is equal to smoking 1 pack per day for 1 year), CRP (mg/L), WBC (cells/mm^3), ESR (mm/hr), SBP and DBP (mm Hg). For ESR, 20 is cutoff for women and 13 for men. Hypertension prevalence refers to 140≤SBP<160 and/or 90≤DBP<100 (Stage I) and SBP≥160 and/or DBP≥100.

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Though body mass, total cholesterol, and triglycerides predict higher blood pressure among Tsimane, the magnitude of these separate effects is small, and combined do not put Tsimane at high risk. Cholesterol and triglyceride elevations of 30 mg/dL coupled with 15 kg weight gain and 20% body fat percentage increase together add <6 mm SBP and 5 mm DBP.

We propose several possible hypotheses to explain the low atherosclerosis and CVD prevalence among Tsimane, and other traditional foraging and horticultural populations living under similar conditions. The combination of low LDL and high physical exertion is a common feature in many of these populations. The Tsimane diet contains wild game and fish, is low in saturated fat, and high in potassium (K). Plantains provide ~1,500 mg K/day. Low BMI and LDL, and sparse tobacco consumption may be protective factors trumping the risk factors of atherosclerosis and CVD. Oxidized LDL is implicated in inflammatory cascades leading to endothelial dysfunction, plaque maturation and rupture; therefore some argue that atherosclerosis and CVD are avoidable when LDL is maintained <70 mg/dL [15]. The Tsimane LDL profile is favorable though only 34% of Tsimane adults age 40+ have LDL below 70. Mean BP and ABI, however, do not differ among those above this LDL cutoff. With low HDL and moderate triglyceride levels, Tsimane have a healthy but "normal" mean total cholesterol to HDL ratio of 4.0 and an LDL to HDL ratio of 2.3 (for adults age 40+).

The physically demanding Tsimane lifestyle may be central for maintaining healthy metabolism and favorable body mass, blood lipids and cardiorespiratory health. Subsistence hunting, fishing and slash and burn farming require extensive daily physical activity, consistent with high VO_2max values found using a variation of the Harvard Step Test on a subsample. Using equations of total energy expenditure with body weights and physical activity levels (PALs) for Tsimane and relatively sedentary U.S. adults [32], we estimate that Tsimane men and women age 40–49 expend 850 and 450 kcals/day more, respectively, in physical activity than U.S. adults. To achieve mean Tsimane adult BMI, U.S. adults would need to expend 200–300 kcals/day above current levels. Two-thirds of U.S. adults age 18+ never engage in vigorous leisure-time physical activities lasting 10 minutes or more per week, and only 25% engaged in such activity 3+ times per week [33]. Only 15% of U.S. adults engage in moderate-to-vigorous physical activity for 30 minutes or more per day as recommended by the CDC/ACSM and stated in the *Healthy People 2010* objective. A recent study using an accelerometer rather than self-report showed that <5% of U.S. adults met this criterion [34]; in contrast, Tsimane adults are physically active most days of their lives.

These results are consistent with evidence for the cardioprotective value of exercise. Exercise reduces oxidative load in muscle, levels of inflammatory cytokines, SBP, macrophage-rich fat and improves insulin sensitivity [10]. Exercise associates with a favorable CVD risk profile independently of leanness [35]. Individuals with high cardio-fitness based on resting and maximal heart rate and VO_2max show the lowest heart disease risk [36,37].

Table 3. Regression of ABI on typical risk factors and infectious disease indicators for Tsimane and US adults, 40+.

	Tsimane				United States			
Variables	**beta**	**std err**	R^2	**N**	**beta**	**std err**	R^2	**N**
Baseline model:								
Sex (ref = female)	**0.052*****	0.009	0.145	258	**−0.041*****	0.003	0.095	7571
Age	**0.008***	0.004			**0.004****	0.001		
Age^2	**0.000***	<.001			**0.000**	0.000		
All analyses below control for sex, age and age^2:								
Total cholesterol (mg/dL)	<0.001	0.000	0.17	127	<**0.001**$^{+}$	0.000	0.098	7219
Triglycerides (mg/dL)	<0.001	0.000	0.171	127	<0.001^{+}	0.000	0.087	3343
estimated LDL (mg/dL)	0.001	0.000	0.135	110	<0.001^{+}	0.000	0.083	3209
HDL (mg/dL)	−0.001	0.001	0.126	110	<**0.001**$^{+}$	0.000	0.097	7218
Body Mass Index (kg/m^2)	−0.001	0.001	0.141	255	<0.001^{+}	0.000	0.093	7467
CRP (mg/L)	−0.004	0.004	0.165	129	−0.001	0.003	0.105	7261
WBC count (#/mm^3)	0.000	0.000	0.163	232	<0.001	0.000	0.107	7353
ESR (mm/hr)	*−0.005*$^{+}$	0.003	0.173	234	**N/A**			
Cigarette pack-years	<.001	0.002	0.145	257	**−0.001**	0.000	0.120	7163
Systolic BP (mmHg)	*−0.001*	0.000	0.154	258	**−0.001**	0.000	0.125	7360
Diastolic BP (mmHg)	**−0.001****	0.000	0.175	258	<0.001^{+}	0.000	0.097	7360

$^{+}$p<.1.
*p<.05.
**p<.01.
***p<.001.
doi:10.1371/journal.pone.0006590.t003

Table 4. Multiple regression analyses of ABI, SBP and DBP among Tsimane and US.

TSIMANE	**ABI (n = 126), R^2 = 0.178**		**SBP (n = 260), R^2 = 0.176**		**DBP (n = 260), R^2 = 0.084**	
Variable	**Beta**	**s.e.**	**beta**	**s.e.**	**beta**	**s.e.**
Intercept	0.825***	0.162	69.703***	6.864	43.965***	5.213
Male (reference = female)	**0.052*****	0.014	**3.211***	1.475	0.692	1.121
Age	*0.010*$^{+}$	0.005	**0.302*****	0.052	**0.123*****	0.039
Age^2	*<−.001**	<.001	–	–	–	–
BMI	<−.001	0.002	**0.904*****	0.236	**0.595*****	0.179
CRP (mg/L)	−0.000	0.000	**−0.016**	0.040	**0.012**	0.030
Total cholesterol	<.001	<.001	0.035	0.025	0.026	0.019
Cigarette Pack-Years	0.003	0.010	−1.023	0.638	−0.555	0.484
UNITED STATES	**ABI (n = 6746), R^2 = 0.130**		**SBP (n = 7476), R^2 = 0.214**		**DBP (n = 7476), R^2 = 0.132**	
Variable	**Beta**	**s.e.**	**beta**	**s.e.**	**beta**	**s.e.**
Intercept	**1.057*****	0.039	**74.674*****	5.773	**39.646*****	3.951
Male (reference = female)	**−0.046*****	0.004	1.088	0.651	**−2.414*****	0.371
Age	**0.007*****	0.001	**0.521***	0.199	**1.214*****	0.143
Age^2	**0.000*****	0.000	0.002	0.002	**−0.013*****	0.001
BMI	0.000	0.000	**0.383*****	0.048	**0.113*****	0.030
CRP (mg/L)	**−0.001*****	0.000	0.018	0.032	−0.022	0.026
Total cholesterol	**0.000****	0.000	**0.038*****	0.007	**0.027*****	0.005
Cigarette Pack-Years	**−0.001*****	0.000	**−0.035****	0.012	**−0.040*****	0.007

$^{+}$p<.1.
*p<.05.
**p<.01.
***p<.001.
doi:10.1371/journal.pone.0006590.t004

Table 5. Regression of blood pressure on typical risk factors and infectious disease indicators for Tsimane and US adults, 20+.

	Systolic BP				Diastolic BP		
	N	beta	std err	R^2	beta	std err	R^2
TSIMANE: Baseline model							
Male (reference = female)	1262	**15.500*****	1.910	0.131	**2.920***	1.430	0.048
Age		**0.335*****	0.034		**0.132*****	0.025	
Sex*age		**−0.248*****	0.047		−0.024	0.035	
US: Baseline model							
Male (reference = female)	13399	**−20.600*****	0.964	0.294	**−3.880*****	0.811	0.015
Age		**0.373*****	0.018		−0.016	0.012	
Sex*age		**0.393*****	0.022		0.015	0.017	
TSIMANE: All analyses below control for sex and age:							
Total cholesterol (mg/dL)	383	*0.036*$^{+}$	0.019	0.135	**0.043****	0.015	0.048
Triglycerides (mg/dL)	383	*0.014*$^{+}$	0.008	0.135	**0.012***	0.006	0.038
estimated LDL (mg/dL)	331	0.041	0.029	0.114	*0.041*$^{+}$	0.023	0.033
HDL (mg/dL)	331	−0.026	0.071	0.108	0.064	0.056	0.026
Body Mass Index (BMI kg/m^2)	1257	**0.782*****	0.116	0.144	**0.534*****	0.086	0.076
CRP (mg/L)	386	−0.005	0.028	0.126	−0.136	0.222	0.027
WBC count (#/mm^3)	1000	0.000	0.000	0.114	**0.000***	0.000	0.036
ESR (mm/hr)	1005	**−0.059*****	0.018	0.123	**−0.055*****	0.013	0.05
Mean Cigarette Pack-Years	788	**−0.789***	0.361	0.099	*−0.481*	0.264	0.041
UNITED STATES: All analyses below control for sex and age:							
Total cholesterol (mg/dL)	12641	**0.027*****	0.005	0.27	**0.041*****	0.004	0.034
Triglycerides (mg/dL)	5758	0.003	0.002	0.259	**0.005****	0.002	0.023
estimated LDL (mg/dL)	5566	*0.013*$^{+}$	0.007	0.263	**0.044*****	0.006	0.034
HDL (mg/dL)	12640	−0.012	0.014	0.267	−0.012	0.012	0.016
Body Mass Index (BMI kg/m^2)	13035	**0.417*****	0.034	0.284	**0.270*****	0.022	0.031
CRP (mg/dL)	12705	**0.081****	0.022	0.263	0.006	0.016	0.015
WBC count (#/mm^3)	12844	**0.000*****	0.000	0.268	**0.000*****	0.000	0.019
Mean Cigarette Pack Yrs	12430	**−0.055*****	0.011	0.270	**−0.030*****	0.006	0.017

$^{+}$p<.1.
*p<.05.
**p<.01.
***p<.001.
doi:10.1371/journal.pone.0006590.t005

Even Sumo wrestlers, despite intentional obesity (BMI>35; >25% body fat), have normal blood lipid levels during training periods, but then suffer from premature morbidity and mortality after retiring in their mid−30's [38]. Industrialization and automation of manual labor have diminished physical activity in most occupations such that much physical activity in the 20th century and beyond comes from sports and leisure. Even prior to entering the workforce, physical activity is extremely low among US adolescents [34].

Several alternative explanations may also be responsible for the low CVD risk profile of Tsimane, and merit future investigation. Tsimane and other Amerindians should be comprehensively investigated for distinct inflammation profiles due to genetic variability in loci affecting expression of CRP [39], apolipoprotein-E [40], mannose-binding lectin (MBL) [41], NR4A nuclear receptor family [42], interleukine-6 (IL-6) [43], IL-1 [44], and toll-like receptor 4 [45]. These reflect the extent to which Tsimane exhibit pro- or anti-inflammatory preconditions. Amerindians also show distinct human leukocyte antigen (HLA) expression at various MHC loci compared with other populations that show evidence of overdominant selection [46]. Although HLA-DR expression in macrophages and T-cells has been linked to plaque eruption and erosion [47], it is an open question whether allelic variation is of clinical significance. Other genetic contributions involve the processes by which inflammation and arterial damage result in acute coronary events. Plaque stability, disruption, erosion and thrombogenicity may be impacted by genes affecting interferon-α, collagen content and smooth muscle density in the fibrous cap [48], inflammatory infiltration of the cap, lipid composition of the atheromatous core and extracellular matrix (e.g. soft cholesterol esters vs. hard crystalline cholesterol), and both mechanical and hemodynamic forces that shear apart plaques. Genetic differences affecting metalloproteinase expression (e.g. collagenases, gelatinases, stromelysins and matrilysin) may also be important, as these have been described as degrading all components of the extracellular matrix and can therefore also impact plaque disruption [49]. Genetics and diet (e.g. flavonol-rich citrus fruits) may also influence platelet aggregation, coagulation and fibrinolysis, which affects blood flow and thrombus formation at the site of disrupted plaques [50]. Genes affecting monocyte

recruitment [e.g. CD14 receptor polymorphisms] [51], lipid transport [e.g., cholesteryl ester transport protein (CETP)] [52], lipid oxidation, and modulation of the inflammatory response to oxidized lipids may also help explain differences in susceptibility of populations to developing atherosclerosis [53].

One preliminary attempt to assess the implications of genetic differences between Tsimane and other populations is to consider atherosclerosis and CVD risk among Amerindians in the U.S. A study among 13 North Amerindian groups revealed a low rate of PAD (5.3%) among adults aged 45–74, little difference in PAD prevalence among the groups, and significant predictive effects of LDL, BMI, cigarette pack-years and fibrinogen [54]. Thus, while PAD is on the low end among North Amerindians, PAD is associated with the same risk factors as those in other populations. Most importantly, CRP levels among North Amerindians are higher than in other U.S. populations (median 3.2 mg/L even after removing the 16% who had CRP>10 mg/L), and predict incident CVD [55]. Despite similar PAD rates and lower LDL levels than national averages, a longitudinal cohort study of CVD among North American Indians has shown that North Amerindians have higher rates of CVD than other U.S. populations, and that standard risk factors (e.g. hypertension, LDL, HDL, BMI) are predictive of CVD [56]. Their high rates of CRP and CVD are likely due to the high prevalence of diabetes, renal disease and obesity; hyperglycemia impedes endothelial function and produces glycation end products that support myocardial dysfunction [57].

Another unexplored potential explanation highlights the hypothesized cardioprotective effects of chronic helminthic infection. Polarized Th-2 immune activation associated with helminthic infection modifies cytokine profiles, whereby anti-inflammatory IL-4, IL-10 and IL-13 protect vessel walls from oxidized LDL-induced monocyte injury in the endothelium, and downregulate fibrinogen synthesis [58]. Th-2 activation may also modulate responses to heat shock proteins, *Chlamydia pneumonia*, and cytomegalovirus, each of which has been tentatively linked to atherosclerosis [59]. Finally, helminthes may modulate host lipid metabolism, and may be responsible for lower blood cholesterol levels in parasitized humans [60]. Indeed, total and HDL cholesterol varied inversely with several infectious markers such as sedimentation rate, IgE and eosinophil count among Tsimane adults [61].

Conclusion

Though our characterization of arterial disease is provisional pending ultrasonographic studies, our study provides evidence that chronic low-grade inflammation in the absence of several other risk factors is not a determinant of CVD in a subsistence population. Inflammation and infection may not accelerate arterial degeneration in the context of restricted caloric intake, parasitism, and daily physical activity that maintains low BMI. We observed low levels of atherosclerosis and associated CVD among Tsimane, suggesting that these conditions may have been rare throughout pre-industrial human history. However, as indigenous populations like the Tsimane rapidly acculturate to western lifestyles, rates of CVD among older adults may rise considerably. Transitioning populations exhibiting western lifestyles but relatively high pathogen load are likely to suffer the double burden of chronic and infectious disease morbidity and mortality [62,63].

Materials and Methods

Ethics Statement

Informed consent was obtained for all protocols at three levels: 1) *Gran Consejo Tsimane*, the local Tsimane government organization that represents Tsimane interests and oversees all projects, 2) community officials and participants in village meetings, and 3) individual consent during medical visits and before each procedure. After explanation of a formal protocol by bilingual Tsimane assistants, consent forms were signed for literate participants, and verbal approval with fingerprint signature given for non-literate participants. Our consent procedures have been approved by the Institutional Review Boards at the Univ. of New Mexico, Univ. of California-Santa Barbara and Univ. of S. California.

Tsimane

Data were collected during annual medical exams of the Tsimane Health and Life History Project co-directed by MG and HK (www.unm.edu/~tsimane). Table 6 provides summary information on the sample population. Volunteers aged 40+ in 15 villages were sampled for ABI, blood pressure and anthropometry (2006 census population: 2,324 individuals; 350 were 40+, final sample $n = 259$, 133 or 52% male; 05–12/2007). Blood pressure was recorded from a larger sample of volunteers aged 20+ in 25 villages (eligible population 3,482; 1,298 are 20+; $n = 1,262$, 50% male; 11/2005–12/2007).

In-field blood analysis of nonfasting venous samples provided estimates of WBC and ESR. Blood measures exist for 234 ABI and 1,000 BP samples. CRP, total cholesterol, HDL and triglycerides were analyzed separately on a subset of serum samples by TriCore Laboratories (Albuquerque, NM). ABI exists for >110 of the 203 (age 40+), and blood pressure for 383 of the 427 (age 20+) samples with blood lipids, CRP and antibodies. Non-fasting LDL is estimated using the Friedewald formula (total cholesterol – HDL – triglycerides/5). CRP, ESR, and WBC are biomarkers of inflammation and infection.

Physicians measured ABI after training by HK and MG according to standard protocol by the American Heart Association. The patient lies supine with feet uncovered while brachial and ankle systolic pressure measurements are made using a SummitDoppler L150 ultrasound machine. Systolic pressure is first measured in the posterior and anterior tibial arteries and the higher of these is selected as the ankle measurement for each foot. The cuffs are inflated on the ankle to roughly 30 mm Hg above the systolic pressure, then followed by a slow release until the first audible sound of systolic pressure is heard. Systolic pressure is then measured in each arm and the highest is chosen as the brachial pressure. The ratio of the left and right ankle pressures to the brachial pressure is the left and right ABI. ABI <0.9 indicates PAD. ABI between 0.5 and 0.9 corresponds to intermittent claudication in the lower limbs, whereas values <0.5 are associated with more severe symptoms such as resting pain, severe occlusion and critical ischemia. ABI values >1.3 suggest calcification of arterial walls and noncompressible vessels, and are therefore also symptomatic of severe PAD.

Systolic (SBP) and diastolic (DBP) pressure were measured during each visit with a Welch Allyn Tycos Aneroid 5090 sphygmomanometer and Littman stethoscope. The systolic brachial pressure using the Doppler highly correlates with aneuroidal SBP ($r = 0.896$, $p<0.0001$). Cumulative experience smoking cigarettes was measured in cigarette pack years based on interviews. One pack year is equal to a pack of cigarettes smoked per day for one year. Bolivian physicians using bilingual Tsimane assistants diagnosed illnesses and trauma presented by patients on annual visits since 09/2002. Diagnoses from the International Classification of Disease (ICD-10) are grouped into gastrointestinal, respiratory, and other infections, over the two most recent exams 10/2005–12/2007.

Table 6. Sample characteristics for key study variables in analyses of ankle-brachial index (ABI) and blood pressure (BP).

Variable	Tsimane				United States (NHANES)			
	40+ ABI sample		20+ BP sample		40+ ABI sample		20+ BP sample	
	Mean	N	Mean	N	Mean	N	Mean	N
Sex (%)	51.6	258	50.8	809	51.7	7571	51.6	13399
Age (yrs)	53.1	258	37.6	1604	56.2	7571	46.1	13399
Height (cm)	156.8	257	156.1	1280	168.7	7479	169.0	13137
Weight (kg)	62.2	257	58.8	1280	80.8	7530	80.2	13149
BMI (kg/m2)	25.2	256	23.7	1266	28.3	7467	28.0	13035
Systolic BP	113.2	258	110.6	1262	128.7	7360	123.6	13399
Diastolic BP	71.1	258	67.4	1263	73.4	7360	71.7	13399
ABI	1.13	258	1.13	242	1.13	7571	1.13	7360
CRP (mg/L)	8.47	129	9.35	430	4.4	7260	4.2	12705
median	2.33		2.64		2.30		2.10	
Total Chol (mg/dL)	146.5	127	137.6	427	210.7	7219	202.8	12641
HDL (mg/dL)	38.1	110	36.7	369	53.2	7218	52.2	12640
LDL (mg/dL)	80.6	108	74.8	366	126.1	3209	121.2	5566
Triglyceride (mg/dL)	134.9	127	129.8	427	162.2	3343	148.2	5758
Cigarette pack-yrs	0.4	257	0.4	800	14.5	7162	10.3	12429

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Age estimation

Age estimates are derived from demographic interviews conducted with all individuals aged 18+ (n = 1,098) and from missionary records. Years of birth were assigned based on methodologies employed by researchers among the !Kung [64], Ache [65] and Hadza [66]. These include using known ages from written records, relative age lists, dated events, photo comparisons of people with known ages and cross-checking of information from independent interviews of kin. For example, Catholic missionaries have recorded the dates of 1,110 births among the Tsimane since 1952, many of the deaths occurring during the same period, and age estimates for an additional 120 individuals who were baptized as small children or as young adults during the early 1950's. In constructing relative age lists, multiple informants were used for each five year age grouping of individuals and inconsistencies were investigated and resolved. The photo comparison method used a sample of seventy photos of individuals with known ages. For older individuals, fifty photos of men and women from ages 50 through 75 were used. Each of these methods provides a roughly independent age estimate. When all estimates yield a date of birth within a 3-year range, the average was used unless one or two estimates were judged to be superior to the others. Further details are given in [1].

United States

Tsimane health status was compared with NHANES data for the years 1999 to 2004 (N = 7,571 for adults age 40+, N = 14,213 for adults age 20+). The NHANES monitors the health and nutrition of a representative sample of the American noninstitutionalized population. Methods have been widely published and so are only briefly summarized here.

Lipid indicators include total, LDL and HDL cholesterol and triglycerides. Triglycerides and LDL were measured for approximately half of the sample that fasted for at least 6 hours. Total and HDL cholesterol and triglyceries were assayed using the Hitachi 704/717/912 Analyzer, Roche Diagnostics. Fasting LDL cholesterol was calculated using the Friedewald equation. CRP was determined by the latex-enhanced Behring Nephelometer. White blood cell differentials were determined using the Beckman Coulter® MAXM.

ABI was measured among the 40+ sample (N = 7,571) by trained technicians. People who had amputations, excessive obesity, or other conditions that inhibited examination were excluded. The procedure was the same as described for the Tsimane. Systolic and diastolic blood pressure was measured by physicians using a stethoscope and sphygmomanometer (Baumanometer® with a Calibrated® V-Lok® cuff, Latex Inflation Bulb, and an Air-Flo® Control Valve). SBP and DBP values are the average of three individual readings.

Analysis

Multiple linear regression (PROC REG in SAS 9.1) was used for continuous values of ABI and blood pressure, as a function of demographic variables, risk factors and disease markers. Each risk factor is included separately in a baseline model that controls for sex, age and age^2 for ABI, and sex, age and sex*age for BP. These results are reported in Tables 3 and 5. Table 4 reports multiple regressions of ABI and BP that include BMI, CRP, cholesterol and cigarette smoking.

Post-hoc power analysis for multiple regression assuming a 0.05 alpha level was performed to assess whether the absence of significant effects in the Tsimane analyses was due to small sample size. Given the observed R^2, number of predictors and sample size, most regressions show power above 92%. Even considering the analysis of HDL on ABI (Table 3), where the sample size and R^2 were lowest, power was still 89.6%. Only in the regressions of diastolic BP (Table 5), where $R^2<0.08$, did power reach as low as 70% (for HDL). The only analyses of Tsimane DBP that did not reveal statistically significant effects, however, also were not significant in the U.S. analyses, where power was 100%.

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Author Contributions

Conceived and designed the experiments: MDG HK CEF EC. Performed the experiments: DER. Analyzed the data: MDG SV JKK. Contributed reagents/materials/analysis tools: MDG JW CEF EC. Wrote the paper: MDG.

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Debe la Presión Arterial Aumentar Inevitablemente con la Edad? Prueba Longitudinal entre Agricultores-Recolectores.

Michael Gurven, Aaron D. Blackwell, Daniel Eid Rodríguez, Jonathan Stieglitz, Hillard Kaplan

Resumen:

El aumento en presión arterial por edad es un factor de riesgo de enfermedades cardiovasculares y renales, accidentes cerebrovasculares y diabetes mellitus. La elevación de la presión arterial por edad se han observado en casi todas las poblaciones del mundo, menos cazadores-recolectores, agricultores y pastores. Aquí probamos si hay aumentos en presión arterial por edad entre los Tsimanes de Bolivia. También probamos si los cambios en estilo de vida producen una mayor presión arterial, y una tasa de aumento de presión arterial por edad más alta. Hemos medido la presión arterial longitudinalmente con 2,248 adultos mayores a 20 años (n=6,468 observaciones cubriendo 8 años). La prevalencia de hipertensión es 3.9% en mujeres y 5.2% en varones, aunque el diagnostico de hipertensión persistente basado en observaciones múltiples ha reducido la prevalencia a 2.9% en varones y mujeres. Los modelos estadísticas muestran aumentos de presión sistólica, diastólica y de pulso de 2.86, 0.95, y 1.95 mmHg, respectivamente por década en mujeres y 0.92, 0.93, y 0.02 mm Hg en varones. Esos niveles son mucho más bajos que las tasas observadas en otras poblaciones. Factores del estilo de vida como el tabaquismo y la habilidad de hablar español, casi no tenían efectos en el aumento de presión arterial. Vivir más cerca de San Borja correlacionaba con menos aumento de presión de pulso. En total, los efectos de modernización fueron mínimos en los Tsimanes, debido quizás a la poca obesidad, actividades físicas diarias y una dieta con factores protectores.

Does Blood Pressure Inevitably Rise With Age?
Longitudinal Evidence Among Forager-Horticulturalists

Michael Gurven, Aaron D. Blackwell, Daniel Eid Rodríguez, Jonathan Stieglitz, Hillard Kaplan

Abstract—The rise in blood pressure with age is a major risk factor for cardiovascular and renal disease, stroke, and type 2 diabetes mellitus. Age-related increases in blood pressure have been observed in almost every population, except among hunter-gatherers, farmers, and pastoralists. Here we tested for age-related increases in blood pressure among Tsimane forager-farmers. We also test whether lifestyle changes associated with modernization lead to higher blood pressure and a greater rate of age-related increase in blood pressure. We measured blood pressure longitudinally on 2248 adults age ≥20 years (n=6468 observations over 8 years). Prevalence of hypertension was 3.9% for women and 5.2% for men, although diagnosis of persistent hypertension based on multiple observations reduced prevalence to 2.9% for both sexes. Mixed-effects models revealed systolic, diastolic, and pulse blood pressure increases of 2.86 ($P<0.001$), 0.95 ($P<0.001$), and 1.95 mm Hg ($P<0.001$) per decade for women and 0.91 ($P<0.001$), 0.93 ($P<0.001$), and −0.02 mm Hg ($P=0.93$) for men, substantially lower than rates found elsewhere. Lifestyle factors, such as smoking and Spanish fluency, had minimal effect on mean blood pressure and no effect on age-related increases in blood pressure. Greater town proximity was associated with a lower age-related increase in pulse pressure. Effects of modernization were, therefore, deemed minimal among Tsimane, in light of their lean physique, active lifestyle, and protective diet. **(*Hypertension*. 2012;60:00.) • Online Data Supplement**

Key Words: hypertension ■ Tsimane ■ blood pressure ■ modernization

An age-related increase in blood pressure (BP) is viewed as a universal feature of human aging.[1–3] Among Westerners over age 40 years, systolic BP (SBP) increases by ≈7 mm Hg per decade.[4] Epidemiological surveys show a progressive increase in SBP with age, reaching an average of ≈140 mm Hg by the eighth decade.[5] Diastolic BP (DBP) also increases with age but at a lower rate than SBP; DBP may even fall at late ages.[6] Women show lower SBP and DBP than men up until the age of menopause, when women's SBP surpasses that of men.[7] By age 70 years, more than three quarters of US adults have hypertension.

Understanding the conditions affecting age-related BP increase is of obvious clinical importance. Higher BP is associated with cardiovascular and renal disease across diverse populations, even controlling for other factors.[5] Hypertension is the leading cause of cardiovascular mortality, and age-related BP increase is a high-priority target for intervention.[8]

The only reported cases of no age-related BP increase come from studies of subsistence-level populations.[9–11] These studies, however, are problematic: they are cross-sectional; use small, sometimes biased samples; and often do not specify explicit measurement methods. Age estimates of older adults are also poor.[12] Because of epidemiological and economic transitions, cohort effects may also have muted age effects; younger adults may have higher BP than older adults did when they were younger.

Nonetheless, results from many studies suggest that "modernization" results in changes in diet, adiposity, activity, and psychosocial stress, leading to higher BP and greater age-related increases in BP.[13–15] Although available evidence shows that hypertension is more common among those with modern lifestyles, it is unclear whether these changes impact the rate of increase in BP. It is also unclear whether these changes impact everyone equally or just high risk subpopulations. Heterogeneity in susceptibility and modernization could reveal further variability in longitudinal age trajectories of BP.

Here we assess the extent to which BP increases with age using longitudinal and cross-sectional data collected among Tsimane of the Bolivian Amazon. Tsimane are lowland forager-horticulturalists (population, ≈11 000) subsisting on plantains, rice, corn and manioc, fish, and hunted game. Tsimane are currently undergoing epidemiological and tech-

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nological transitions,[16] although there was no electricity, running water, or waste management at the time of study. Villages vary in their degree of healthcare access. Modernization takes several forms, including visits to the town of San Borja (population, ≈24000), wage labor with loggers or colonists, debt peonage with itinerant river merchants, and schooling. Schools now exist in >75% of villages, but many older adults have little or no schooling.

We first assessed hypertension prevalence and examined age-related changes in SBP, DBP, and pulse pressure (PP) to test the general hypothesis that BP increase is a robust feature of human aging. We then tested whether both BP and age-related increase in BP increased with modernization, operationalized by Spanish fluency, distance to town, smoking frequency, and body mass index (BMI). We also assessed whether an increase in BP with age occurred uniformly or was instead concentrated among a high-risk subpopulation.

Methods

Study Population

A total of 2248 adults aged 20 to 90 years (n=82 villages) participated in the Tsimane Health and Life History Project from July 2002 to December 2010. Adults were sampled anywhere from 1 to 9 times during medical rounds, yielding a sample of 6468 person-observations; 61% of adults were sampled at least twice and 36% ≥4 times (Table S1, available in the online-only Data Supplement). Sample size varied from 268 to 1186 individuals across 9 medical rounds (Table S2).

BP and Controls

SBP and DBP were measured on the right arm by trained Bolivian physicians with a Welch Allyn Tycos Aneroid 5090 sphygmomanometer and Littman stethoscope. Patients were seated or supine for ≥20 minutes before measurements. After 2008, all of the hypertensive readings were repeated after ≥30 minutes to confirm preliminary diagnoses. No Tsimane has ever taken medication to control hypertension. We use the Joint National Committee on Prevention, Detection, and Treatment of High Blood Pressure classification scheme to define BP categories as hypertensive (SBP ≥140 mm Hg or DBP ≥90 mm Hg), prehypertensive (120–139 mm Hg SBP or 80–89 mm Hg DBP), and normotensive (SBP <120 mm Hg and DBP <80 mm Hg).

Height (in centimeters) was measured by trained Tsimane research assistants with a portable Seca stadiometer. Weight (in kilograms) and body fat percentage were measured using a Tanita BF-572 weigh scale.

Modernization

Village-level variance in distance to San Borja is substantial (mean±SD, 41±23 km; minimum, 6; maximum, 82). Highest level of schooling and Spanish fluency were assessed during census updates and demographic interviews. Cumulative smoking was measured in cigarette pack-years based on interviews of number of cigarettes smoked per week and age at which the interviewee started smoking. One pack-year is equal to a pack of cigarettes smoked per day for 1 year. Given potential problems with recall bias, cumulative smoking experience was categorized into tertiles, including first (0.003–0.070 pack-years), second (0.07–0.30 pack-years), or third (>0.30 pack-years).

Statistical Analysis

Cross-Sectional Analyses

We used mixed- and fixed-effect models with linear and nonlinear age parameters. Linear models were fit with the *lm* and *lme* procedures in R 2.13.1. Nonlinear models used generalized additive models.[17,18] Generalized additive models use a thin-point spline to fit nonlinear age patterns while allowing for the simultaneous inclusion of parametric terms. Generalized additive models were fit with *gam* in the *mgcv* package and *gamm4* in the *gamm4* package. Mixed models were used to control for both individual variation in age trajectories and correlated errors between repeated samples.[19]

Longitudinal Rates of BP Change

Longitudinal analyses included only individuals with ≥5 years between first and last observation (please see the online-only Data Supplement). Repeat BP values were recoded as changes from the mean of a subject's BP measures (ΔBP); times were coded as days before or after the subject's median examination date. Linear models were fit to ΔBP including subject identification, a subject-by-time interaction term, season, and pregnancy status as controls. Parameter values for ΔBP were obtained from the subject-by-time interaction terms.

Two-Stage Mixed Model

To examine the effect of modernization on absolute BP levels and rates of BP change, we use a 2-stage mixed model (Tables 2 and S3). In the first stage, a standard mixed generalized additive model was run with a nonparametric age term, and individual variation in slope was modeled as a random effect. Individual slopes were obtained by adding the overall population slope for an individual's age plus that individual's random slope, both from the stage 1 model. These slopes were used as the dependent variable in model 2 to examine factors affecting rate of BP change.

Ethical Concerns

Informed consent was obtained for all of the protocols at 3 levels, Tsimane government, community, and individual. After explanation of protocols by bilingual Spanish-Tsimane research assistants, consent forms were either signed by literate participants or fingerprinted by nonliterate participants. All of the protocols have been approved by the institutional review boards at University of New Mexico and University of California-Santa Barbara.

Results

Sample Characteristics

Average age was 38.0 and 39.3 years for women and men, respectively (Table 1). Women represented 52.6% of observations. In comparison with normotensives, hypertensive men and women were older, shorter, had more body fat, were less likely to be nonsmokers, were less educated, and were more likely to speak Spanish.

Mean BP and Hypertension Prevalence

In the largest medical round (October 2008–2009), any observation of hypertension was followed with a confirmatory reading within a half hour. Mean BP for Tsimane men and women, respectively, was 113, 108 mm Hg (SBP); 70, 66 mm Hg (DBP); and 43, 41 mm Hg (PP). This cross-sectional analysis shows a notable increase in SBP and PP with age for women and a very modest increase in SBP for men (Figure S1). Prevalence of hypertension was 3.9% for women and 5.2% for men (Figure S2). It was highest among women over age 70 years (30.4%). Isolated systolic hypertension accounted for 49.3% of hypertensive cases, and isolated diastolic accounted for 22.3%. Prehypertension prevalence was 17.4% for women and 29.1% for men.

Prevalence of hypertension declined substantially if we required additional observations of elevated BP in other rounds. Among people sampled ≥3 times, only 38% were

Table 1. Sample Means by BP Status for Tsimane Adults Aged ≥20 y

	Women						Men						
	Blood Pressure Group			*P* Value§			Blood Pressure Group			*P* Value§			Sex by BP Group‖
Variable	Normal	Prehypertensive	Hypertensive	NvP	NvH	PvH	Normal	Prehypertensive	Hypertensive	NvP	NvH	PvH	
Age, y	38.0	56.0	66.5	‡	‡	‡	39.3	46.8	65.8	‡	‡	‡	‡
Height, cm	150.8	150.8	148.3	NS	†	†	162.7	162.2	159.5	NS	‡	†	NS
Weight, kg	53.6	56.3	52.5	†	NS	*	62.8	63.7	63.3	†	NS	NS	NS
Body fat, %	25.9	28.5	28.2	‡	†	NS	17.5	18.9	21.1	‡	‡	*	NS
BMI, kg/m^2	23.6	24.7	23.8	‡	NS	NS	23.6	24.2	24.8	‡	*	NS	NS
Years of schooling	1.4	0.5	0.5	‡	NS	NS	2.8	2.5	1.0	NS	NS	NS	NS
Distance to San Borja, km	37.7	35.0	35.9	NS	NS	NS	38.5	41.1	36.2	NS	NS	NS	NS
SBP, mm Hg	103.8	122.2	146.5	‡	‡	‡	107.9	122.5	144.3	‡	‡	‡	‡
DBP, mm Hg	64.4	73.9	80.0	‡	‡	‡	66.6	74.0	95.0	‡	‡	‡	‡
PP, mm Hg	39.2	47.0	65.2	‡	‡	‡	41.6	47.3	54.7	‡	‡	NS	‡
Smoking tertile, %													
None	78.9	69.3	58.8	*	*	NS	15.8	21.4	18.8	NS	NS	NS	NS
First	14.9	13.3	23.5				27.5	21.4	18.8				
Second	3.9	16.0	11.8				27.5	23.3	31.3				
Third	2.3	1.3	5.9				29.3	34.0	31.3				
Spanish fluency, %													
None	55.8	72.1	38.5	*	NS	*	24.6	31.4	16.7	NS	NS	NS	NS
Moderate	27.3	18.0	38.5				36.6	36.4	66.7				
Fluent	16.9	9.8	23.1				38.8	32.2	16.7				
n (cases)	942	158	44				838	288	51				

For each individual the median value of repeated measures on a given variable was used to calculate group means and determine hypertensive category. NvP indicates normal vs prehypertensive; NvH, normal vs hypertensive; PvH prehypertensive vs hypertensive; NS, not significant; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; BMI, body mass index; BP, blood pressure.

*$P \leq 0.05$.

†$P \leq 0.01$.

‡$P \leq 0.001$.

§*P* values for comparisons are from a Mann-Whitney U or χ^2 test.

‖*P* values indicate the significance of a sex×blood pressure group interaction in a linear model with Gaussian link or a geneneralized linear model with ordinal response and logit link function. Models also included main effect terms for sex and hypertension group (not shown).

hypertensive more than once, and only 1% were hypertensive for all of the readings (Table S1). Even among those sampled 8 times, 50% of those with a hypertensive measurement were hypertensive only once. It is, therefore, likely that the true prevalence of hypertension may be as low as one third the rates based on single measurements reported in Table S1 and preliminarily described in Reference 20. Among those sampled multiple times, frequency of ≥2 instances of hypertension was low (Figure 1). Only 7.7% and 27.3% of men and women, respectively, in the highest risk age category (aged ≥70 years) were hypertensive more than once, whereas an additional 18% of each sex were hypertensive only once. Overall, prevalence of repeat hypertension was 2.9% for both sexes.

Rise in BP With Age

We estimated age trajectories of SBP, DBP, and PP for Tsimane and a US comparison (National Health and Nutrition Examination Survey 2005–2006; Figure 2). Men's SBP is much flatter across adulthood than women's, whose SBP rises substantially around menopause. DBP increase with age is modest for women, whereas DBP decreases for men after age 60 years. This decrease in DBP is observed for both men and women in the U.S. PP increases for women after age 40 and less steeply for men after age 45. Despite these sex differences, Tsimane age profiles indicate substantially less change in BP with age than US age profiles, even after controlling for BMI (Figure 2). However, both populations show similarities, including lower SBP for women than men at younger ages and increasing BP in women after menopause. Although blunted, Tsimane males also show an increase in DBP early in life and a decrease later in life. PP increases at later ages in both populations.

The 2-stage mixed-modeling strategy tests for effects on both the intercept and rate of increase in BP for individuals (Tables 2 and S3). Stage 1 models main effects of predictors on BP, using random effects to control for repeated observations. Stage 2 assigns a slope to each individual consisting of the population slope for that age from stage 1 plus the individual's difference from the population mean obtained from the stage 1 random-effects model. These analyses include controls for sex, pregnancy status, season, BMI,

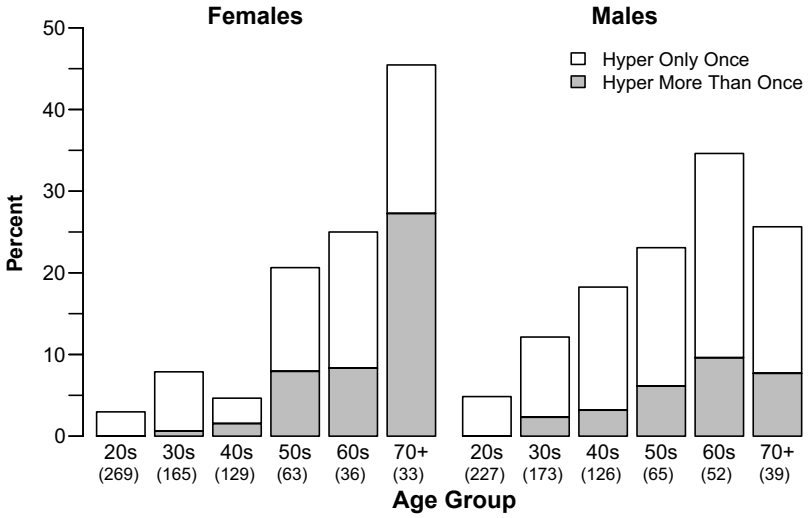

Figure 1. Prevalence of hypertension by age and sex among those sampled at least twice. □, hyper only once; ▨, hyper more than once.

Spanish fluency, years of schooling, and distance to San Borja. Substantial variability exists among individuals in ΔBP (Figure 3). Overall, SBP increases throughout life for women. Average ΔSBP increases significantly among women aged 40 to 55 years and then declines gradually (Figure 3A). The net ΔSBP for men increases from a negative slope to a positive one by the mid-30s, increases slightly for a few decades to a maximum of 2 mm Hg per decade, and then declines after age 50 years (Figure 3B). ΔDBP is constant and positive at ≈1 mm per decade for women but declines continuously with age in men (Figure 3C and 3D). ΔPP shows a similar pattern as ΔSBP in women, given the lack of age-related change in ΔDBP. ΔPP changes little before age 40 years given similar changes in ΔSBP and ΔDBP (Figure 3E). For men, ΔPP increases from negative before age 40 years to positive after age 40 years and close to 0 after age 60 years (Figure 3F).

Cross-Sectional Versus Longitudinal Analysis

Although analyses above include repeated measures, they are cross-sectional because they estimate the overall population pattern for a given segment of time. An explicit longitudinal analysis looks at within-individual changes. We estimated ΔBP for each individual with ≥5 years between first and last observation using linear regression models and controlling for season of measurement and pregnancy status. ΔBP varies somewhat among cross-sectional and longitudinal analyses, although less so when cross-sectional analyses are restricted to the same set of individuals with ≥5 observations (Table 3). Because of intraindividual lability of BP, SEs of longitudinally estimated slopes are much higher than those estimated cross-sectionally, and in many cases slopes were not significantly different from 0.

Across ages, men had positive but moderate ΔSBPs, ranging from 0.32 mm per decade in longitudinal to 1.23 mm per decade in the restricted cross-sectional analyses. Women had higher overall ΔSBP, ranging from 1.81 to 3.08 mm per decade. Men had little net increase in ΔDBP, with estimates ranging from −2.99 mm per decade in longitudinal to 0.93 mm per decade in the cross-sectional analysis. Similarly, female ΔDBP ranged from −1.86 mm per decade in longitudinal to 0.95 mm per decade in cross-sectional analysis. PP increased the most in longitudinal analyses, 3.31 and 3.67 mm per decade, but this increase was modest in cross-sectional analysis, with −0.02 and 1.95 mm per decade for men and women, respectively.

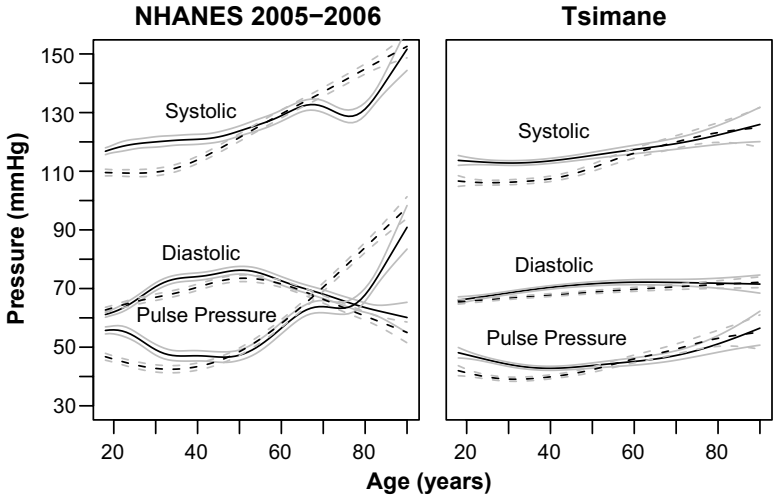

Figure 2. Blood pressure (BP) by age and sex. Generalized additive models of systolic BP (SBP), diastolic BP (DBP), and pulse pressure (PP) for males (solid lines) and females (dashed lines), controlling for body mass index (BMI) and pregnancy status. Tsimane models are mixed models to control for repeated observations (n=5528 observations, 1749 individuals). National Health and Nutrition Examination Survey (NHANES) models are based on a single time point (n=7359). Both models are illustrated at BMI=25.84, which is the midpoint between mean BMI for Tsimane (23.67) and NHANES (28.00). Gray lines are 95% CIs for the mean.

Table 2. Two-Stage Mixed Models

	Stage 1 Main Effects, mm Hg			Stage 2, ΔBP, mm Hg per Decade		
Parameter	SBP	DBP	PP	SBP	DBP	PP
Constant	94.5‡	57.6‡	36.3‡	2.0‡	0.9‡	0.6
Sex (male)	2.7‡	1.4*	1.1	−2.7‡	0.03	−3.0‡
BMI	0.6‡	0.4‡	0.3‡	0.02	0.01	0.03
Years of schooling	0.1	0.1	0.01	0.01	0.01	0.01
Distance to San Borja (per 10 km)	−0.3*	−0.1	−0.2	0.03	0.01	0.08‡
Pregnant	−2.8†	−3.3‡	0.4			
Smoking (tertile§)						
First	−1.2	−1.4*	0.2	−0.1	−0.03	−0.20
Second	1.1	0.5	1.1	−0.01	0.10	−0.10
Third	0.5	−0.4	1.2	−0.02	0.05	−0.08
Spanish fluency‖						
Moderate	1.1	0.5	0.5	0.05	0.07	0.01
Fluent	−1.1	0.4	−1.8*	0.08	0.06	0.2
Season¶						
Dry	3.9‡	2.8‡	1.0*			
Intermediate	−0.6	0.02	−0.6			

Stage 1 models have a random slope and intercept for each individual in the study, with blood pressure (BP) as the dependent variable. Stage 2 models use the individual random-effect slopes plus population main effect of age from stage 1 as the dependent variable. Age was included as a nonlinear thin-plate spline in both models. Only individuals with data for all of the variables and ≥2 observations were included (n=695 individuals; n=2876 observations). For more details please see the online-only Data Supplement. BMI indicates body mass index; SBP, systolic BP; DBP, diastolic BP; PP, pulse pressure.

*$P \leq 0.05$.

†$P \leq 0.01$.

‡$P \leq 0.001$.

§Data are relative to no smoking.

‖Data are relative to speaks no Spanish.

¶Data are relative to wet season.

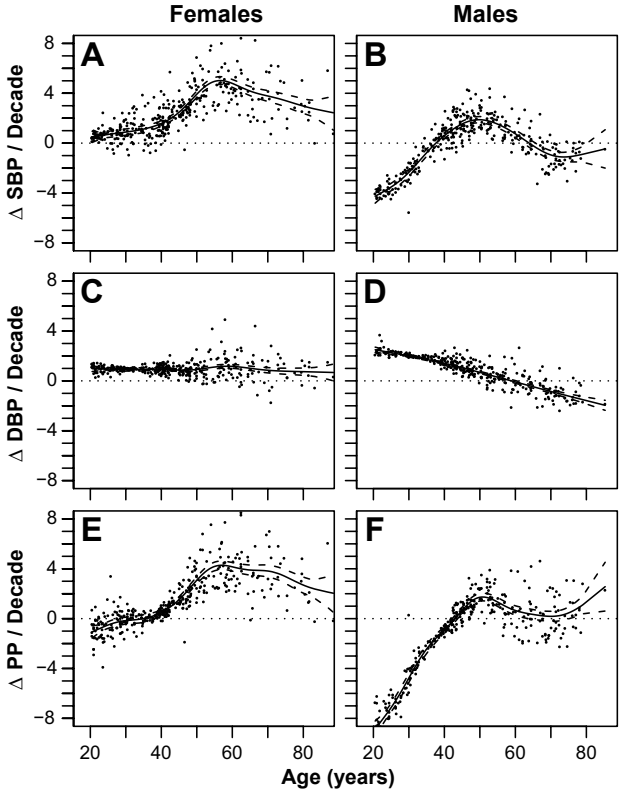

Figure 3. Change in systolic blood pressure (BP; SBP; **A** and **B**), diastolic BP (DBP; **C** and **D**), and pulse pressure (PP; **E** and **F**) per decade by sex and age. Points are ΔBP vs mean observation age (Table 2, step 1). Lines are spline fits and 95% CIs for the slopes as a function of mean observation age, estimated with a generalized additive model (Table 2, step 2).

After segregating the sample by age, cross-sectional and longitudinal analyses showed similarities but with notable exceptions. Men aged 20 to 39 years had significantly decreasing ΔPP in the cross-sectional model, including all Tsimane, but increasing ΔPP in the restricted sample. In all 3 of the models, male ΔPP increased between ages 40 and 59 years, but only ΔSBP in the full cross-sectional model increased significantly above 0. Male ΔDBP declined significantly in individuals aged ≥60 years in all of the analyses. Like men, women aged 20 to 39 years had increasing ΔPP in the restricted sample and no change in the full cross-sectional sample. ΔSBP increased in all 3 of the models, although not significantly in the longitudinal analysis. For women aged 40 to 59 years, ΔSBP, ΔDBP, and ΔPP increased in both cross-sectional analyses. Increases in ΔSBP and ΔPP in the longitudinal analysis were not statistically significant. Women aged ≥60 years showed increasing ΔSBP, declining ΔDBP, and increasing ΔPP, but only ΔPP changed significantly and only in the full cross-sectional sample.

Variance in BP

To test whether BP patterns were consistent for all of the individuals or affected subpopulations differentially, we examined differences in variance in BP and longitudinal slopes by sex, age, and population. Overall, variance in SBP, DBP, and PP was higher in women than in men and higher in Americans than in Tsimane, particularly after age 40 years (Figure 4 and Table S4). Variance in both sexes and populations increased with age; both Tsimane and American women showed higher variance in BP with age. Examining longitudinal slopes, Tsimane women had higher variance over age 40 years, but variance did not increase significantly at age ≥60 years compared with ages 40 to 59 years (Table S4). Tsimane men's SBP variance increased after age 40 years, and men's variance in slope also increased after age 60 years. Tsimane men's variance in DBP did not change significantly with age, whereas Tsimane and American women's DBP and PP variance increased with age (Figures 4 and S4). Overall variance was greatest for SBP, and the greater variance with age among women is evident. By age 60 years, although mean and median slopes for women were positive for SBP and PP, a significant portion of women showed slopes ≤0.

Effects of Modernization

We examined effects of modernization on SBP, DBP, and PP controlling for age, sex, season, and pregnancy status (Table 2, Stage 1). BMI was associated with higher SBP (β=0.61), DBP (β=0.39), and PP (β=0.25). BMI was not associated with significant differences in ΔBPs with age. Living farther

Table 3. Comparison of 10-y Increase in BP as Estimated From CS vs L Analyses

		Men			Women		
Variable	Pressure	CS All, β	CS≥5 y, β	L≥5 y, Mβ	CS All, β	CS≥5 y, β	L≥5 y, Mβ
Age, y							
20–39	ΔSBP	−0.33	3.65†	2.09	1.83†	2.59*	1.82
	ΔDBP	2.28‡	2.22*	−3.90	1.61‡	0.49	−1.93
	ΔPP	−2.71‡	1.32	5.99†	0.11	1.89†	3.75*
40–59	ΔSBP	2.03*	0.85	0.69	4.36‡	5.62‡	2.12
	ΔDBP	0.43	−0.87	−0.72	1.72†	1.91*	−0.97
	ΔPP	1.75†	1.67*	1.41	2.83‡	3.66‡	3.09
≥60	ΔSBP	−2.64	−2.86	−5.71	1.89	0.82	0.45
	ΔDBP	−4.08‡	−4.50†	−7.26*	−0.96	−2.03	−5.07
	ΔPP	1.4	1.65	1.55	3.09*	2.99	5.52
All	ΔSBP	0.91‡	1.23†	0.32	2.86‡	3.08‡	1.81
Ages	ΔDBP	0.93‡	0.23	−2.99*	0.95‡	0.72†	−1.86
	ΔPP	−0.02	0.97‡	3.31	1.95‡	2.38‡	3.67†

CS indicates cross-sectional; L, longitudinal; BP, blood pressure; SBP, systolic BP; DBP, diastolic BP; PP, pulse pressure. CS slopes were estimated on both the full sample and a subset with repeated observations ≥5 years apart, controlling for season, pregnancy, repeated measures, and subject identification. For values from CS analyses, parameter estimates (β) are shown; for values from L analyses, mean parameters (Mβ) are shown. Significance is given for a 1-sample *t* test for results from L analyses and for the model parameter from CS analyses.

*$P \leq 0.05$.

†$P \leq 0.01$.

‡$P \leq 0.001$.

from town was associated with lower SBP ($\beta = -0.30$ per 10 km) and a greater ΔPP ($\beta = 0.08$ mm/10 years per 10 km). Fluent Spanish speakers had lower PP than those with no Spanish fluency ($\beta = -1.8$ mm Hg). Individuals in the lowest smoking tertile had lower DBP than nonsmokers ($\beta = -1.43$), but other tertiles did not differ from nonsmokers. Smoking and Spanish fluency were not associated with significant ΔBPs, and schooling was not associated with significant changes in baseline BP or ΔBP.

Discussion

Age-related increases in BP are modest among Tsimane compared with Westerners. BP changes little with age among Tsimane men, whereas a larger increase occurs among Tsimane women. Such increases are not uniform across the population. Longitudinal analyses reveal variability in age-related slopes, and variability increases with age, particularly among women. Overall, hypertension prevalence is low among Tsimane, and point observations of hypertension are not sustained over time.

To place the Tsimane age-related increase in context, we compared Tsimane ΔSBP and ΔDBP with those from 52 populations from Intersalt,[21] a cross-sectional study of hypertension using standardized methodology among adults aged 20 to 59 years (Figure 5). Tsimane slopes were derived from a mixed model with the same controls over the age range 20 to 59 years. Tsimane ΔSBP and ΔDBP were among the lowest, comparable with those from 4 other subsistence populations, the Xingu and Yanomamo of Brazil, Papua New Guinean highlanders, and rural Kenyans. National populations show ΔSBPs that are 2 to 8 times higher and ΔDBPs that are 2 to 4 times higher than Tsimane. Given their median level of adult SBP and DBP, Tsimane ΔBPs were smaller than that predicted by the regression lines (Figure 5). Overall, Tsimane BP and ΔBPs were small compared with other populations, even after controlling for BMI (Figure S3).

Despite the minimal age-related increases in BP, Tsimane BP age profiles shared similarities with Western profiles. Women had lower BPs than men at young ages, but beyond age 50 years, women's BPs equaled men's. In addition, DBP declined at older ages across populations. Explanations for the late drop in DBP include "burned out" diastolic hypertension, reduced cardiac output, and increased large arterial stiffness.[6] Burned out hypertension seems unlikely given the DBP decrease in a population with minimal hypertension and longitudinal BP increase.

Effects of modernization were small and not consistent with the notion that greater exposure leads to poor health outcomes. Although no indicator of modernization predicted a greater age-related increase in BP, BMI had the most substantial effect on BP level. Cohort increases in BMI have been linked to reduced physical activity, poor diet, and other changes associated with modernization.[22] Indeed, >85% of hypertension diagnoses occur in overweight or obese individuals (BMI ≥25 kg/m^2) among Westerners.[23] It might be expected, therefore, that behavioral changes associated with modernization should impact BP primarily through an indicator of obesity, that is, BMI. BMI is almost universally positively and independently associated with morbidity and mortality from hypertension, cardiovascular, and other chronic diseases and type 2 diabetes mellitus.[24] Greater body mass increases blood volume and viscosity, impairs pressure natriuresis, and can lead to renal tubular sodium reabsorp-

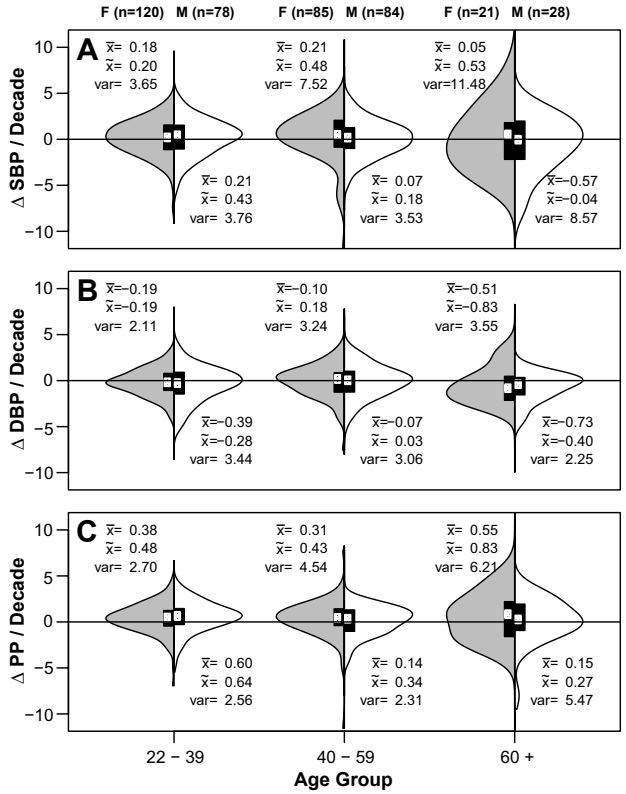

Figure 4. Distribution of individual systolic blood pressure (BP; ΔSBP; **A**), diastolic BP (ΔDBP; **B**), and pulse pressure (ΔPP; **C**) per decade by sex and age. Females are shown on the left (gray) and males on the right (white). Only individuals with ≥2 measures and ≥5 years between their earliest and latest BP measures were included. Box plots show the first to third quartile range. Distributions are smoothed density plots. White circles indicate medians.

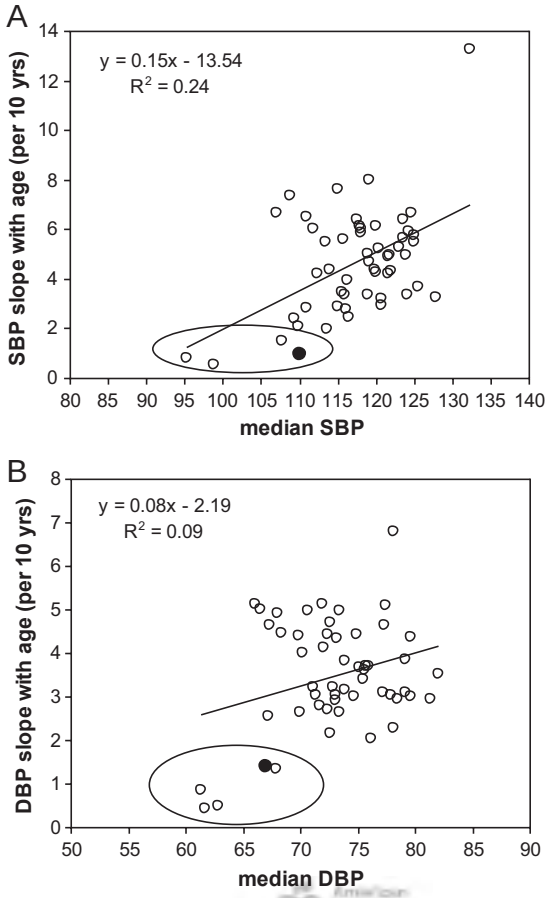

Figure 5. Increase in (**A**) systolic blood pressure (SBP) and (**B**) diastolic blood pressure (DBP) per decade. Cross-cultural sample includes 52 populations from the Intersalt study (ages 20–59 years).[21] Tsimane slope estimates are represented by black dots. Other populations inside ovals include the Brazilian Yanomamo and Xingu Amerindians, Papua New Guinea highlanders, and Kenyans.

tion.[25] Adipocytes also release angiotensinogen, a precursor of angiotensin.

The effect of a unit change in BMI on BP is similar among Tsimane and Americans (β=0.39, 0.13, and 0.26 for SBP, DBP, and PP from the National Health and Nutrition Examination Survey; β=0.61, 0.39, and 0.25 for Tsimane), but Tsimane BMI did not increase substantially throughout adulthood. Although obesity was rare among Tsimane (5.6% of women and 1.6% men age ≥20 years), overweight was not uncommon, including 27.8% of women and 21.9% of men. Heavy smokers and moderate Spanish speakers with greater schooling were more likely to be overweight or obese (Table S6). However, BMI was not greater in villages closer to town (Table S7), nor was overweight and obesity more prevalent (Table S6). Even if the average Tsimane was obese, Tsimane BP would not resemble US patterns. Based on the model from Table 2, a Tsimane woman with US average BMI at ages 40 and 70 years would have SBPs of 113 and 117 mm Hg, respectively, whereas an American woman with Tsimane average BMI at the same ages would have SBPs of 116 and 122 mm Hg, respectively (Table S8).

Despite the significant relationship between BMI and BP among Tsimane, Tsimane display lower median SBP and DBP and lower ΔSBP and ΔDBP than expected based on comparative BMIs of 52 Intersalt populations (Figure S3). Based on regressions using all of the Intersalt populations, Tsimane ΔSBP and ΔDBP from ages 20 to 59 years should be 339% and 134% greater, respectively, given their median BMI of 23.5. One possibility for the low BP given Tsimane BMI is that higher BMI among lean, active forager-horticulturalists reflects greater muscle rather than fat mass. However, this is not the case; BMI is highly correlated with body fat percentage in men and women across the BMI range (men, r=0.76, P<0.0001; women, r=0.55, P<0.0001; Figure S4). Body fat percentage per unit increase in BMI also appears similar among Tsimane and US adults (1.5% from BMI of 20–35; Figure S4 for Tsimane women; Reference 26 for US women).

Unlike patterns documented in the developed world,[23] Tsimane BMI reached its peak by age 45 years and then declined by 1.0 kg/m^2 by age 70 years (Table S6), although body fat percentage increased with age (men r=0.27, P<0.0001; women, r=0.13, P<0.0001). So, although we find evidence that modernization may lead to higher BMI among Tsimane, only cumulative smoking increased with age, whereas schooling and Spanish fluency were greater among younger adults. The net effect is a decline in BMI at late ages and only a minimal age-related increase in BP.

Distance to town showed minimal effect on BP and a positive effect on PP rise with age. However, indicators of modernization, such as smoking, Spanish fluency, and schooling, showed no consistent effects on BP. This finding contrasts with many published patterns of "0-slope" populations that underwent rapid modernization, where mean BP increased and also rose with age.[11] A meta-analysis of effects of modernization on BP shows universal positive effects with similar effect sizes worldwide (≈4 mm higher for SBP and 3 mm for DBP, on average).[14] That study, however, did not examine modernization effects on the rate of BP increase. Migration and initial contact (<3 years) in a modernized setting had the greatest positive impacts on BP, more than BMI or other variables. This high level of modernization is not representative of the Tsimane at present. Few Tsimane live in towns, and even those living in the most modernized villages still actively practice horticulture, fishing, and hunting. Most Tsimane have not given up their traditional lifestyle. Their diet remains rich in potassium, fiber, and omega-3 fatty acids and low in saturated fat.[20] Perhaps the greatest differences across regions is in access to market foods (eg, sugar, salt, and cooking oil), medical attention, and schools. A comparison of risk factors across regions does not show consistent high risk in more acculturated regions (Table S7). For example, whereas women near town and the mission show highest Spanish fluency, literacy, and schooling (Figure S5), women living downstream from San Borja show the highest body fat and BMI, whereas women living in remote villages smoke more (Table S7 and Figure S6). Despite increasing modernization, low hypertension prevalence and minimal age-related increase in BP among Tsimane are noteworthy given that Native Americans display higher susceptibility to hypertension; they show similar genetic profiles affecting salt avidity and cardiovascular reactivity as high-risk African populations, despite recent descent from cold-adapted north Asian populations.[15] This genetic propensity with rising obesity and changing diets is likely responsible for rising levels of cardiovascular disease and metabolic disease among native North Americans. However, among North American Indians from the Strong Heart Study, BP increased substantially with age but was minimally affected by obesity despite cardiovascular disease being the leading cause of death[27] (but see Reference 28). North American Indians show similar rates of hypertension compared with other US groups.[28] The nontrivial prevalence of prehypertension among Tsimane does suggest that imminent changes in cardiovascular risk factors are likely if physical activity, diet, or other hypertension-promoting conditions increase over time. Among "partially acculturated" island-dwelling Kuna, BP is also low and does not rise with age, whereas Kuna migrants to Panama City show relatively high prevalence of hypertension and rising BP with age.[29]

Finally, sex differences in Tsimane BP are striking. Most of the substantial rise in SBP and PP occurs in women, especially during the 40s and 50s (Figures S1 and 2–4). We find greater variation in women's BP and ΔBP with age (Figure 4 and Table S4). Unlike the sex profiles of BP among Westerners, Tsimane women have higher rates of hypertension and are at greater risk of BP-related morbidity than men. Although age profiles of BMI do not vary markedly by sex, body fat increases at a higher rate among women (Figure S4; 17.2% versus 12.2% per decade). BMI also has a 61% greater effect on SBP in women than in men (β=1.16 versus 0.72; Table S5). Postmenopausal increases in BP have been documented among Westerners and have been attributed to declines in estradiol production.[30] Estradiol influences vascular tone and structure and endothelial vasodilation and might inhibit vascular response to arterial injury.[31]

Strengths and Limitations

To our knowledge, the Tsimane are the only foraging-horticultural population sampled longitudinally. Their active lifestyle, lack of BP medication, and variable experience with modernization provided a unique opportunity to investigate BP change with age. Little bias is expected, because ≥90% of adults present were sampled per medical round. Few adults, however, were sampled ≥5 times, and the maximum time depth of the study was only 8 years. Although we include several measures of modernization, we did not consider its direct effects via individual-level measures of diet, physical activity, and other behavioral changes, although these are being collected in ongoing studies.

Perspectives

We found low levels of persistent hypertension and minimal age-related BP increase among Tsimane Amerindians compared with Westerners. Tsimane women were at greater risk of hypertension at late ages. Proximity to town affected SBP but not rate of BP increase in the predicted direction; BMI impacted BP level, but not BP slope, with age. Many aspects of traditional diet and activities were preserved even among more modern Tsimane, suggesting that they have not yet experienced severe changes that would otherwise promote greater hypertension and cardiovascular disease. Prehypertension prevalence was moderate, suggesting that further changes in diet and behavior could place Tsimane at elevated risk.

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Disclosures

None.

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Mortalidad Infantil y Fetal en una Población con Alta Fertilidad y Mortalidad en la Cuenca Amazonica de Bolivia

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Resumen

Poblaciones de indígenas tienen tasas de pobreza, enfermedades y mortalidad más alta que poblaciones non-indígenas. Para evaluar riesgos actuales y en el futuro entre los indígenas Tsimanes de Bolivia, presentamos tasas de mortalidad y crecimiento durante la niñez, y los cambios en riesgo debido a la modernización, basado en entrevistas de demografía hecho entre Septiembre 2002 a Julio 2005. Los Tsimanes tienen altos niveles de fertilidad (9 partos a traves de la vida de una mujer) y mortalidad infantil (13% mueren en primer año). Las infecciones son la causa principal de la muerte infantil (55%). La mortalidad infantil es más común en mujeres jóvenes que no hablan español, que tienen partos muy seguidos, y las que viven lejos de San Borja. La tasa de mortalidad infantil ha bajado durante el tiempo 1990-2002, y una tasa más alta de abortos reportados durante el tiempo de años 1950-1989. La muerte de los infantes es más común entre los nacidos durante el tiempo de lluvia. El retraso del crecimiento infantil es común (34% retraso por larga, 15% retraso por peso, 12% desnutridos) y más común en madres de bajo peso y en infantes nacidos de alta paridad. Análisis estadísticos de crecimiento infantil muestran pocas diferencias entre regiones del territorio Tsimane. Los infantes varones sufren más problemas de bajo peso, desnutrición y de abortos espontáneos. Mientras la morbilidad y la desnutrición crónica son frecuentes en la infancia, una mayor disponibilidad de alimentos más adelante en la vida aún no ha dado lugar a enfermedades crónicas (por ejemplo la hipertensión, la aterosclerosis y ladiabetes) en adultos debido al estilo de vida relativamente tradicional de los Tsimanes.

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Infant and fetal mortality among a high fertility and mortality population in the Bolivian Amazon

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ABSTRACT

Indigenous populations experience higher rates of poverty, disease and mortality than non-indigenous populations. To gauge current and future risks among Tsimane Amerindians of Bolivia, I assess mortality rates and growth early in life, and changes in risks due to modernization, based on demographic interviews conducted Sept. 2002–July 2005. Tsimane have high fertility (total fertility rate = 9) and infant mortality (13%). Infections are the leading cause of infant death (55%). Infant mortality is greatest among women who are young, monolingual, space births close together, and live far from town. Infant mortality declined during the period 1990–2002, and a higher rate of reported miscarriages occurred during the 1950–1989 period. Infant deaths are more frequent among those born in the wet season. Infant stunting, underweight and wasting are common (34%, 15% and 12%, respectively) and greatest for low-weight mothers and high parity infants. Regression analysis of infant growth shows minimal regional differences in anthropometrics but greater stunting and underweight during the first two years of life. Males are more likely to be underweight, wasted, and spontaneously aborted. Whereas morbidity and stunting are prevalent in infancy, greater food availability later in life has not yet resulted in chronic diseases (e.g. hypertension, atherosclerosis and diabetes) in adulthood due to the relatively traditional Tsimane lifestyle.

Introduction

The selective environment of early life, with infant mortality ranging up to 25% in human populations, determines the representation of genes impacting viability, immune function and metabolism in a population. Survivors thus carry the stamp of early-life exposures with them throughout adulthood. The importance of infancy and the fetal period have gained renewed attention given the effects of early nutrition and morbidity on health outcomes in adulthood (e.g. Blackwell, Hayward, & Crimmins, 2001; Elo & Preston, 1992; Kuh & Ben-Shlomo, 1997; Painter et al., 2006). Indigenous populations worldwide suffer from the poorest nutrition and health, and therefore merit special attention. The persistence of poor infant and child health in indigenous populations can negatively impact cognitive development and human capital investments such as school attendance and performance, wage income and occupational status. It can also elevate risks for obesity, type 2 diabetes and cardiovascular disease if modernization leads to rapid "catch-up" growth, high energy intake and other lifestyle behavioral changes. These effects of early-life conditions on chronic disease in late adulthood are the basis of the "developmental origins of health and disease" (DOHaD) paradigm (Gluckman & Hanson, 2006; Kuzawa & Adair, 2003). Populations in the developing world with high morbidity and mortality suffer not only from high levels of infant and child sickness, malnutrition and growth stunting, but are also likely to show high rates of chronic ailments in the future when younger cohorts reach adulthood, lifestyles change and mortality levels decline (Finch & Crimmins, 2004). Children of parents under greater resource stress are also likely to show greater deficits themselves, thereby creating a legacy of poor health. The intergenerational inheritance of health risks is well established and a critical component of the DOHaD paradigm.

A first step to help gauge current and future risks of disadvantaged indigenous populations is to assess mortality and morbidity rates and their etiology early in life, and recent changes in risks due to modernization. Epidemiological transitions are experienced differently among poor sub-populations than those represented by national averages (Barrett, Kuzawa, McDade, & Armelagos, 1998; Gurven, Kaplan, & Zelada Supa, 2007). Vital registries and other demographic or medical surveys in developing countries are often incomplete or unrepresentative of indigenous populations who rate amongst the poorest in their respective home countries.

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Existing research, however, suggests that infant mortality rates (IMRs) are often 2–4 times greater among indigenous than among non-indigenous people (Gracey & King, 2009). Infant mortality is often used as a signature measure of population health, and disparities are often interpreted as evidence of societal inequality. The mosaic experience of modernization through changes in schooling, access to wage labor and experience with national culture can have both positive and negative impacts on health (Godoy, 2001). While greater market access provides opportunities to obtain vaccinations, purchase medicines and seek medical advice from health professionals and pharmacies, it can also lead to depleted wild game and fish, father absence due to migrant wage labor, alcoholism, sexually transmitted diseases and increased consumption of refined sugar and other unhealthy foods.

This paper examines infant mortality and miscarriage, and infant growth among indigenous Tsimane forager-horticulturalists inhabiting the neo-tropical forests of Bolivia. The populace of Bolivia is 50–70% indigenous (Hall & Patrinos, 2006). While most indigenous are of Aymara, Quechua or Guarani origin, Bolivia is also home to several dozen indigenous populations in the Amazonian lowlands. Bolivia is the second poorest country in South America, with anywhere from 59% to two-thirds living in poverty (per capita income $940 in 2005 – INE, 2001). Bolivia ranks 95 of 169 according to the Human Development Index (UN, 2010). In the Beni Department where the Tsimane reside, 76% of residents live below the national poverty line (Census 2001). Poverty rates are higher among indigenous than non-indigenous Bolivians and economic inequality has increased over time. Whereas non-indigenous poverty rates have declined over the past fifteen years, indigenous poverty rates have not (Hall & Patrinos, 2006).

Bolivia has not yet developed a system to record vital statistics, with under-registration of mortality as high as 63% (PAHO, 2011). National-level life expectancy at birth, e_0, is estimated to be 66.3 years and IMR to be 42.2 per 1000 live births in 2010, the worst in South and Central America (USAID, 2011). Bolivia's IMR remains one of the highest outside of sub-Saharan Africa despite having dropped by half over the past two decades, due in large part to new health programs. These health programs helped improve adult survivorship over the past two decades, but infant health, especially in remote areas, has improved little. Morbidity remains high in rural regions lacking suitable sanitation and clean water, where over 30% of Bolivia's population resides. Much of the populace continues to be affected by gastrointestinal diseases, measles, pertussis, pulmonary tuberculosis, Chagas disease, tetanus, malaria, yellow fever and other febrile illnesses (USAID, 2011). A study of mortality among the Tsimane showed that IMR from 1990 to 99 was about 130 per 1000 live births. This rate changed relatively little since 1950, despite the fact that IMR at the national level showed a consistent linear decline (Gurven et al., 2007).

Recently a growing presence of immunization campaigns, health outreach programs, NGOs and anthropologists have provided improved access to medical care for Tsimane, at the same time that market integration has been increasing. Health conditions are therefore likely to improve for younger cohorts. If younger cohorts reach adulthood under conditions of greater food and nutrient availability, they may also experience elevated risk of chronic non-communicable diseases due to environmental mismatch of improved conditions with a "thrifty phenotype" associated with restricted early-life growth and other metabolic changes under food-limited conditions (Gluckman, Hanson, & Beedle, 2007).

Organization of paper

This paper characterizes early-life condition among Tsimane. The first section documents mortality rates during the first year of life ($n = 2098$ births) in four regions that vary in proximity to town, market integration, schooling and access to healthcare. Second, I examine whether infant births ($n = 1758$) and deaths ($n = 107$) are more concentrated in the wet or dry season months. While many foods are available year-round to Tsimane, fish is more abundant in the dry season, hunted game and many fruits are more abundant in the wet season, and rice is sometimes scarce before the annual wet season harvest. Tsimane complain about contaminated water and sickness during the wet season months of December through April when flooding is common.

Third, I examine infant growth during the first two years of life ($n = 238$) to assess risk of stunting (short length-for-age) or wasting (small weight-for-length). Child height at age two may be the best predictor of future health status (Victora et al., 2008). I compare growth deficit by region and sex, and by two features of maternal condition—parity and weight. I test whether high parity infants and infants of low-weight mothers have compromised growth, as might be expected as a result of depleted maternal condition and resource stress.

The fourth section examines the profile of preterm fetal deaths ($n = 121$) (hereafter miscarriages). To my knowledge, miscarriage has never been investigated in an indigenous subsistence population. Whether an infectious environment and high fertility render Tsimane mothers more susceptible to miscarriages is an open question. Intrauterine bacterial infections can trigger cytokine cascades that lead to fetal damage, preterm delivery, and fetal death in extreme cases (Athayde et al., 2000; Romero et al., 1998). The frequency of miscarriage can provide indirect clues about whether infections or perinatal problems such as umbilical cord complications and uteroplacental insufficiency are sources of morbidity (Silver, 2007).

The fifth section explores risks experienced early in life by examining causes of infant mortality and miscarriage. Future initiatives designed to improve infant and maternal health, and to forecast adult health given early exposures, require such an analysis. Whether deaths are largely due to infectious disease, perinatal complications or trauma has different implications for prevention and for understanding risk of morbidity and mortality over the rest of the life course.

The final section links maternal condition with infant mortality and miscarriage. I test for effects of maternal age at pregnancy, maternal body size, parity, history of past infant deaths, and spacing between births on the probability of infant and fetal death. I predict that teenage and late-age mothers experience elevated risks. Offspring born to young mothers that are still growing are more likely to be low birthweight and are at higher risk of dying (Fraser, Brockert, & Ward, 1995). Similarly, older women have been shown to be more likely to deliver premature offspring that are at greater risk of dying (Wood, 1994). Younger and especially older mothers experience increased risk of miscarriage in developed nations (Andersen, Wohlfahrt, Christens, Olsen, & Melbye, 2000). I also expect shorter interbirth intervals (IBIs) to correlate with higher risk of infant death. The Tsimane have short IBIs (2–3 years), which coupled with their high fertility, may lead to maternal depletion that compromises high parity infant health (Tracer, 1991). I indirectly examine depletion effects by testing whether current maternal body size relates to rate of infant mortality and miscarriage. Lastly, I test whether women with more schooling and greater Spanish fluency are less likely to experience infant and fetal death. When greater human capital leads to lower infant mortality, women often respond by reducing their fertility, thereby leading to demographic transition.

Methods

Tsimane and infancy

The Tsimane inhabit small villages of extended family clusters in the Maniqui, Apere and Quiquibey River systems in the Ballivián

and Yacuma provinces of Bolivia. Over 11,000 Tsimane inhabit ~90 villages in the forest and savanna regions east of the foothills of the Andes. Most of their diet still comes from subsistence activities. Tsimane cultivate plantains, rice, corn, and sweet manioc in small garden plots and regularly fish, hunt and gather fruits.

Although the Tsimane were exposed to Jesuit missionaries before the 17th century, they were never successfully settled in missions and remain relatively unacculturated (Chicchón, 1992). Rice and various citrus fruits were likely introduced by the Jesuits at this time. Other neighboring lowland groups such as the Mojeño and Yuracaré engaged in intensive agriculture and were more easily concentrated in centralized missions. Tsimane language is an isolate, sharing a similar vocabulary and grammar only with Mosetene, whose speakers inhabit the outskirts of Tsimane territory.

New mission posts in several villages were established in the 1950s, around the same time that roads connecting the region with the highlands were built. The greatest influence of the 35-year-old New Tribes Mission was to create a system of bilingual Spanish-Tsimane schools with trained Tsimane teachers. In 1989 a central representative organization, the *Gran Consejo Tsimane*, was founded with assistance from the New Tribes Mission. In 1990, the Mission also organized a small health clinic on the outskirts of San Borja, providing sporadic access to medicines in exchange for labor. Immunization campaigns are confined mostly to the past decade, and include *pentavalente* (diphtheria, tetanus, pertussis, hepatitis B, influenza B), yellow fever, measles, mumps and rubella. Coverage in Tsimane communities is sporadic, limited primarily to villages close to San Borja, during months of the year when travel is possible. Since 2002 the health insurance program *Seguro Universal Materno Infantil* (SUMI) has covered most expenses for prenatal and postnatal care (up to six months for mothers and 5 years for children). While Tsimane have benefited from SUMI, these benefits have been limited by poor management of funds, and because many Tsimane lack the photo identification card required to obtain coverage.

During pregnancy there are few taboos concerning diet and activity. Sexual intercourse with the mother is taboo (*micdyì*) during the last two trimesters up until about three months after the birth. Violation of the taboo is believed to make the infant sick and the father lazy. Tsimane women usually spend the first week of the infant's life maintaining direct contact, with both remaining exclusively inside a mosquito net in the house. It is considered taboo for a mother to leave the mosquito net during this time. Newborns are often painted with *bi* (*Genipa americanus*), a black dye common in tropical South America. It is believed that the blackness renders the baby invisible from malevolent spirits that might otherwise cause harm. It is common for infants to not receive proper names until about a year after birth. Children are breastfed exclusively for about four months; supplementary foods include plantains, fish, and meat. By about 16 months infants spend more time consuming solid foods than breastfeeding. The average IBI is 2.5 years and total fertility rate (TFR) is 9 live births (McAllister, Gurven, Kaplan, & Stieglitz, in press).

The Tsimane territory for this paper is divided into four regions: riverine (8 villages), forest (7 villages), near town (2 villages) and mission (1 village). Riverine and forest villages are the most remote, located about 40 km from San Borja. In the dry season, it may take several days to reach the riverine villages located upstream on the Maniqui River from town. About 30 years ago, a logging company created a dirt road that then motivated forest communities to migrate closer to the road. In the wet season forest villages are largely unreachable along the logging road because the temporary bridges crossing the streams and small rivers are destroyed each year by the rains. The villages in close proximity to the market town of San Borja are referred to as "near town". The Mission village is located upstream at the confluence of the Maniqui and Chimanes Rivers. Despite its remote location, the presence of the Catholic Mission and the relatively reliable primary healthcare it provides merits its separation from the eight smaller riverine communities. Tsimane in all regions practice horticulture, fish, hunt and gather; although lifestyles are not dramatically different across Tsimane regions, villages near town have greater access to market foods, wage labor, cash cropping, schooling, immunizations and healthcare.

Demographic interviews: infant mortality and miscarriage

Infant mortality was derived from retrospective reproductive histories with all resident women over the age of 14 ($n = 363$ individuals from 18 villages) conducted from Sept. 2002 through July 2005. Details on age estimation are given elsewhere (Gurven et al., 2007). The outcome of each reported pregnancy was recorded as either ending in a live birth or terminating preterm (miscarriage). Tsimane identify an early birth (*jojoì nài*) where the infant is born dead as miscarriage (*jìshubudyè*), and so stillborns are likely counted as miscarriages. Age at death for miscarriages, when known, is reported by mothers as the number of moons that passed since they first recognized they were pregnant. The sex of the aborted fetus was also reported by the mother in 82/121 of cases. In consultation with a Tsimane Health and Life History Project (THLHP) physician (Dr. Daniel Eid Rodriguez), causes of death based on verbal autopsy interviews were assigned using the International Classification of Disease version 10 (ICD-10) (WHO, 1990). Verbal autopsy interviews used a combination of open-ended questions and directed questions oriented toward arriving at a clinical diagnosis. No cause could be determined for 16% of the 268 infant deaths in the sample, due more to a lack of information by informants than inexplicable symptoms. Our estimates of the percentages of deaths due to specific causes, and of cause-specific death rates, are underestimates of their true values because deaths with unknown causes are included in the denominator but never in the numerator. Cause-specific death rates were calculated by dividing the number of deaths due to specific causes by the appropriate number of risk years. A sample of 1763 individuals with known birthdates is used to investigate seasonal mortality patterns.

Infant growth and maternal body size

Height, length, and weight were measured on all individuals during annual village visits by the THLHP medical-anthropological team. Infant length is measured with the use of a Seca 210 Length Measuring Mat. Standing height for adults is measured using a Seca Road Rod 214 Portable Stadiometer. Weight and percentage body fat for adults are measured using either a Tanita BF680 Scale and Body Fat Monitor or estimated using the age- and sex-specific Durnin and Womersley (1974) equations that use subcutaneous fat skinfold measurements on the bicep, tricep, subscapular and suprailiac regions.

For a sample of 238 infants with exact birthdates, growth is examined in the first two years of life by region. Growth measurements for infants include *z*-scores of length-for-age (HAZ), weight-for-age (WAZ), weight-for-length (WHZ) and body mass index-for-age (BAZ) using the World Health Organization Multicentre Growth Reference Study anthropometric standards for breastfed children (WHO, 2010). HAZ is usually interpreted as a measure of chronic stunting, WAZ as a measure of underweight, and WHZ and BAZ as measures of acute wasting (Frisancho, 1990).

Data analysis

Infant mortality curves over the first year of life are analyzed using Kaplan–Meier estimation with PROC LIFETEST in SAS 9.2.

Anthropometrics by region, age and sex are compared using chi-square tests and multiple linear regression (PROC GLM). Probabilities of infant death and miscarriage were modeled using generalized estimation equations (GEE) with PROC GENMOD. These mixed models use a logistic link function and account for the repeated pregnancies, births, or risk years from the same women.

Research was conducted with the approval of the Institutional Review Board of the University of California-Santa Barbara, and with approval from the Tsimane government (*Gran Consejo Tsimane*). Additional approval was granted during village meetings with leaders and residents, and by direct conversations with participants.

Results

Infant mortality

Fig. 1 shows survivorship (l_x, probability of surviving to age x) during the first year of life. 12.9% of Tsimane infants die in their first year. The riskiest period is the first two weeks, where 4% of infants die. 40% of infants that die in their first year do so in the first month of life. The neonatal mortality rate is thus 51.1/1000 live births. Mortality differs significantly by region (Wilcoxon test: chi-square = 18.94, $p = 0.0003$). It is highest in the riverine (IMR = 15.4%) and forest villages (15.3%), and lowest in the villages near town (8.1%). Greater distance from town positively correlates with IMR, varying three-fold from 8% to 26% (Fig. 2). Distance from town alone explains 25% of the inter-village variation in IMR. Forest villages show higher IMR than riverine villages, even after controlling for town distance ($\beta = 50.0$, $p = 0.021$, $R^2 = 0.484$).

Effect of seasonality on births and infant mortality

Fig. 3 shows the relative likelihood of births and deaths by month, and whether birth month affects the likelihood of infant death. December through April are wet season months, while May through August comprise the dry season. While heavy rains during the wet season can lead to flooding, poor water quality and crop loss, periodic spells of cold, southerly winds from the Argentine pampas (called *surazos*) are common during dry season months.

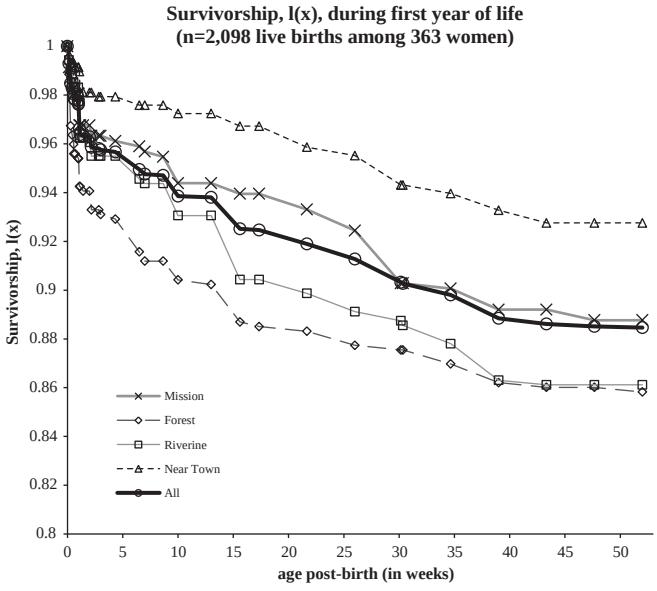

Fig. 1. Survivorship over the first year of life by geographical region. Sample includes 2098 live births among 363 women from time period 1950–2002.

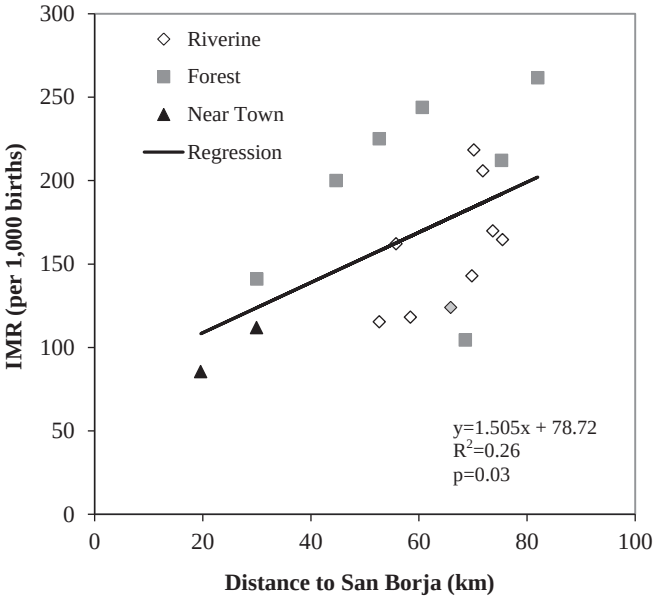

Fig. 2. Infant mortality rate (IMR) by proximity of villages to the town of San Borja.

There is no consistent pattern of birth timing throughout the year when considering the sample of pregnancies where birth month is known ($n = 1758$). Infant deaths, however, are more common during wet season months of February and March, and dry season months of May and August. Odds of infant death are 1.3–1.7 times greater during these months. Odds of infant death are lowest in the dry season month of July, the wet season month of January, and the transitional months, September and October. During these low risk months, infant deaths are 36–71% lower than expected by chance. Infant death rates, however, are correlated with monthly birth rates ($r = 0.67$, $p < 0.05$); after controlling for birth rates, the residual death rates only trend toward significantly mirroring the patterns in Fig. 3 ($p = 0.073$, binomial test).

I next examined whether infants were more likely to die in the first year of life if born in certain months (solid line in Fig. 3). IMR was 1.38 times greater than average for infants born during peak wet season months (February and March), compared with 0.91 for the rest of the year (chi-square = 4.49, $p = 0.034$). IMR was slightly elevated for births in August and November. In contrast, birth in the early dry season months was associated with significantly lower likelihood of death (35–64% lower than average). When controlling for monthly birth rates, the relationship between likelihood of death and month born remains significant ($p < 0.001$, binomial test).

Infant growth

Table S1 (Electronic supplementary material) reports the prevalence of stunting, underweight and wasting. 32% of infants show moderate to severe stunting, 15% show a similar level of underweight, and 13% show wasting. These levels correspond to a high severity of stunting and wasting according to World Health Organization criteria (Blossner & de Onis, 2005). There is a higher prevalence of (1) stunting among older infants, (2) underweight among males, older infants and infants farther from town, and (3) wasting in the riverine villages (Table S1). Regression of anthropometric z-scores on region, sex and age confirms these results, although regional differences in wasting are no longer significant after controlling for sex and age (Table 1). Regression models in Table 1 explain at most only 9% of the variation in infant anthropometrics.

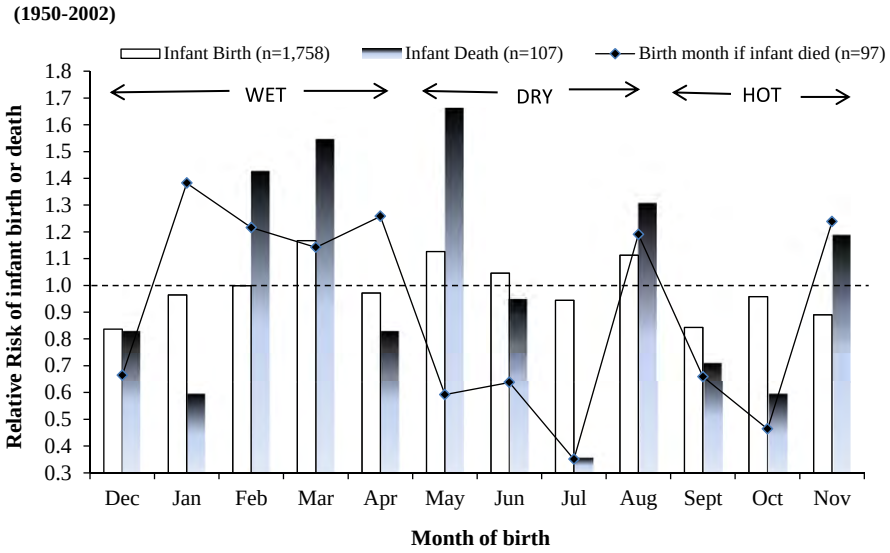

Fig. 3. Seasonality in infant births and deaths, relative risk of (a) birth by birth month, (b) death by month, (c) death in first year of life by birth month.

Infant stunting and underweight varies by maternal weight, maternal age and birth order. Maternal age and birth order are highly correlated ($r = 0.85$, $p < 0.0001$), and so I report analysis based on birth order, as it is a more robust predictor than maternal age. Mean ± SD birth order is 4.8 ± 3.1, mean ± SD maternal age is 28.3 ± 7.2, and mean ± SD maternal weight is 52.7 ± 7.0 kg. Fig. 4 shows predicted *z*-scores of HAZ and WAZ for the ±1 SD unit range in maternal weight (45–60 kg) and ±1 SD unit range in birth order (2–8), controlling for infant age and sex. High parity infants of underweight mothers show the lowest *z*-scores for HAZ and WAZ, while low parity infants of overweight mothers show the highest. Parity and maternal weight effects are greater for HAZ ($\beta_{\text{parity}} = -0.185$, $\beta_{\text{maternal weight}} = 0.077$) than for WAZ ($\beta_{\text{parity}} = -0.076$, $\beta_{\text{maternal weight}} = 0.049$). Neither maternal weight, maternal age, nor birth order are significant in multiple regressions of wasting (WHZ and BAZ) after controlling for infant age and sex.

Frequency of miscarriage

The rate of fetal death is 55.1/1000 pregnancies (based on a sample of 121 miscarriages from 2195 pregnancies by 363 women). 59% of Miscarriages were reported as having occurred within the first several months after last menses (first trimester), 22% during second trimester and 19% during third trimester. There was no difference in overall miscarriage rate before 1990 (54.2/1000) and from 1990 to 2002 (66.8/1000) (chi-square = 1.13, $p = 0.288$) although this result changes in the multiple regression analysis reported in Table 3. Miscarriage rates varied by region (Forest: 90.1/1,000, Near Town: 44.9/1,000, River: 45.2/1,000, Mission: 37.9/1000; chi-square = 17.2, $p < 0.001$). They also varied by maternal age, such that youngest and oldest mothers were at increased risk of miscarriage (Fig. 5, chi-square = 14.49, $p = 0.013$). Odds of miscarriage for women aged 15–20 are 2.7 times greater than women aged 25–30; odds of miscarriage for women age 40+ are 5.4 times greater using the same reference group.

Causes of infant and fetal death

Causes of infant mortality are clustered into macro-categories like gastrointestinal (e.g. diarrhea, gut obstruction), respiratory infection (e.g. pneumonia, influenza), other infection (e.g. measles, whooping cough, fever), violence/accidents (e.g. falls, drowning, infanticide, neglect), and congenital (perinatal complications).

Table 1
Multiple regression of nutritional status variables (HAZ, WAZ, WHZ, BAZ) on infant sex, age and region of residence. Parameters in bold refer to $p < 0.05$, italics $p < 0.10$.

Parameter	HAZ		WAZ		WHZ		BAZ	
	β	*p*-Value	*β*	*p*-Value	*β*	*p*-Value	*β*	*p*-Value
Intercept	−0.761	0.014	−0.651	0.003	−0.120	0.652	−0.299	0.260
Sex (female)	0.185	0.443	**0.402**	0.020	**0.446**	0.033	**0.424**	0.043
Region								
Near town (vs. river)	0.488	0.118	**0.580**	0.010	0.360	0.183	0.424	0.116
Forest (vs. river)	0.242	0.550	0.345	0.234	0.255	0.466	0.306	0.380
Mission (vs. river)	0.224	0.479	0.088	0.696	−0.133	0.628	−0.117	0.667
Age group								
18–24 mos (vs. <6 mos)	**−1.200**	0.004	**−0.577**	0.050	−0.225	0.531	0.266	0.459
12–18 mos (vs. <6 mos)	**−0.844**	0.011	**−0.476**	0.043	−0.265	0.353	0.092	0.745
6–12 mos (vs. <6 mos)	−0.473	0.114	*−0.393*	0.065	−0.248	0.339	−0.146	0.572
R^2	0.062		0.086		0.043		0.043	
F	2.11		3.04		1.41		1.44	
p-Value	0.043		0.005		0.203		0.190	

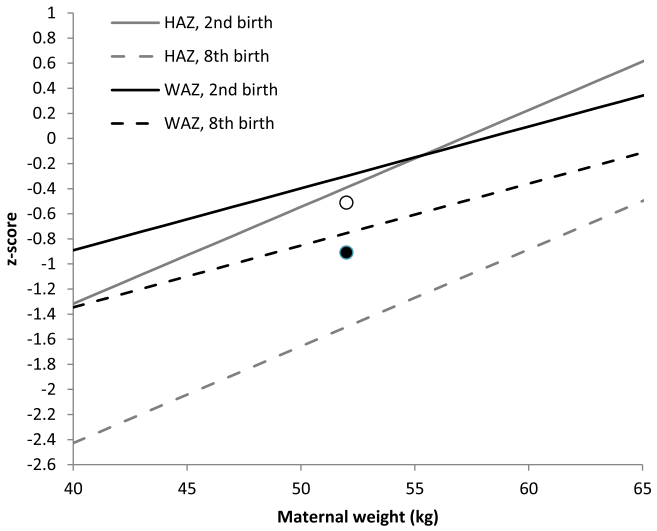

Fig. 4. Regressions of height-for-age (HAZ) and weight-for-age (WAZ) *z*-scores as a function of infant birth order and maternal weight, controlling for infant age and sex ($n = 84$). For HAZ regression, $\beta_{\text{maternal weight}} = 0.077$, $p = 0.020$, $\beta_{\text{birth order}} = -0.185$, $p = 0.012$; WAZ: $\beta_{\text{maternal weight}} = 0.049$, $p = 0.019$, $\beta_{\text{birth order}} = -0.076$, $p = 0.098$. Lines are plotted at sample averages for infant age and sex. Solid (open) circle refers to sample mean HAZ (WAZ). Stunting (underweight) reflects HAZ (WAZ) *z*-score < -2.

Distribution of causes by infant age is shown in Fig. 6. Overall, 55% of infant deaths are due to infection (29% respiratory, 15% gastrointestinal, 11% other). 13.6% of deaths are due to violence and accidents. Infanticide alone accounts for 8.7% of infant deaths. Including deaths from the larger demographic sample based on kin reproductive histories yields 26 infanticides: 10 as a consequence of infidelity, 5 "unwanted" infants, 2 born with deformities and 2 born "too soon" after the previous infant.

Deaths by violence, accidents and infection are less common in the 1990–2002 time period than in 1950–1989 (Table S2, Electronic supplementary material). Villages near town also show the lowest IMR from congenital problems, respiratory infection and violence/accidents. Mission IMR is similar to forest and riverine, except the Mission shows lower risk of death by gastrointestinal infection and by violence and accidents.

Emic views for why infants die often depart from clinical diagnoses. For a sample of 48 infant deaths where emic views were expressed, it was reported that infants died because of husbands having sex with other women ($n = 19$), and because of sorcery from angered spirits (*jäjäba* or *òpito*) due to norm violations ($n = 20$). Accusations regarding a husband's philandering are also common when infants get sick, as threats of men disinvesting from the family are viewed as harmful. Infant sickness is often linked to

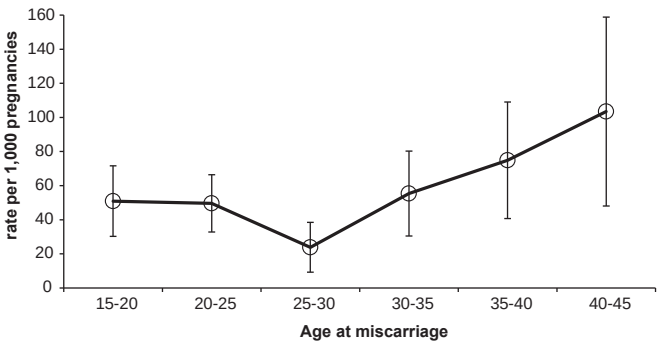

Fig. 5. Fetal death rate by trimester of pregnancy and maternal age.

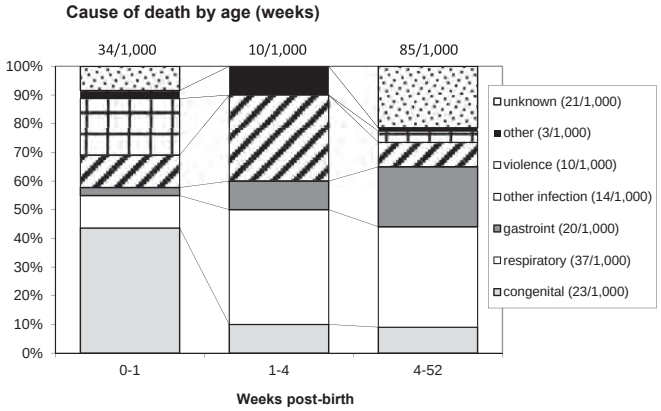

Fig. 6. Causes of infant death in first year of life.

norm violations, such as violating food, menstrual, or hunting taboos, as well as angering other people believed to be sorcerers.

Our "verbal autopsy" approach is to be interpreted with caution, especially for fetal deaths. Even with modern medical facilities, it has been estimated that as many as 12–50% of stillbirths and miscarriages have no identifiable etiology (Incerpi et al., 1998). Placental abruption and other clinical diagnoses were not possible here. Causes of miscarriage as reported by women fall into several categories: 39% of miscarriages ($n = 100$) occurred as a result of falling, often on one's stomach, usually in the context of hauling water, firewood, clothes or food, 18% from "working too hard" (includes heat exhaustion), 13% were self-induced (reportedly by beating and pressing one's stomach with force), and 10% from maternal sickness.

Predicting infant and fetal death

Tables 2 and 3 model the probability of infant death up to age two, and the probability of miscarriage, respectively. Predictors in the base model include infant age and sex, region, and maternal age. Consistent with Fig. 2, I find that infant mortality is about 50–100% higher in forest and riverine regions than near town. Consistent with Table S2, infant deaths are 25–50% more likely in the recent past (1950–1989) than during the 1990–2002 period.

Additional predictors added to the base model include maternal anthropometric variables measured concurrently with the demographic interview (controlling for the time difference between risk year and anthropometric measurement), maternal socioeconomic variables (maternal education and Spanish fluency) and demographic variables (birth order, and IBIs from the previous birth to the current, and from the current to the next).

Women who were heavier (greater WAZ) were about 40% more likely to have experienced an infant death. An obese woman (BMI ≥ 30) was almost 3 times as likely to have experienced an infant death in the past compared to a woman in the normal BMI range (<25). Larger women may have had greater completed fertility and experienced greater infant mortality as a consequence, but even after controlling for fertility, the effect of women's current obesity is significant (reducing OR to 2.52, $p = 0.05$). Women who do not speak any Spanish are about 50% more likely to have had an infant die than those who are fluent, whereas maternal education shows no significant effect.

Short IBIs are highly predictive of infant death. Waiting an additional year after the birth of the previous child is associated with a 25% lower chance of the next infant dying, whereas an additional year before the next infant's birth is associated with a 32% lower chance of the previous infant dying. Birth order shows no effect on infant death when added to the baseline model.

Table 2
Probability of infant death in first two years of life, using generalized estimating equations (GEE) with a logistic link function (243 deaths across 3498 person-years for 419 women). Parameters in bold refer to $p < 0.05$, italics $p < 0.10$.

Variable	Model 1: baseline		Model 2: maternal anthropometrics		Model 3: maternal human capital		Model 4: demography	
	Odds ratio	*p*-Value	Odds ratio	*p*-Value	Odds ratio	*p*-Value	Odds ratio	*p*-Value
Age of infant (yr)	**0.162**	<0.0001	**0.157**	<0.0001	**0.150**	<0.0001	**0.134**	<0.0001
Sex (ref = male)	1.062	0.656	1.052	0.727	1.082	0.597	1.234	0.244
Region								
Mission (vs. near town)	1.316	0.220	1.402	0.196	1.351	0.202	*1.588*	0.060
Forest (vs. near town)	*1.531*	0.093	*1.636*	0.091	1.413	0.132	**1.718**	0.023
River (vs. near town)	**1.781**	0.014	**1.935**	0.014	**1.849**	0.004	1.322	0.260
Period 1950–1989 (vs. 1990–2002)	**1.385**	0.048	**1.520**	0.023	*1.291*	0.112	1.256	0.270
Maternal age								
35+ (vs. 20–34)	0.983	0.946	1.051	0.855	0.765	0.247	0.987	0.975
<20 (vs. 20–34)	*1.340*	0.094	1.291	0.182	1.255	0.219	0.796	0.481
Mother height-for-age *z*-score			0.914	0.286				
Mother weight-for-age *z*-score			**1.418**	0.010				
Mother body mass index								
Obese (vs. normal)			**2.650**	0.034				
Overweight (vs. normal)			1.116	0.665				
Mother body fat (%)			1.005	0.714				
Mother Spanish								
None (vs. fluent)					*1.553*	0.099		
Moderate (vs. fluent)					1.354	0.293		
Mother education								
None vs. (3rd grade+)					1.345	0.291		
1st–2nd Grade (vs. 3rd grade+)					1.401	0.254		
Birth order							0.984	0.729
Interbirth interval (pre-birth)							**0.748**	0.002
Interbirth interval (post-birth)							**0.675**	0.002

I performed a similar analysis for the probability that a woman has a miscarriage (Table 3). Male fetuses were about twice as likely as female fetuses to be aborted. Miscarriages were about twice as likely to be reported in the more recent period 1990–2002. Mothers under age 20 were about 50% more likely to have a miscarriage than prime reproductive age women (20–34 yrs) in two of the four models where statistical significance was only marginal (see also Fig. 5). The only other maternal variable that predicted miscarriages was mother's education. Women with no education were over 5 times as likely to miscarry (or report a miscarriage) as women with at least a third grade education level. One to two years of education was marginally associated with a three-fold greater likelihood of miscarriage than at least a third grade education.

Discussion

Infant mortality among Tsimane Amerindians is high, and is greatest in remote regions lacking access to modern healthcare facilities. Infections account for over half of all infant deaths. While pathogen exposure may vary by geographical proximity to town, it is likely that infant deaths are instead more preventable close to town due to greater medical access, prenatal care and vaccinations. Medical attention during critical periods, such as during the wet season and peak *surazo* dry season, could help reduce IMR.

Infant stunting is prevalent, affecting a third of infants, but underweight and wasting are less frequent. Stunting is greatest among older infants close to weaning age (18–24 months) and far from town, while underweight affects boys more than girls. The high fertility of Tsimane women is a key factor, as later born infants are at greatest risk of being small for their age. Small mothers are also more likely to have small infants. Whether small infants show evidence of catch-up growth or are more likely to die has not yet been determined among Tsimane. Nonetheless, small infants are likely to be at higher risk of morbidity and death.

Despite frequent stunting (overall 34% prevalence), however, there was less evidence of wasting (12%). In a compilation of 37 studies in Latin America, Victora (1992) found the median prevalence of child stunting to also be 34% but was only 3% for wasting. A higher stunting prevalence (47%) but similar wasting prevalence (5%) was found among Tsimane children under age 9 (Foster et al., 2005). Based on low prevalence of wasting and of low muscularity, Foster et al. (2005) concluded that Tsimane children do not suffer severe acute protein-energy malnutrition. As adults, Tsimane are taller than the mean for 42 lowland Amerindian populations, but are still below the 5th percentile for height among U.S. adults, and shorter than pre-modern Europeans from the 18th and 19th century (Godoy et al., 2006). There is also no evidence for secular changes in adult Tsimane height over the past seven decades, suggesting that increasing market integration and healthcare has not yet had a steady, continuous impact on chronic well-being (Godoy et al., 2006). Consistent with the lack of secular change is the relative lack of regional variability in infant and child anthropometrics reported here. Only weight-for-age was higher in villages near town, whereas stunting and wasting did not vary

Table 3
Probability of miscarriage, using generalized estimating equations (GEE) with a logistic link function (61 miscarriages in 1934 person-years on 394 women). Parameters in bold refer to $p < 0.05$, italics $p < 0.10$.

Variable	Model 1: baseline		Model 2: maternal anthropometrics		Model 3: maternal human capital		Model 4: demography	
	Odds ratio	*p*-Value	Odds ratio	*p*-Value	Odds ratio	*p*-Value	Odds ratio	*p*-Value
Sex (ref = male)	**0.459**	0.006	**0.499**	0.014	**0.463**	0.009	**0.459**	0.006
Region								
Mission (vs. near town)	0.483	0.119	0.542	0.214	0.704	0.462	0.484	0.126
Forest (vs. near town)	1.432	0.398	1.369	0.482	1.380	0.414	1.433	0.409
River (vs. near town)	1.182	0.670	1.109	0.806	1.375	0.421	1.181	0.677
Period 1950–1989 (vs. 1990–2002)	**0.529**	0.041	*0.591*	0.096	**0.495**	0.016	**0.528**	0.041
Maternal age								
35+ (vs. 20–34)	1.274	0.512	1.151	0.720	0.750	0.502	1.340	0.555
<20 (vs. 20–34)	1.620	0.103	1.525	0.152	*1.677*	0.100	1.571	0.209
Mother height-for-age *z*-score			0.969	0.845				
Mother weight-for-age *z*-score			0.729	0.171				
Mother body mass index								
Obese (vs. normal)			0.342	0.311				
Overweight (vs. normal)			0.913	0.833				
Mother body fat (%)			1.023	0.339				
Mother Spanish								
None (vs. fluent)					0.516	0.190		
Moderate (vs. fluent)					0.822	0.692		
Mother education								
None vs. (3rd grade+)					**5.236**	0.018		
1st–2nd Grade (vs. 3rd grade+)					3.088	0.103		
Birth order							0.990	0.879

regionally. Overall, stunting and slow growth reduces energetic support costs for Tsimane parents who wean early. High fertility in natural fertility populations like the Tsimane results in women having multiple dependent offspring simultaneously, thereby requiring energetic subsidies from spouses and other kin (Gurven & Walker, 2006).

The higher wasting prevalences I report for infants suggest greater risk in the first several years of life than in later childhood. Infants are protected by exclusive breastfeeding for about four to six months, then supplemented with other foods to accommodate demands of infant growth. The prevalence of moderate to severe stunting increased during the period of food supplementation and weaning. Greater pathogen exposure from unhygienic feeding practices and poor nutrient absorption from infectious disease, immature dentition and inefficient digestion may contribute to the increase in stunting over this period (McDade & Worthman, 1998). Indeed, body fatness, as assessed in the Foster et al. study, was most compromised between ages 1–3. The higher level of underweight and wasting among boys also merits further attention. Parents anecdotally report a preference for sons, due to perceptions about the value of their future economic contributions. However, male infants may be costlier to raise as they require more calories than females (estimated 32 cals/day for 1 year olds, 145 cals/day for 2 year olds using Oxford equations (Henry, 2005)). Godoy et al. (2006) also report that wealth among Tsimane mothers is more likely to be associated with greater BMI among daughters but not sons.

Population comparisons of miscarriage rates are complicated by different operational definitions, detection ability and reporting bias. For this reason clinical miscarriages (those occurring after the 10th week since the woman's last menses) are often used in epidemiological studies. The preliminary Tsimane data on reported miscarriages suggests that Tsimane women show similar risk of fetal loss as other documented populations (Fig. S1, electronic Supplementary material). This is surprising given their high fertility, infectious exposure and relative lack of prenatal care. Accidents, self-induced trauma and sickness were reported as the main causes of fetal death among Tsimane. While trauma can lead to placental separation, reasonable trauma does not usually lead to fetal loss; criteria used to establish a causal link are often not met (Ribe, Teggatz, & Harvey, 1993). However, deliberate violence may induce abruption. Intimate partner violence has been associated with greater likelihood of prenatal hemorrhage, intrauterine growth restriction and fetal death (Janssen et al., 2003). Tsimane women report a high level of domestic violence (Stieglitz, Kaplan, Gurven, Winking, & Tayo, 2011). While pregnancy reduces the likelihood that a Tsimane woman experienced physical abuse by 19%, women nonetheless experienced abuse during 33.5% of their pregnancies (243/725, $n = 1600$ risk years on 110 women) (J. Stieglitz, pers. comm.).

It is likely that miscarriages in the first trimester were underreported or undetected. Premature stillbirths may have also been misclassified as infant deaths, and gestational ages were probably imprecise. It has been estimated that stillbirth rates are usually about 20% of IMR (Knodel, 1974), which would be roughly 26 per 1000 live births; however, the Tsimane stillbirth rate is 14.5. Both rates are much higher than those reported in high-income countries (3.1 per 1000 births in 2009) but similar to those found in other world regions (Cousens et al., 2011). A study

of over 14,000 fetal deaths in hospitals in Latin America found that the lack of prenatal care was associated with a fourfold increase in likelihood of miscarriage; fetuses small for gestational age, high parity and maternal age (≥35 yrs) were also important factors (Conde-Agudelo, Belizán, & Díaz-Rossello, 2000). Other factors include smoking, obesity, maternal and gestational diabetes and maternal hypertension (Flenady et al., 2011). Tsimane women of reproductive age rarely smoke, few are obese, hypertension is rare and diabetes is almost non-existent. On average, a woman has 2.58 births after age 35 and 1.15 after age 40. Miscarriage is most common in younger and older mothers (Fig. 5). However, given the young age structure of the Tsimane population, only 5.7% of pregnancies are among women over age 40.

There was mixed evidence that a woman's human capital affected the likelihood of infant or fetal death. Mothers unable to speak Spanish are only marginally more likely to experience an infant death, and those with no schooling a greater probability of fetal loss. These effects were independent of region and maternal age. Neither father's education nor Spanish fluency bore a relationship with infant or fetal death (analysis not shown). These findings are noteworthy because they contradict a consensus view that maternal education is the most important predictor of offspring mortality (Gakidou, Cowling, Lozano, & Murray, 2010).

Other patterns found among Tsimane mirror those observed elsewhere. First, short interbirth intervals were associated with a higher risk of infant death. Post-birth interval might correlate with infant death because of the rapid post-death resumption of ovulation, rather than from being weaned too soon. However, short pre-birth spacing may lead to subsequent infant death due to the compromised growth, nutrition and health of these infants. Short spacing might not allow mothers enough time to replete energetic reserves to support the next pregnancy (Tracer, 1991). Similar effects between birth spacing and infant mortality were found among Bolivian mothers using Demographic and Health Survey data (Forste, 1994). Second, death rates were higher for male fetuses. It has been postulated that premature rupturing of membranes is more common with preterm male fetuses that are typically greater mass at lower gestational age (Di Renzo, Rosati, Sarti, Cruciani, & Cutuli, 2007), suggesting that males may be more fragile or more costly to bring to term (Kraemer, 2000). Third, obese women were more likely to have experienced infant death. The prevalence of obesity in Tsimane women aged 20–39 is only 5.1%. In the U.S., obese women experience more neonatal mortality, regardless of weight gain during pregnancy, due to more pregnancy complications related to short gestation and low birthweight, preeclampsia and prolonged labor (Chen, Feresu, Fernandez, & Rogan, 2009). There was no support for greater likelihood of infant death for underweight women.

Despite the evidence presented here on compromised early-life conditions, Tsimane remain relatively lean as adults and do not currently experience high levels of chronic disease. Peripheral arterial disease, atherosclerosis and type 2 diabetes are absent, while hypertension, obesity and other cardiovascular risk factors are minimal (Gurven et al., 2009). Chronic disease accounts for relatively few deaths, whereas infections are responsible for the majority of adult deaths (Gurven et al., 2007). In Bolivian cities, however, diabetes, hypertension and obesity are increasingly prevalent, and are rising public health threats, as has already been shown in other Latin American countries (Barceló & Rajpathak, 2001). Lifestyle changes associated with modernization have impacted diet and physical activity and reduced pathogen exposure at the national and regional level, thereby increasing risk factors for chronic disease. Obesity, insulin resistance and type 2 diabetes, heart and renal disease and stroke are likely to increase if Tsimane diet, activity and other lifestyle behaviors change with rapid modernization, as they have for North Amerindians, Australian aborigines and other indigenous populations (Dressler, 1982; Herrera & Rodríguez-Iturbe, 2003; Leonard, Snodgrass, & Sorenson, 2005; Narva, 2003; Shephard & Rode, 1996; Spencer, Silva, Snelling, & Hoy, 1998). Whereas the effects of modernization on anthropometrics and Tsimane lifestyle are not yet substantial, changes in fertility and health may be on the horizon, consistent with the decrease in infant and child mortality observed only after 1990 (Gurven et al., 2007; McAllister et al., in press). Recent cohorts may be particularly susceptible to adult chronic disease in the coming decades due to the "mismatch" between the legacy of maternal effects and "thrifty phenotype" associated with past, poor environments and the improved health and nutritional conditions of the imminent future (Gluckman et al., 2007). During the future epidemiological transition, reduced activity and changed diet, but with high levels of inflammation from infection, could lead to a rise in adult chronic disease. In conclusion, this paper provides a glimpse into past and present conditions among a population of indigenous South Amerindians in socioeconomic and epidemiological transition. Infant health, growth and survivorship are tied to maternal condition, and to access to traditional and novel resources. While Tsimane subsistence efforts may be currently sufficient to support the caloric demands of high fertility, infants nonetheless suffer the costs of short birth intervals through higher mortality and compromised growth.

The main limitation of this paper is that it is based largely on retrospective demographic interviews requiring recall of past information. More precise information (e.g. exact interbirth interval), and proper covariates (e.g. infant birthweight, pre-birth maternal anthropometrics) are more appropriately measured in longitudinal study. Longitudinal study will also be required to link variation in nutrition, growth and health early in life to health outcomes later in life. This study, based on demographic records and baseline measures collected during the first three years of the THLHP, forms the foundation for these prospective studies of the effects of early conditions on health outcomes in late childhood, adolescence and adulthood.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.socscimed.2012.09.030.

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La composición de grasa en la leche materna de agricultores-recolectores: comparaciones con una muestra de los EEUU

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Informe sobre el control de la leche materna (Tacuaral del Mato)

En 2009 el Proyecto de Salud y Antropología Tsimane empezó investigar la salud materna e infantil con enfoque en la leche materna y las prácticas de mamar, alimentar y cuidar a los infantes. Tal investigación se realizaba por Melanie Martin, una alumna del director Dr. Michael Gurven. Sra. Martin entrevistó a las madres de Tacuaral y con su permiso tomo unas muestras de leche materna para analizar en los Estados Unidos.

Las muestras de leche materna se analizaban en un laboratorio de los Estados Unidos para ver la composición de los ácidos grasos. Los ácidos grasos de la leche cambian con la dieta y por eso las muetras Tsimanes se comparaban a unas de mamas norteamericanos para ver las diferencias al respeto de las dietas promedio de estas poblaciones. Hay unos ácidos grasos del tipo omega-3 que son de alta importancia para el desarrollo del cerebro del infante, especialmente lo del ácido docosahexaenoic (DHA). La cantidad de DHA en los Estados Unidos y otros países industriales generalmente es muy pobre, por el poco consumo de pescado y el alto consumo de aceites vegetales y alimentos procesados. Estos productos llevan altos cantidades de ácidos grasos de tipo omega-6 e interfieren con la absorción y síntesis de DHA en el cuerpo.

Encontramos que los porcentajes de omega-3 y DHA eran mucho más altos en la leche de las mamas Tsimane que en la de las mamas norteamericanas. Eso puede ser porque las mamas Tsimane consumen bastante pescado y poco se alimentan con productos procesados. Por tanto, concluimos que con respeto a la composición de ácidos grasos, la leche materna de los Tsimanes es de alta calidad. Los resultados se publicaron en ingles en una revista académica internacional (*Maternal and ChildNutrition)* y eran reportados por varias noticias populares, como el *Science News Daily* y el *BBC Mundo*. Se adjuntó una copia de la noticia publicado por el BBC Mundo.

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Original Article

Fatty acid composition in the mature milk of Bolivian forager-horticulturalists: controlled comparisons with a US sample

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Abstract

Breast milk fatty acid (FA) composition varies greatly among individual women, including in percentages of the long-chain polyunsaturated FAs (LCPUFA) 20:4n-6 (arachidonic acid, AA) and 22:6n-3 (docosahexaenoic acid, DHA), which are important for infant neurological development. It has been suggested that owing to wide variation in milk LCPUFA and low DHA in Western diets, standards of milk FA composition should be derived from populations consuming traditional diets. We collected breast milk samples from Tsimane women at varying lactational stages (6–82 weeks). The Tsimane are an indigenous, natural fertility, subsistence-level population living in Amazonia Bolivia. Tsimane samples were matched by lactational stage to samples from a US milk bank, and analysed concurrently for FA composition by gas-liquid chromatography. We compared milk FA composition between Tsimane ($n = 35$) and US ($n = 35$) mothers, focusing on differences in LCPUFA percentages that may be due to population-typical dietary patterns. Per total FAs, the percentages of AA, DHA, total n-3 and total n-6 LCPUFA were significantly higher among Tsimane mothers. Mean percentages of 18:2n-6 (linoleic acid) and *trans* FAs were significantly higher among US mothers. Tsimane mothers' higher milk n-3 and n-6 LCPUFA percentages may be due to their regular consumption of wild game and freshwater fish, as well as comparatively lower intakes of processed foods and oils that may interfere with LCPUFA synthesis.

Keywords: lactation, diet, docosahexaenoic acid, arachidonic acid, breast milk, infant and child nutrition.

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Introduction

Infant growth and development require adequate sources of fatty acids (FAs), all of which are available in maternal breast milk. For breastfed infants, breast milk is the only source of the long-chain polyunsaturated FAs (or LCPUFA) 20:4n6 (arachidonic acid, AA) and 22:6n3 (docosahexaenoic acid, DHA), which are elevated in the infant brain both pre- and postnatally (Smit *et al*. 2002; Innis 2007b; Milligan *et al*. 2008). DHA in particular is important in the development of the central nervous and visual systems, and early deficiencies may have long-term effects on behavioural and cognitive function (Bazan & Scott 1990; Innis 2007a). However, breast milk FA composition is highly variable among women, with maternal diet the main factor affecting the percentages of many specific FAs, including DHA, in milk (Jensen 1999; Innis 2007b).

FAs secreted in milk are mobilized from adipose tissue stores, absorbed directly from maternal dietary lipids and/or endogenously synthesized (Del Prado *et al*. 2001). The essential PUFA 18:2n-6 (linoleic acid, LA) and 18:3n-3 (α-linolenic acid, ALA) can only be

obtained through dietary sources. The major portion of PUFA in milk, LA and AA, originate primarily from maternal fat stores, influenced by long-term dietary intake (Demmelmair *et al*. 1998; Del Prado *et al*. 2001). Dietary sources of preformed DHA may be especially important for DHA content in milk. DHA milk percentages may be increased with short-term intake and supplementation (Makrides *et al*. 1996; Fidler *et al*. 2000, Brenna & Lapillonne 2009), although long-term intakes affect composition of bodily stores (Sauerwald *et al*. 2001). N-6 and n-3 LCPUFA (more than 20 carbon chains in length) are also synthesized from their respective precursors, LA and ALA, although conversion of AA, eicosapentaenoic acid (EPA) and DHA is low (Del Prado *et al*. 2001; Brenna *et al*. 2009). Supplementing nursing mothers with ALA, for instance, does not increase the DHA content of milk (Francois *et al*. 2003). DHA conversion may also be diminished by competitive inhibition from LA and *trans* FAs (TFAs) (Aitchison *et al*. 1977; Emken *et al*. 1994; van Eijsden *et al*. 2008; Gibson *et al*. 2011).

Concern over low LCPUFA availability in infancy, particularly of DHA, has prompted a wealth of research on maternal FA intake during pregnancy and lactation (Innis 2007b; Brenna & Lapillonne 2009), and considerable debate remains as to what FA intakes and milk compositions should be considered optimal (Yuhas *et al*. 2006; Smit *et al*. 2009; Uauy & Dangour 2009). Cross-cultural studies have shown that dietary intakes and percentages of DHA and total n-3 PUFA in milk are lower in populations with Westernized (i.e. industrial, agricultural) diets than in populations with traditional marine diets (Innis & Kuhnlein 1988; Koletzko *et al*. 1992; Krasevec *et al*. 2002; Yuhas *et al*. 2006; Brenna *et al*. 2007). The current ratio of n-6/n-3 PUFA in Westernized diets is estimated at 10/1 to 20/1, in contrast to ancestral estimates of 1/1 to 2/1, a result of both lower fish intake and high consumption of n-6-rich vegetable oils, processed foods and grain-fed domestic meat (Eaton 2006; Kuipers *et al*. 2010; Lindeberg 2010; Lassek & Gaulin 2012). The increasing dominance of n-6 relative to n-3 in Westernized diets may contribute to the increasing prevalence of childhood obesity (Ailhaud *et al*. 2007, 2008, Massiera *et al*. 2010), while higher intake of dietary LA relative to ALA may interfere with immune functioning (Whelan 1996) and result in lower incorporation of DHA into plasma phospholipids in infants (Sauerwald *et al*. 1996). Currently, infant formulas are modelled on breast milk compositions of US women, despite high interpopulation variability in milk LCPUFA composition, and the high LA/low n-3 LCPUFA in US milks (Gibson *et al*. 2011). It has been suggested, therefore, that standards for formula and milk FA composition should derive from populations consuming non-industrialized diets (Smit *et al*. 2002).

To date, studies of milk FA composition among traditional populations are few, and have been largely limited to coastal populations with heavy reliance on n-3-rich marine foods (e.g. the Innuit, Innis & Kuhnlein 1988), and rural African populations with low fat intake and variable access to n-3-rich foods (e.g. Prentice *et al*. 1989; Koletzko *et al*. 1991; Glew *et al*. 1995). Relatively little research on milk FA composition has been done on traditional populations consuming lacustrine resources, which likely accounted for a sub-

Key messages

- Higher percentages of AA and DHA in milk from Tsimane women may be favourably influenced by a traditional diet of cultigens, freshwater fish and wild game.
- Although Tsimane frequently consume LA-rich plant foods such as maize, they rarely consume LA-rich vegetable oils or processed foods, which, by reducing enzymatic competition, may contribute to their elevated milk DHA.
- Higher parity was not associated with lower LCPUFA in milk.
- Milk AA and DHA did not vary with lactational age in either US or Tsimane samples.
- LCPUFA supplied by prolonged lactation may support infant requirements during the postnatal brain growth spurt.

stantial amount of LCPUFA intake during the evolution of *Homo sapiens* (Broadhurst *et al*. 1998; Kuipers *et al*. 2005), or on forager-horticulturalists, whose diets are largely plant-based (Lindeberg 2010), but contain minimal processed foods and grain-fed meats. For extant forager-horticulturalist populations residing in and around the Amazonian Basin, freshwater fish and wild game may continue to serve as rich sources of LCPUFA.

There has also been little comparative analysis of milk FA composition between populations with divergent reproductive characteristics, such as average parity or typical duration of breastfeeding, which may also influence variation in milk LCPUFA composition. For example, maternal FA stores (Samur *et al*. 2009) may be mobilized with increasing parity (Lassek & Gaulin 2006) or weight loss (Prentice *et al*. 1989), and high parity and/or short interbirth intervals have been associated with reduced maternal and infant DHA stores (Al *et al*. 2000; Brenna & Lapillonne 2009). Milk FA composition has also been shown to vary across the first year of lactation, although trends for specific FA differ within and across studies (Harzer *et al*. 1983; Marangoni *et al*. 2000; Mitoulas *et al*. 2003). In a study of Italian mothers, milk AA and DHA percentages did not vary significantly from the first to twelfth month of lactation (Marangoni *et al*. 2000); however, little is known about variation in these FAs at later lactational stages.

We assessed milk FA composition in milk samples from indigenous Tsimane women residing in lowland Bolivia. We compared the FA composition of Tsimane milk samples with that of lactational stage-matched milk samples obtained from a Midwestern, urban US population, and analysed the additional effects of maternal age, body mass index (BMI), parity and infant age on milk FA composition in both populations.

Materials and methods

Study population: the Tsimane

The Tsimane are a high-fertility forager-horticulturalist population (most women give birth by age 18, and total fertility rate is nine children), with minimal access to modern medicine and market foods (Gurven *et al*. 2007). On average, mothers exclusively breastfeed for 3–6 months and fully wean infants 1–2 years thereafter, generally following a subsequent pregnancy or childbirth. The Tsimane diet consists primarily of freshwater fish, hunted game, and locally cultivated starches (plantains, rice, manioc) and fruit. Since 2002, researchers with the Tsimane Health and Life History Project (THLHP) have worked extensively with the Tsimane in Bolivia, providing primary medical care and collecting demographic, anthropological and biomedical data. These data and the THLHP have been summarized elsewhere (Gurven *et al*. 2007, 2008).

The Tsimane dietary estimates presented later are based on community-wide time-allocation studies conducted from 2002–2003 and 2005 across seven different villages. Researchers followed randomly selected subjects from 7 am to 7 pm, recording all activities at 30-min intervals. For the present analysis, we calculated the frequency of all food and liquid items eaten during these observations for male and female subjects aged 20 and up (319 total subjects, 145 female, 174 male, 2031 total eating observations, 93 total different food items). Following Food and Agriculture Organization specifications (2004), we estimated the average Tsimane adult daily energy requirement (DER) by multiplying estimated physical activity levels (PALs) by estimated basal metabolic ratios (BMR) for each sex and age group (age 20–29, 30–39, 40–49, 50 + years), and proportionally averaging across the individual sex/age group DERs. PAL and BMR estimates were calculated from population-wide time allocation data, and individual height and weight measurements. The average adult DER was calculated as 8687 kJ day^{-1} (2075 kcal day^{-1}) for women and 11 685 kJ day^{-1} (2834 kcal day^{-1}) for men, for an overall average of 10 278 kJ day^{-1} (2455 kcal day^{-1}). We next calculated a proportional caloric contribution of each food item by dividing the estimated average DER by the frequency of consumption per item. This caloric contribution was then weighted by the item's energetic density (kcal/100 g). The fat, protein, carbohydrate and FA content of each item was calculated from the

weighted caloric contribution and published estimates obtained from the United States Department of Agriculture and international databases (Tabla de Composición de Alimentos Bolivianos 1984; INFOODS Food Composition Database for Biodiversity, version 1.0, 2010). Estimates were based on edible portions of food items only. Consumption observations did not account for cooking methods, portion sizes or portions of foods consumed (e.g. different cuts of meat or organs), and these are not factored into the nutritional estimates. When necessary, values for wild animal species and fruits were approximated from similar items.

Tsimane milk samples were collected from 37 women in a single village (population ~450) during August and September 2009 (during the dry season). All lactating women with infants under age 1 and present during the study ($n = 21$) were asked to participate; 20 women consented and one candidate deemed the study too time consuming and declined. An additional 17 lactating women with infants aged 1–2 later volunteered to participate or were approached for inclusion in the study, for a total of 37 subjects. All infants were singleton births; no information on birthweight was available. All subjects gave verbal consent to participate the day before and immediately prior to collection.

Milk was collected by MM between 8 am and noon in the subjects' own homes at pre-arranged times. Mothers were instructed not to feed their infants from one breast at least 1 h prior to scheduled milk collection. Mothers were administered a 24-h dietary recall, weighed (Tanita® BF-679W) and measured for height; infants were weighed (Salter Brecksell® 235-6S) and measured for length (Pediatric Infantometer). Subjects were instructed on the use of a manual breast pump (Medela Harmony™) and assisted as needed by MM. Milk was collected until completely expressed, measured for volume and manually agitated in sterile 50-mL containers, and then aliquoted on-site into four 2-mL cryotubes. Any remaining milk was given to the mother to feed to her infant or discard. Following milk collection, mothers were given a commercial, nutritional beverage and small compensatory gifts such as hair combs, soap, necklaces and clothespins.

Milk samples were stored in liquid nitrogen until transport to the Centro Nacional de Enfermedades Tropicales (CENETROP) laboratory in Santa Cruz, Bolivia, where they were stored at –20°C. Samples were later transported to the United States on dry ice and stored at –80°C. All protocols for Tsimane subject recruitment, milk collection and analysis were reviewed and approved by Tsimane community leaders and the University of California Santa Barbara Office of Research, Human Subjects Committee (ID # 09-312), and complied with research and ethical standards previously set by joint agreements between the THLHP and the indigenous Tsimane Council. The University of Pittsburgh Institutional Review Board approved all milk FA analysis protocols.

Study population: US women (Cincinnati, OH)

The comparison samples were selected from participants in a longitudinal study (2004–2007) at the Cincinnati Children's research human milk bank (RHMB). The RHMB serves as a repository where human milk and corresponding data are collected and stored for a wide range of research purposes (Geraghty *et al*. 2005). Participation in the RHMB programme is voluntary. Mothers agreed to provide milk samples and clinical data weekly for the first month, then monthly for the duration of lactation (up to 18 months post-partum); they received a nominal reimbursement and could discontinue participation at any time.

Participants for the 2004–2007 cohort were solicited in the pre-partum and immediate post-partum period through flyers at doctors' offices and other local outlets. All mothers at least 18 years of age, in good health and intending to feed their infants at least 50% breast milk for 6 months or more were eligible. A trained lactation nurse visited eligible mothers in their homes within the first week post-partum to review the protocol and obtain consent. At birth, infants must have been singletons, of at least 37 weeks gestation, weighed more than 2.5 kg, and considered to be in good health.

At all visits, the nurse measured mothers' and infants' height and weight (E-Z Carry Portable

Digital Scale, Hopkins Medical Products, Baltimore, MD). Milk was collected between 10 am and noon using a hospital grade, electric breast pump (Medela, McHenry, IL), from one breast until fully expressed; mothers were asked not to feed for at least two hours prior to their scheduled sessions. Collected milk samples were stored on ice for transportation to RHMB, then aliquoted and frozen at –80°C.

For the current analysis, single samples from 37 RHMB participants whose infants' ages best approximated those of the Tsimane infants were selected. The Institutional Review Board at the Cincinnati Children's Hospital Medical Center approved all methods for consent, milk donation, questionnaire delivery, referral, and sample analysis. Dietary information on the Cincinnati mothers was unavailable for the comparative analysis; we referenced published U.S. estimates (Ervin 2004; Wright *et al*. 2004) for discussion of population differences in average dietary intake.

Milk FA analyses

Milk lipids were extracted from 100 µL of milk following established protocols (Bligh & Dyer 1959). The samples, plus 1, 2-dinonadecanoyl-sn-glycero-3-phosphocholine (Avanti Polar Lipids, Inc. Alabaster, AL) (50 µg of 19:0) used as an internal standard, were homogenized in 4 mL of methanol, 2 mL of chloroform and 1.6 mL of water. After 15 min, an additional 2 mL of chloroform and 2 mL of water were added and the samples vortexed. The lower phase was dried under nitrogen and resuspended in 1.5 mL 14% boron trifluoride methanol. The samples were then heated at 90°C for 40 min and after cooling extracted with 4.0 mL pentane and 1.5 mL water. The mixtures were then vortexed and the organic (upper) phase recovered (Morrison & Smith 1964). The extracts were dried under nitrogen and resuspended in 50 µl heptane, and 2 µL of the solution were injected into a capillary column (SP-2380, 105 m × 53 mm ID, 0.20-µm film thickness; Supelco Inc., Bellefonte, PA, USA). Individual FAs were separated with a Perkin Elmer Clarus 500 gas chromatograph (Shelton, CT, USA) equipped with a flame ionization detector. Identification of components was done by comparison of retention time with those of authentic standards (Sigma Chemical Co., St. Louis, MO, USA). The coefficients of variation between runs were: 16.8% (12:0), 4.1% (14:0); 1.9% (16:0); 1.3% (16:1n7); 2.6% (18:0), 1.4% (18:1n9), 1.9% (18:1n7), 2.3% (18:2n6), 3.0% (18:3n3), 3.0% (20:3n6), 6.3% (20:4n6), 6.0% (20:5n3), 5.5% (22:6n3). Short-chain FAs of 10 carbons or less tend to be lost during evaporation of solvents, and were not measured for the present study, which focuses on long-chain FAs at least 14 carbons in length. Drying time for the samples was minimized to limit loss of 12:0. Nevertheless, as noted earlier, the coefficient of variation% for 12:0 was higher than those reported for the other FAs. As samples from both populations were analysed concurrently, any sampling bias because of underestimation of 12:0 would not systematically affect comparisons between the two.

Statistical analyses

Percentages of specific FAs (% weight/total weight of FAs) were available for all 74 samples collected from the Tsimane and Cincinnati populations. For statistical analyses, we excluded results from mothers of one Tsimane and one Cincinnati infant aged 10 and 12 days, respectively. Although removing these infants did not affect statistical results, researchers have observed marked differences in milk FA composition between very early (7–12 days) and later lactation, and have recommended these age ranges not be compared (Harzer *et al*. 1983; Luukkainen *et al*. 1994). We also excluded results from the mothers of one Tsimane infant at very late lactation (785 days) and the closest matched Cincinnati infant (573 days); exclusion of these infants did not affect statistical results related to infant age. The final statistical analyses thus covered milk samples from 35 Tsimane mother–infant dyads (17 female and 18 male infants) and 35 Cincinnati dyads (16 female and 19 male infants).

To compare differences in infant growth between the two populations, we calculated infant WAZ (weight-for-length *z*-score), LAZ (length-for-age *z*-score), and WLZ (weight-for-length *z*-score). The *z*-scores were calculated according to the 2006 WHO international standards for breastfed infants (WHO Multicentre Growth Reference Study Group 2006).

The means, standard deviations and ranges of the following descriptive characteristics were calculated for each sample population: maternal age, weight, height, BMI, parity, lactational stage, infant WAZ, infant LAZ and infant WLZ. Mean differences for each characteristic were compared with paired-sample Student's *t*-tests, with pairs matched by lactational stage. Significance levels were adjusted using the using the false discovery rate (FDR) method to correct for multiple comparisons (Benjamini & Yekutieli 2001).

Population means, standard deviation, medians and first to third interquartile ranges were calculated for the individual percentages of each FA (% weight/total weight) and the total FA concentration (mg mL^{-1}). Individual FA are presented as a weight percentage of total FA weight because FA concentrations are significantly affected by fat content, which varies with milk sampling conditions and nursing patterns. However, percentage contributions of FAs are unaffected by variability in milk fat content and can be reliably determined through random sampling (Koletzko *et al*. 1992). To facilitate comparison with existing literature, we additionally present the summed totals of all n-6 and n-3 FA analysed, the total n-6 and n-3 LCPUFA, and various ratios of interest. To minimize assumptions about the distribution of the FA data, population differences for specific FA percentages were compared by paired-sample Wilcoxon signed rank tests, with significance levels adjusted using the FDR method. For each population, we also computed Spearman's rank correlation coefficients between 18:0, 18:1n-9, LA, ALA, AA and DHA, adjusting significance levels by the FDR method to correct for multiple comparisons. For each population, we then computed Spearman's rank correlation coefficients between AA, DHA, maternal parity and lactational stage, with significance levels adjusted by the FDR method. All statistical analyses were conducted using Predictive Analytics Software Statistics version 18.0 (SPSS Inc., Chicago, IL, USA). Comparing all of these tests with their parametric equivalent, no inferences were changed regarding statistical significance.

Results

Descriptive statistics for the mother–infant dyads are given in Table 1. The Tsimane mothers were on average significantly younger, shorter, weighed less and had higher parity than Cincinnati mothers; Tsimane infants had significantly lower length-for-age scores than Cincinnati infants. The sample populations did not significantly differ by maternal BMI, infant age, infant weight-for-age or infant weight-for-length (Table 1).

In 24-hr dietary-recall interviews taken at milk collection, 83% of the Tsimane mothers reported eating fish at least once the day prior; 63% reported eating meat, 49% reported eating both and only one reported eating neither. From previously gathered

Table 1. Descriptive characteristics of Tsimane and Cincinnati mothers and infants*

	Tsimane ($n = 35$)		Cincinnati ($n = 35$)	
	Mean ± SD	Range	Mean ± SD	Range
Maternal age (years)	26 ± 8.5	15–45	32 ± 4.9†	22–42
Maternal weight (kg)	55.9 ± 9.2	43.1–79.7	63.8 ± 10.1‡	50.9–95.7
Maternal height (cm)	151.1 ± 4.3	142.0–162.0	163.7 ± 5.2§	153.7–178.4
Maternal BMI (kg m^{-2})	24.5 ± 3.7	18.6–34.0	23.8 ± 3.7^{NS}	19.7–35.1
Maternal parity	4.3 ± 2.8	1–11	1.9 ± 0.8‡	1–4
Lactational stage (weeks)	43.8 ± 23.5	6.4–82.1	43.8 ± 23.5^{NS}	7.0–80.7
Infant WAZ	–0.9 ± 1.4	–4.1–1.8	–0.3 ± 1.1^{NS}	–2.1–2.3
Infant LAZ	–1.4 ± 1.4	–3.5–2.1	–0.3 ± 1.0‡	–2.0–2.0
Infant WLZ	–0.1 ± 1.1	–2.5 ± 2.3	–0.2 ± 1.1^{NS}	–2.1–2.8

WAZ, weight-for-age *z*-score; LAZ, length-for-age *z*-score; WLZ, weight-for-length *z*–score; NS, non-significant; SD, standard deviation; BMI, body mass index. *Values are means ± SD. Sample population differences were compared by paired-sample Student's *t*-tests. Significance levels are adjusted *q*-values obtained by the false discovery rate method to control for multiple comparisons ($^{\dagger}q < 0.05$, $^{\ddagger}q < 0.01$, $^{\S}q < 0.001$, NS).

population-wide dietary observations, we estimate that for adults aged 20 and older, the average Tsimane diet comprises 74% plant and 26% animal foods. Locally cultivated staples (rice, plantain, manioc and corn) account for 66% of total dietary energy, wild and cultivated fruits and nuts 6%, and market foods (crackers, bread, pasta, sugar) 2%. Game meat (primarily species of peccary, tapir, capybara and monkey) accounts for 17% of total dietary energy; freshwater fish 7%; and beef, poultry, and pork from free-ranging animals 2%. The Tsimane do not consume domestic milk or dairy products, and eggs account for less than 0.5% of the diet. An estimated 14% of average daily energy is derived from fat, 14% from protein and 72% from carbohydrates. Minimally, the average adult Tsimane diet contains 38 g fat per day, with 11 g saturated fat, 14 g monounsaturated fat and 8 g polyunsaturated fat. Comparatively, the average US diet contains 67 g fat per day, with an estimated 33% of daily energy derived from fat, 15% from protein and 50% from carbohydrates (Wright *et al*. 2004).

Saturated, trans and monounsaturated FA composition in breast milk

Tsimane mothers had significantly higher percentages of most saturated FAs (SFA), with the exception of significantly lower 18:0, and non-significant differences in 12:0 and 14:0 (Table 2). Oleic acid (18:1n-9) was the predominant monounsaturated FA (MUFA) in both populations (90% and 75% of total MUFA in the Cincinnati and Tsimane samples, respectively), but was significantly higher among Cincinnati mothers (Table 2). Palmitoleic (16:1n-7) and vaccenic acid (18:1n-7) in Tsimane samples accounted for 17% and 8%, respectively, of total MUFA, as compared with 6% and 3% of total MUFA in Cincinnati samples. TFAs accounted for 0.6% and 1.7%, respectively, of total FA in Tsimane and Cincinnati milk, with differences largely due to significantly higher 18:1*t* in Cincinnati mothers (Table 2).

PUFA composition in breast milk

Tsimane milk samples had higher percentages of total n-3, total n-3 LCPUFA, and total n-6 LCPUFA, but Cincinnati samples showed significantly higher total n-6 (Table 3). Mean ratios of total n-6/n-3 and n-6/n-3 LCPUFA were significantly lower among the Tsimane (4/1 and 1/1, respectively) than those of Cincinnati mothers (8/1 and 3/1). Although the mean percentage of 20:4n-6 (AA) was twice as high in the Tsimane mothers (Table 2), the mean *ratio* of AA/DHA was 50% higher in the Cincinnati mothers. No significant population differences were observed in the means of 18:3n-3 (ALA), 18:3n-6 or 20:3n-6 (Table 3). Total n-6 and n-3 LCPUFA accounted for 3.5% and 1.6% of total FA among the Tsimane and Cincinnati samples, respectively; and 22% and 7% of total PUFA. In both populations, 18:2n-6 (LA) was the most predominant PUFA. Among Tsimane mothers, mean LA (10.2%) accounted for 64% of total PUFA. The mean percentage of LA among Cincinnati mothers (18.9%) was nearly twice as high and accounted for 84% of total PUFA in the North American sample (Table 2).

As shown in Table 4, EPA and DHA were significantly correlated with their precursor ALA in Tsimane mothers only. Positive correlations between metabolically distinct FAs were also observed: in Tsimane mothers, LA and oleic acid, and ALA and AA were moderately correlated, while AA was strongly correlated with EPA and DHA. LA and ALA were highly correlated among Cincinnati mothers (Table 4). In separate nonparametric correlations run for each population, neither AA or DHA was significantly correlated with maternal parity or lactational stage.

Discussion

The present study demonstrates that milk FA composition differs significantly between a well-studied forager-horticulturalist population and a Westernized reference population. The differences in milk FA composition are consistent with differences in the average dietary composition of the two populations. Our discussion of dietary influences on Tsimane and Cincinnati milk FA composition draws from the population-wide Tsimane dietary estimates presented earlier and US estimates published elsewhere (Ervin 2004; Wright *et al*. 2004; Oh *et al*. 2005). These

Table 2. Mean saturated, trans, monounsaturated, and polyunsaturated fatty acid content of Tsimane and Cincinnati milk*

Fatty acid % wt/wt	Population	Mean + SD	Median	Interquartile range	Significance *q* value
Medium-chain FA					
12:0 (lauric)	Tsimane	5.72 ± 2.39	5.30	3.41	0.079
	Cincinnati	6.68 ± 2.27	6.61	2.40	
14:0 (myristic)	Tsimane	9.81 ± 4.18	9.08	6.15	0.335
	Cincinnati	8.67 ± 2.81	8.43	3.85	
Saturated FA (even)					
16:0 (palmitic)	Tsimane	24.96 ± 3.13	25.17	4.01	<0.001
	Cincinnati	20.00 ± 2.64	20.53	4.19	
18:0 (stearic)	Tsimane	5.54 ± 1.49	5.03	2.10	0.002
	Cincinnati	6.67 ± 1.51	6.49	1.73	
Saturated FA (odd)					
13:0	Tsimane	0.06 ± 0.04	0.04	0.05	0.002
	Cincinnati	0.03 ± 0.02	0.03	0.02	
15:0	Tsimane	0.43 ± 0.17	0.40	0.28	0.001
	Cincinnati	0.29 ± 0.09	0.30	0.13	
17:0 (margaric)	Tsimane	0.53 ± 0.18	0.53	0.30	<0.001
	Cincinnati	0.27 ± 0.06	0.26	0.08	
Trans FA					
16:1t	Tsimane	0.43 ± 0.12	0.42	0.13	<0.001
	Cincinnati	0.32 ± 0.04	0.33	0.05	
18:1t	Tsimane	0.21 ± 0.30	0.12	0.22	<0.001
	Cincinnati	1.23 ± 1.05	0.93	1.11	
18:2tt	Tsimane	0.00 ± 0.01	0.00	0.01	<0.001
	Cincinnati	0.11 ± 0.07	0.10	0.05	
Monounsaturated FA					
16:1n-7 (palmitoleic)	Tsimane	6.06 ± 1.72	5.70	2.27	<0.001
	Cincinnati	1.96 ± 0.61	1.91	0.92	
18:1n-7 (vaccenic)	Tsimane	2.84 ± 0.76	2.92	0.98	<0.001
	Cincinnati	1.03 ± 0.22	1.03	0.36	
18:1n-9 (oleic)	Tsimane	27.50 ± 4.56	26.99	7.21	0.020
	Cincinnati	30.16 ± 3.44	30.39	4.58	
20:1n-9	Tsimane	0.10 ± 0.11	0.06	0.09	<0.001
	Cincinnati	0.30 ± 0.16	0.37	0.25	
24:1n-9 and 22:4n-6[†]	Tsimane	0.06 ± 0.08	0.01	0.09	0.002
	Cincinnati	0.12 ± 0.04	0.13	0.05	
n-6 Polyunsaturated FA					
18:2n-6 (LA)	Tsimane	10.23 ± 4.56	9.31	5.45	<0.001
	Cincinnati	18.88 ± 5.10	18.09	6.04	
18:3n-6 (GLA)	Tsimane	0.12 ± 0.04	0.11	0.07	0.390
	Cincinnati	0.13 ± 0.05	0.13	0.08	
20:2n-6	Tsimane	0.23 ± 0.08	0.20	0.16	0.589
	Cincinnati	0.22 ± 0.07	0.21	0.08	
20:3n-6 (DGLA)	Tsimane	0.47 ± 0.12	0.44	0.15	<0.001
	Cincinnati	0.33 ± 0.08	0.33	0.10	
20:4n-6 (AA)	Tsimane	1.06 ± 0.33	0.96	0.52	<0.001
	Cincinnati	0.55 ± 0.09	0.56	0.13	
22:5n-6 (Osbond)	Tsimane	0.21 ± 0.07	0.19	0.10	<0.001
	Cincinnati	0.05 ± 0.03	0.04	0.00	
n-3 Polyunsaturated FA					
18:3n-3 (ALA)	Tsimane	1.90 ± 0.84	1.64	1.04	0.114
	Cincinnati	1.58 ± 0.65	1.39	0.78	
20:4n-3 (ETA)	Tsimane	0.25 ± 0.18	0.17	0.23	<0.001
	Cincinnati	0.06 ± 0.03	0.05	0.03	

Table 2. Continued

Fatty acid % wt/wt	Population	Mean + SD	Median	Interquartile range	Significance *q* value
20:5n-3 (EPA)	Tsimane	0.20 ± 0.12	0.17	0.13	<0.001
	Cincinnati	0.06 ± 0.04	0.06	0.04	
22:5n-3 (DPA)	Tsimane	0.40 ± 0.14	0.36	0.17	<0.001
	Cincinnati	0.14 ± 0.04	0.14	0.03	
22:6n-3 (DHA)	Tsimane	0.69 ± 0.26	0.62	0.31	<0.001
	Cincinnati	0.16 ± 0.09	0.13	0.09	
Total FA (mg mL^{-1})	Tsimane	11.46 ± 6.12	9.51	7.44	0.027
	Cincinnati	13.33 ± 3.66	13.54	5.79	

SD, standard deviation; FDR, false discovery rate; FA, fatty acid; LA, linoleic acid; GLA, gamma linolenic acid; DGLA, dihomogamma-linolenic acid; AA, arachidonic acid; ALA, α-linolenic acid; ETA, eicosatetraenoic acid; EPA, eicosapentaenoic acid; DPA, dipicolinic acid; DHA, docosahexaenoic acid. *Values are mean weights (%wt: total FA weight) ± SD, medians and twenty-fifth and seventy-fifth percentile range. Population differences for each specific FA were compared with Wilcoxon paired-sample signed ranks tests, with samples matched to lactational stage. Significance values are *q*-adjusted *P*-values obtained using the FDR method to control for multiple comparisons. †24:1n-9 and 22:4n-6 did not always separate during analysis and are reported together.

Table 3. Summary of polyunsaturated fatty acid composition in Tsimane and Cincinnati milk*

Fatty acid totals and ratios	Tsimane	Cincinnati
Total n-6	12.47%	20.58%
Total n-3	3.44%	2.00%
Total n-6/Total n-3	3.48/1	7.56/1
Total n-6 LCPUFA	1.97%	1.15%
Total n-3 LCPUFA	1.54%	0.42%
n-6 LCPUFA/n-3 LCPUFA	1.28/1	2.75/1
LA/ALA	5.38/1	11.95/1
AA/EPA	5.34/1	8.86/1
AA/DHA	1.53/1	3.43/1

LCPUFA, long-chain polyunsaturated fatty acid; AA, arachidonic acid; ALA, α-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid. *Total n-6 is the sum of mean 18:2n-6, 18:3n-6, 20:2n-6, 20:3n-6, 20:4n-6 and 22:5n-6 percentages. Total n-3 is the sum of mean 18:3n-3, 20:4n-3, 20:5n-3, 22:5n-3 and 22:6n-3 percentages. Total n-6 LCPUFA is the sum of mean 20:2n-6, 20:3n-6, 20:4n-6 and 22:5n-6 percentages. Total n-3 LCPUFA is the sum of mean 20:4n-3, 20:5n-3, 22:5n-3 and 22:6n-3 percentages.

estimates are good approximations of habitual dietary intake that would influence milk FA composition from both direct intestinal absorption and body stores.

The high n-3 LCPUFA contents in Tsimane milk were expected given their regular intake of freshwater fish. As compared with mean DHA percentages reported in 84 international studies of milk FA composition (Brenna *et al.* 2007), Tsimane milk mean DHA (0.74%) ranks in the ninety-fifth percentile of means and Cincinnati milk in the seventeenth percentile. The Tsimane milk DHA percentage ranks below only mean values reported for women in the Dominican Republic (van Beusekom *et al.* 1990), Japan (Wang *et al.* 2000; Yuhas *et al.* 2006) and the Canadian Arctic (Innis & Kuhnlein 1988) (0.91–1.4%). Although the FA concentrations of fish species consumed by the Tsimane are not known, freshwater Amazonian species examined elsewhere show lower levels of DHA (18–55 mg g^{-1}) as compared with coldwater ocean species such as bluefin tuna (181 mg g^{-1}), Atlantic salmon (175 mg g^{-1}), and mackerel (100 mg g^{-1}) (Inhamuns & Franco 2008). Fish intake by the Tsimane may also be less frequent and more seasonal than that of coastal populations. While small fish may be obtained from the stream that transects the sampled Tsimane community, larger fish catches are generally obtained by making treks to neighbouring communities with larger rivers, especially during the peak dry season (May–August) when water levels are low and fishing is most productive.

Among the same international studies compiled by Brenna *et al.* (2007), the percentage of AA in Tsimane milk (1.12%) ranks highest, while that of Cincinnati (0.59%) ranks in the eighty-first percentile (Brenna *et al.* 2007). The percentage of AA was not signifi-

Table 4. Nonparametric correlations between specific FA*

	Tsimane						
–	18:0	Oleic	LA	ALA	AA	EPA	DHA
18:0	–	-0.104^{NS}	-0.125^{NS}	0.034^{NS}	0.147^{NS}	-0.058^{NS}	0.089^{NS}
Oleic	0.105^{NS}	–	**0.558**†	-0.171^{NS}	-0.239^{NS}	-0.364^{NS}	-0.396^{NS}
LA	-0.375^{NS}	-0.237^{NS}	–	0.230^{NS}	-0.144^{NS}	-0.069^{NS}	-0.171^{NS}
ALA	-0.187^{NS}	-0.352^{NS}	**0.805**‡	–	**0.581**†	**0.806**‡	**0.607**‡
AA	0.081^{NS}	0.282^{NS}	-0.166^{NS}	-0.166^{NS}	–	**0.760**‡	**0.780**‡
EPA	0.183^{NS}	0.096^{NS}	-0.163^{NS}	-0.019^{NS}	0.356^{NS}	–	**0.809**‡
DHA	-0.126^{NS}	-0.030^{NS}	-0.066^{NS}	-0.083^{NS}	-0.061^{NS}	0.202^{NS}	–
	Cincinnati						

LA, linoleic acid; AA, arachidonic acid; ALA, α-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; NS, non-significant. *Values are Spearman's rank correlation coefficients. Significance levels are adjusted *q*-values obtained by the false discovery rate method to control for multiple comparisons ($^{\dagger}q < 0.01$, $^{\ddagger}q < 0.001$, NS).

cantly correlated with its precursor LA in either Tsimane or Cincinnati milks, suggesting AA synthesis from LA is not a limiting factor for milk AA content. Freshwater fish may also be a source of AA for the Tsimane. In a study of milk FA composition in African mothers with regular freshwater fish consumption, median milk AA content (0.52–0.70%) was higher than that of European (0.37%) and Caribbean (0.50%) mothers, with regularly consumed fish species showing higher AA content and higher AA/DHA ratios as compared with North Sea and Caribbean species (Kuipers *et al*. 2005). The high percentage of AA in Tsimane milk may also reflect their regular consumption of animal organs, including brain and liver tissue, which contain high concentrations of both AA and DHA (Cordain *et al*. 2002). Of note, AA was strongly correlated with both EPA and DHA in Tsimane milk samples (Table 4). Because of metabolic competition during synthesis from precursors (LA and ALA, respectively), an inverse relationship between AA and EPA or DHA might have been expected. The positive relationships between these LCPUFA may suggest common dietary sources.

The differences in LCPUFA composition between Tsimane and Cincinnati mothers may also reflect differences in body fat composition and parity-related mobilization of fat and FA stores (Butte & Hopkinson 1998; Lassek & Gaulin 2006). However, we observed no significant differences in maternal BMI between the two populations (Table 1). BMI and body fat percentages are also highly correlated in Tsimane adults, and body fat percentage per unit increase in BMI in Tsimane women is similar to that of US women (Gurven *et al*. in press). There was also no significant negative correlation between AA or DHA and parity in either population. However, such effects may not be expected among the relatively low-parity Cincinnati mothers, while habitual intake of AA- and DHA-rich foods may be sufficient to supply milk content in the higher parity Tsimane mothers.

We also observed no significant correlations between AA or DHA and lactational stage, which is consistent with previous studies showing no decrease in milk AA or DHA from 3 to 6 months to 1 year post-partum (Marangoni *et al*. 2000; Mitoulas *et al*. 2003), and no change in FA composition in milk triglycerides or infant phospholipids up to 23 months of lactation (Lauber & Reinhardt 1979). Stable milk AA and DHA composition may be needed during the 2-year postnatal brain-growth spurt, when uptake of AA and DHA by the brain is maximal (Marangoni *et al*. 2000; Milligan *et al*. 2008). Prolonged breastfeeding of up to 2 years post-partum may therefore provide infants with a steady supply of AA and DHA during this critical period of brain growth and development.

The higher percentages of LA and total TFAs in Cincinnati mothers' milks are consistent with values previously reported for US women, and likely reflect regular consumption of LA-rich vegetable oils (Brenna & Lapillonne 2009) and processed foods

containing LA and hydrogenated oils (Szabo *et al*. 2007; Samur *et al*. 2009).Tsimane women generally cook with rendered animal fat, and rarely purchase or use vegetable oils. Importantly, LA and ALA compete metabolically for the enzymes used in synthesizing AA and DHA (Gibson *et al*. 2011) and, although conversion of ALA to DHA is low, replacing LA-rich oils with ALA-rich oils may increase plasma DHA levels (Brenna *et al*. 2009). We observed higher ratios of LA/ALA and AA/DHA in Cincinnati as compared with Tsimane mothers (Table 3), suggesting that high LA intake and elevated synthesis of n-6 LCPUFA metabolites may reduce DHA synthesis in the Cincinnati samples. *Trans* FA content in milk has also been shown to vary inversely with LCPUFA content (Szabo *et al*. 2007). *Trans* fat intake in the United States has dropped from 2.2% to 1.6% of total daily energy between 1980 and 1998 (Oh *et al*. 2005), and appears to have decreased even further in the last decade (Vesper *et al*. 2012). Still *trans* fat intake is likely even lower among the Tsimane, with processed market foods comprising less than 1% of daily energy in the adult Tsimane diet. Thus, in addition to DHA-rich dietary sources, the DHA status of Tsimane mothers may be favourably influenced by their lower LA/ALA ratios and *trans* FA percentages.

It is notable that the Tsimane mothers did not significantly differ from the Cincinnati mothers in their percentages of lauric (12:0) or myristic acid (14:0) (Table 2). These medium-chain FAs are synthesized in the mammary gland, and synthesis may be increased by low-fat/high-carbohydrate diets, as has been observed for some rural African mothers (Koletzko *et al*. 1991; Kuipers *et al*. 2005). The higher percentage of 16:0 in Tsimane milk (Table 2) may similarly reflect increased synthesis, lower PUFA intake, or unaccounted-for sources of fat in the Tsimane diet. Wild game is generally lower in saturated fat than is domestic meat (Cordain *et al*. 2002), and our estimated Tsimane saturated fat intake (10.6 g day^{-1}) is less than half that of US adults (22.5 g day^{-1}) (Ervin 2004). However, our behavioural observations of foods eaten did not account for organ meat consumption or the addition of cooking fat, which may substantially increase saturated fat intake. The higher mean percentages of 15:0 and 17:0 in the Tsimane samples were also perplexing, as the Tsimane rarely consume dairy fats, which are associated with 15:0 and 17:0 in serum and adipose tissue levels (Brevik *et al*. 2005). Future research will better quantify Tsimane saturated fat intake from animal sources.

There are several limitations to the current study. First, although most mean differences in milk FA composition between the two populations may be reasonably ascribed to differences in average dietary composition, we lack direct quantitative data on long-term dietary intakes from the subjects sampled here. We also caution that without measurements of 24-h milk energy density and yield, we cannot determine actual infant FA intake (Mitoulas *et al*. 2003; Milligan *et al*. 2008). Total FA concentrations were significantly lower and more variable in Tsimane mothers as compared with the Cincinnati mothers (Table 2), which may reflect greater variation in Tsimane mothers' parity and nursing patterns – characteristics known to substantially affect milk yield (Motil *et al*. 1997) and milk fat and FA concentrations (Koletzko *et al*. 1992). Lower milk FA concentrations may not equate to lower FA intake, however, as any differences may be balanced out across total daily milk and/or milk lipid intake (Mitoulas *et al*. 2003; Milligan *et al*. 2008). Future research is needed to better quantify and evaluate the effects of intrapopulation variation in diet, parity, body fat and lactational stage on Tsimane milk FA composition. Such research should also include longitudinal measures of average daily milk energy density and yield in order to track changes in infant FA intake over the course of prolonged lactation.

In conclusion, we have presented evidence of high LCPUFA content in milk from Tsimane mothers consuming a traditional diet of wild game, fish and cultigens. Modern diets and weaning practices are vastly different from those under which human milk FA synthesis and infant postnatal developmental patterns evolved. Milk from women practising prolonged lactation and consuming traditional diets rich in n-3 and free of industrially extracted n-6 may be more reflective of ancestral milk LCPUFA availability and thus may serve as better reference standards for FA composition in both milk and infant formula.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

MAM, WDL, SJG, MG, HK, JGW and ALM made substantial contributions to conception and design of study. MAM, WDL, RWE, MG, HK, JGW, ALM, BSD and SRG made substantial contributions to the acquisition and/or analysis and interpretation of data. The paper was drafted by MAM and critically revised by SJG, WDL, RWE, MG, HK, JGW and ALM. All authors gave final approval of the version submitted for publication.

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Por Que las Mujeres Tienen Más Hijos que Quieren? Entendiendo Diferencias en el Numero de Hijos Ideal y Actual en una Población de Fertilidad Natural

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Objetivos: Nosotros desarollamos y probamos un modelo conceptual de los factores que influyen el tamaño de la familia (IFS) en una población de fertilidad natural, los Tsimanes de Bolivia. El modelo supone los efectos de ambiente, historia reproductiva, condición materna y IFS de los hombres. Probamos tres hipótesis de por qué las mujeres pueden superar sus IFS a pesar del desarrollo económico: autonomía limitada (H1), mejoras en condición materna (H2) y baja rentabilidad de las inversiones en capital humano.

Metodos: La historia reproductiva de mujeres y datos de fecundidad fueron recolectados desde 2002 a 2008 (n=305 mujeres). Las entrevistas fueron hecho con mujeres Tsimanes para estudiar el valor percibido de inversiones de recursos en hijos (n=76). Usamos modelos estadísticas (regresiones lineales, t-tests) para probar predicciones del modelo.

Resultados: El IFS de las mujeres se pudo predecir por factores del ambiente, historia reproductiva, condición materna y IFS de maridos. Se apoya el H2 y H3. Parejas viviendo cerca de San Borja prefieren tener familias más pequeñas (mujeres = 3.75, varones = 3.87) y menos diferencias entre ellos. Sin embargo, los que viven más cerca de San Borja tienen más grande diferencia entre parejas en su preferencia por los números de hijos. Mujeres que viven cerca del pueblo están en mejor condición materna pero 64% valoran habilidades tradicionales más que educación formal y 88% creen que vivir en pueblo no es posible.

Resultados: Mientras que menos hijos están preferidos con el desarrollo económico, el descenso de la fecundidad no puede inmediatamente seguir. Cuando los beneficios percibidos de inversión en recursos humanos más modernos son muy pocos, y cuando la riqueza corporal y redes sociales de parentesco siguen como aspectos importantes para el éxito en la vida, la fecundidad puede mantenerse alta y aumenta si la condición materna mejora.

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Original Research Article

Why Do Women Have More Children Than They Want? Understanding Differences in Women's Ideal and Actual Family Size in a Natural Fertility Population

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Objectives: We develop and test a conceptual model of factors influencing women's ideal family size (IFS) in a natural fertility population, the Tsimane of Bolivia. The model posits affects of socioecology, reproductive history, maternal condition, and men's IFS. We test three hypotheses for why women may exceed their IFS despite experiencing socioeconomic development: (H_1) limited autonomy; (H_2) improved maternal condition; and (H_3) low returns on investments in embodied capital.

Methods: Women's reproductive histories and prospective fertility data were collected from 2002 to 2008 ($n = 305$ women). Semistructured interviews were conducted with Tsimane women to study the perceived value of parental investment ($n = 76$). Multiple regression, t-tests, and analysis of variance (ANOVA) are used to test model predictions.

Results: Women's IFS is predicted by their socioecology, reproductive history, maternal condition, and husband's IFS. Hypotheses 2 and 3 are supported. Couples residing near town have smaller IFS (women = 3.75 ± 1.64; men = 3.87 ± 2.64) and less variance in IFS. However, the degree fertility exceeds IFS is inversely correlated with distance to town (Partial $r = -0.189$, $df = 156$, $P = 0.018$). Women living near town have greater maternal condition but 64% value traditional skills over formal schooling and 88% believe living in town is unfeasible.

Conclusions: While reduced IFS is evident with socioeconomic development, fertility decline may not immediately follow. When perceived benefits of investment in novel forms of embodied capital are low, and somatic wealth and large kin networks persist as important components of fitness, fertility may remain high and increase if maternal condition improves. Am. J. Hum. Biol. 24:786–799, 2012.

INTRODUCTION

Among many Latin American indigenous populations, market integration and socioeconomic development are associated with increases in fertility despite declines in ideal family size (IFS) (Bremner et al., 2009; Casterline and Mendoza, 2009; Hern, 1994; Kennedy and Perez, 2000; McSweeney and Arp, 2005; Perz et al., 2008; Terborgh et al., 1995; Williams, 2011). High fertility, despite smaller IFS, may impair maternal or child health and survival and can reduce women's socioeconomic status and autonomy (Casterline and Mendoza, 2009; Gipson et al., 2008; Williams, 2011). The rapid population growth associated with increasing fertility—e.g., 3–5% in many Southern Amerindian populations with population doubling times of 14–23 years (Kennedy and Perz, 2000; Perz et al., 2008)—may accelerate environmental degradation of indigenous lands (Speidel et al., 2007; Williams, 2011). This is problematic as indigenous peoples face sociopolitical discrimination, and limited land rights and prospects for upward mobility (Hall and Patrinos, 2006, McNamee, 2009; Psacharopoulos and Patrinos, 1994; Speidel et al., 2007). Increases in fertility during the first stage of demographic transition are not rare (Dyson and Murphy, 1985; Gibson and Mace, 2002; Hirschman, 1994). However, the mechanisms underlying these fertility increases have not been extensively explored. Furthermore, fertility patterns observed among subsistence-level populations—populations that have only recently been exposed to Western norms, schooling, wage labor opportunities, access to contraception or healthcare—may deviate markedly from fertility patterns observed during the demographic transition of national populations in developed and developing countries, where socioeconomic development led to marked fertility declines (Borgerhoff Mulder, 1998; Kaplan, 1996; Preston et al., 2000; Vining, 1986; Wilson and Airey, 1999).

In this article, we examine the impact of socioeconomic development on women's IFS and fertility among Tsimane forager-farmers of Bolivia. The Tsimane are a natural fertility population currently undergoing market integration. However, Tsimane villages vary in their degree of socioeconomic development. The novelty of our approach is to present a conceptual framework linking fertility goals and perceptions with behavior during the initial stages of the

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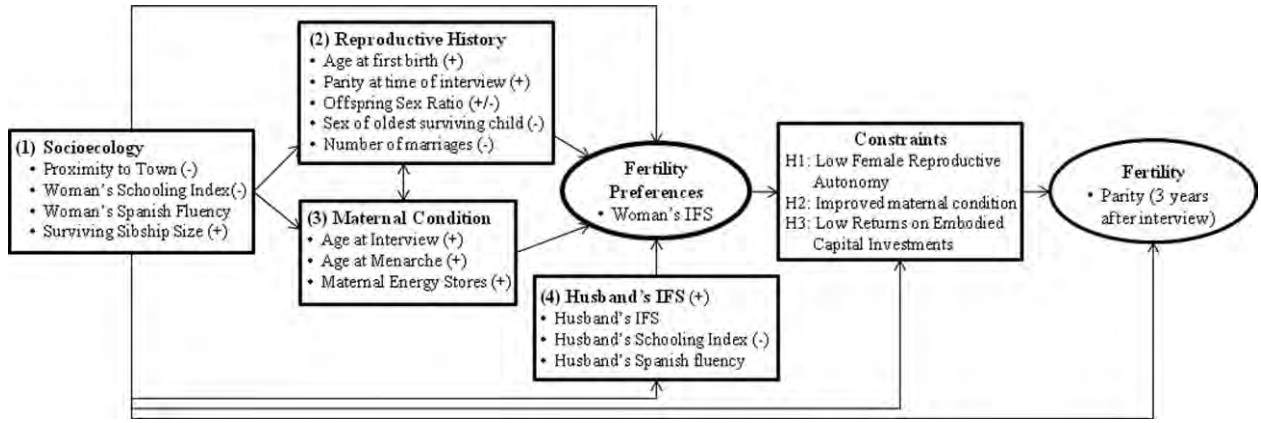

Fig. 1. Conceptual model of factors influencing women's IFS. The + and – symbols indicate the predicted direction of effect (+ = positive, – = negative).

demographic transition to small family size. We expand upon standard treatments of the demographic transition among rural indigenous populations by use of individual-level data in ethnographic context. First, we develop a conceptual model of factors influencing women's IFS. The model posits direct and indirect affects of socioecology, women's reproductive history, maternal condition, and husband's IFS. We then test three hypotheses for why women may exceed their IFS despite experiencing early stages of demographic transition: (H_1) low female reproductive autonomy; (H_2) improved maternal condition; and (H_3) low returns on embodied capital investments for women and their children.

Explaining ideal family size

Women's IFS is influenced by numerous inter-related factors. Here, we examine four factors and how socioeconomic change may interact with them to affect women's IFS: (1) socioecology, (2) reproductive history, (3) maternal condition, and (4) husband's IFS. We believe these factors affect women's IFS by impacting the perceived costs and benefits of parental investment. Figure 1 depicts the relationships between these factors, IFS and fertility.

1. Socioecology: Socioecology refers to features of the physical habitat, access to food, extractive technology, and degree of market integration. Greater involvement in a competitive, skills-intensive, wage-based economy increases the importance of schooling for parents and their offspring (Kaplan, 1996; Shenk, 2009). Greater schooling and employment opportunities for women may increase women's independence and reproductive autonomy, while providing alternate "lifestyle options" beyond mothering (Borgerhoff Mulder, 2000, 2009; Cain, 1984; Caldwell, 1982; Jejeebhoy, 1995; Newson et al., 2005). These changes may encourage women to have smaller IFS, and enable them to break from cultural norms that either favor investment only in "somatic" wealth, or that measure women on the basis of their homemaker and mothering abilities.

Market integration is also associated with the breakdown of kin networks (Rosenzweig, 1988; Shenk, 2009). In many traditional societies, resource sharing within kin networks is a form of insurance against individual fluctuations in resource access (Fafchamps, 1992; Hoff and Sen, 2006). Increased reliance on private savings and the market instead of reciprocal sharing networks may lead to less externalizing of the costs of children, thereby encouraging smaller IFS. Kin networks are also pathways of influence and information dissemination (Hoff and Sen, 2006; Shenk, 2009). As kin influence declines, women's reproductive autonomy may increase, enabling women to state lower IFS (Newson et al., 2005, 2007).

2. Reproductive history: A woman's reproductive history influences her current IFS (Belsky et al., 1991; Miller and Pasta, 1995). In natural fertility populations, women who start reproducing earlier will have longer reproductive life spans (all else equal), higher fertility, and may state larger IFS. A woman's parity affects her IFS through post-rationalization bias (Bongaarts, 1990; Bushan and Hill, 1995; Kent and Larson, 1982): women may not state IFSs lower than their current parity. Offspring sex ratio and the sex of the oldest child may affect the energetic cost of reproduction and maternal workload through access to alloparents (Hrdy, 2005; Kramer, 2005). Women with more alloparents experience reduced costs of reproduction and may thus be more willing to have large families and state correspondingly larger IFS. The number of prior marriages may have mixed effects on IFS: (1) women who change partners may have greater reproductive autonomy and thus state smaller IFS (Borgerhoff Mulder, 2009); (2) women with larger IFS may be more likely to remarry so that they can achieve their IFS; or (3) divorced women may state higher IFS as leverage to attract a new husband on the mating market.

3. Maternal condition: Agriculture and socioeconomic development are usually associated with relatively predictable access to calorically dense foods, healthcare, and public sanitation. These affect maternal morbidity, fat stores, ovarian hormone levels, and maternal energetics (Ellison, 1990; King, 2003; Nohr et al., 2009; Osteria, 1982; Voland, 1998; Wood, 1994). All else equal women with larger energy budgets have a greater capacity to support gestation and lactation while still meeting their own somatic needs (Jasienska, 2009; Valeggia and Ellison, 2003). Women in better condition may consequently be more willing to support larger families, proxied by higher IFS.

4. Husband's IFS: In natural fertility populations men generally experience lower costs of investment per child compared to women, resulting in larger IFSs for men than women (Bongaarts, 2001; Borgerhoff Mulder, 2009; Dodoo et al., 1997; Mason and Taj, 1987; Terborgh et al., 1995). Moreover, completed family size is partially determined by coital frequency, over which women may have limited control (Borgerhoff Mulder, 2009). Husbands' larger IFS may lead to higher fertility than what their wives desire, and/or may encourage wives to adjust their IFS to accommodate their husbands' needs (Kulczycki, 2008; Mason and Taj, 1987; Smuts, 1992; Voas, 2003). Education and reliance on market goods may encourage both sexes to reduce IFS, thereby reducing the divergence between husbands' and wives' IFS (Cain, 1984; Mason and Taj, 1987) and enabling women to freely state smaller IFS (Cleland and Van Ginneken, 1988; Hobcraft, 1993; Jejeebhoy, 1995; Newson et al., 2007; Riley, 1997).

Hypotheses regarding the discrepancy between ideal family size and fertility

Discrepancies between IFS and fertility have raised questions about the validity of IFS as a construct (Bongaarts, 1990). We propose that IFS is a viable representation of women's intended fertility and that the discrepancy with fertility requires explanation. Stated intentions for having additional children or for having no additional children have been shown to be reliable predictors of subsequent fertility, and important mediators in predicting several fertility-related behaviors (Bushan and Hill, 1995; Hagewen and Morgan, 2005; Rindfuss et al., 1988; Schoen et al., 1997, 1999; Thomson, 1997; Westoff, 1988; Westoff and Ryder, 1977). These relationships hold even after controlling for the replacement of deceased children or cultural norms of gender inequality (Bongaarts, 2001, 2002).

We investigate the empirical validity of three hypotheses to explain the discrepancy between IFS and fertility in rural indigenous populations undergoing socioeconomic transition. In the national populations of both developed and developing countries, socioeconomic development and cultural changes associated with modernization have encouraged smaller IFS (McSweeney and Arps, 2005; Terborgh et al., 1995; Westoff and Moreno, 1996; Williams, 2011). Among the Tsimane, we expect proximity to town (a proxy of socioeconomic development) to be negatively correlated with IFS in both men and women.

(**H1) Female reproductive autonomy hypothesis:** Women may exceed their IFS to accommodate the high fertility expectations of a spouse or kin, particularly if female reproductive autonomy is low (Borgerhoff Mulder, 2009; Dodoo et al., 1997; Jejeebhoy, 1995; Voas, 2003). Socioeconomic development may improve women's reproductive autonomy, through reducing influence of kin and increasing the economic independence of women, enabling them to achieve their desired fertility (Jejeebhoy, 1995; Newson et al., 2005). However, socioeconomic development may initially reduce women's reproductive autonomy if women's access to modern wealth, and consequently market goods and services, are controlled by their husbands (Dodoo and Seal, 1994).

Among the Tsimane, if women's reproductive autonomy is limited by their husband, we predict that fertility will show a stronger correlation with husbands' IFS than with wives' IFS (**P1.1**). With increasing proximity to town we predict lower discrepancies between women's IFS and parity (**P1.2**). An alternative prediction is that lower excess fertility (IFS—parity) may be due to lower discrepancies between husbands' and wives' IFS near town (**P1.3**) and not from increases in women's autonomy.

(H2) Improved maternal condition hypothesis: Greater access to healthcare, reduced morbidity, and other benefits associated with socioeconomic development may increase women's energy budgets, fecundity, and offspring survival (Cleland and Van Ginneken; 2001; Ellison, 1990; Osteria, 1982; Stearns, 1992; Valeggia and Ellison, 2003; Voland, 1998; Wood, 1994). In a natural fertility population such as the Tsimane, women in better condition should have higher parity (**P2.1**) and/or lower infant and child mortality than other women (**P2.2**).

Women residing near town are expected to have smaller IFS relative to their remote-dwelling peers, but higher fertility and consequently larger discrepancies between their IFS and parity (**P2.3**). However, as discussed in the previous section, women in better condition may be more willing to have large families. Among more market integrated Tsimane women, those in better condition may have larger IFS (**P2.4**); thus, even though their fertility may be higher, we predict no corresponding increase in the discrepancy between their IFS and parity (**P2.5**).

Predictions 2.1, 2.3, and 2.5 assume that women are not actively controlling their fertility. Use of modern contraceptives is rare among the Tsimane. Few women have used Depo Provera injections or oral contraceptive pills, and no women use contraception regularly. However, Tsimane do employ traditional methods to prevent fertilization, using cultivated plants such as *bui'si mäbdyes* a member of the *Leguminosae* family (Reyes, 2001). Its efficacy has not been assessed. Post-conception and post-partum control methods are also common, including self-inflicted physical damage to induce miscarriages and infanticide. Improvements in maternal condition increasing women's fecundity and offspring survival are a concern if women are unable to control their fertility. If Tsimane women lack effective methods of fertility control, women should be equally likely to have additional children, irrespective of their desired IFS (**P2.6**).

(H3) Low returns on embodied capital investments hypothesis: Increased fertility in rural indigenous populations may be due to incomplete market integration. Although educational and wage opportunities exist, there may still be a real or perceived lack of economic returns on investments in schooling. Additional schooling did not predict greater wage earnings in a sample of 257 Tsimane households across 13 villages, and even moderate Spanish fluency bore no association with wages (Godoy et al., 2007a). Opportunities for wage labor are limited, male biased, and most do not require formal schooling. Rural indigenous populations also face discrimination, further limiting viable employment opportunities (Perez et al., 2008). Those with novel forms of extra-somatic wealth may achieve greater social status by remaining in their villages, and using wealth to amass traditional somatic markers of success, such as larger body size and large families. Thus, despite socioeconomic development, and declines in mortality and IFS, if somatic wealth remains the most important component of status, the motivation to deliberately control fertility will be low and fertility will remain high (Kaplan, 1996). Moreover, large families are not only an indicator of wealth and status but

are also important sources of social and economic support, possibly cementing their desirability (Caldwell, 1982).

Hypothesis 3 makes similar predictions about IFS and fertility outcomes as H2. The discrepancy between women's IFS and parity should be greater with increased proximity to town (P2.3). However, controlling for maternal condition, we expect to see greater discrepancies between IFS and parity closer to town (**P3.1**). Moreover, we expect Tsimane women to express opinions suggesting that somatic wealth is the main component of perceived success (**P3.2**), and that investment in schooling and greater market integration is undesirable or infeasible (**P3.3**).

METHODOLOGY

Study population

The Tsimane are lowland South Amerindian forager-horticulturalists living in the Beni Department of Bolivia. Swidden horticulture accounts for roughly two-thirds of their diet, supplemented with fishing, hunting, and gathering. The amount of consumed fat and protein varies by proximity to rivers and primary forest where hunting is still prominent (Gurven and von Rueden, 2006). Modernization is a mosaic experience, depending on access to schools, contact with non-Tsimane, and Spanish fluency, all of which are greater closer to the nearby town of San Borja (pop. $\approx$ 24,000). Market participation includes cash cropping of cultigens, wage labor as farmhands or loggers, and trade with merchants or missionaries. However, most wage labor opportunities are only available to men, low income, and sporadic. Residence near town is associated with greater wage-related absenteeism for men (unpublished data).

Infant mortality and total fertility rate (TFR) are high among the Tsimane [13% infant mortality rate (IMR), TFR = 9.1; Gurven et al., 2007]. Both IMR and TFR covary with distance to San Borja. IMR is $\sim$ 25% and TFR is 8.0 in remote forest villages, whereas IMR is 10% and TFR is 9.5 in villages near town (Gurven, in press). Mean $\pm$ SD inter-birth interval (IBI) for women for whom accurate birth dates for their children are known is 30.7 $\pm$ 10.6 months (N = 213) with no significant variation across villages [$F(3,209) = 1.194$, $P = 0.313$]. The consistency in IBI may be due to breastfeeding practices among Tsimane women, which are relatively unaltered by market integration; breast milk has not been replaced by formula, powdered milk, or cow's milk, and most women only wean when they are pregnant again (mean $\pm$ SD age at weaning for a subsample of 76 women was 1.74 $\pm$ 0.70 years with no significant variation among villages [$F(3,72) = 0.988$, $P = 0.404$].

Data collection

Fertility preferences and behavior of 305 Tsimane women aged 15–45 years, and 216 of their husbands, were investigated during demographic interviews by MG between 2002 and 2005. Follow-up fertility outcomes for these women were analyzed in 2008 based on censuses and interviews during medical checkups. The study sample constitutes 19% of all Tsimane women of reproductive age. Participants are from 22 villages spanning the Tsimane territory that we group into two regions: the more market integrated villages located "near town" (N = 94) and the more isolated villages "far from town" (N = 213). Villages located far from town are further divided into "Mission" (N = 63), remote "forest" (N = 64) and "riverine" (N = 86). The Mission village is separated from the riverine sample, despite its remote riverine location, as the Catholic Redemptorist Mission has provided schooling, religious services, medical attention, trading opportunities, and greater contact with nationals and pro-natalist beliefs for over 50 years (Gurven et al., 2007). Riverine and forest villages are considered separately because, while they are both remote regions with limited access to education and healthcare, they differ in wage labor opportunities and consumption of fish versus meat, which may affect women's health status, body composition, and physiological condition (Martin et al., 2012).

Methods used to gather reproductive histories and to ascribe ages to living and dead individuals have been previously described (Gurven et al., 2007). Demographic interviews also measured IFS, schooling (highest grade completed), literacy (coded as none/moderate/good), and Spanish fluency (coded as none/moderate/fluent). IFS was queried as: "What number of children do you think is the best number of children for you to have so that you can live well? Think about your own experience, life and wishes. There are no correct or incorrect answers to this question."

Additional interviews conducted by LM focused on women's views on mate choice, parenting and social aspirations (N = 76; 59 women from a near town village and 17 from a forest village). Five questions relevant here include: (1) "Who in your village is a good (influential) woman and why?"; (2) "Who in your village is a good (influential) man and why?"; (3) "What is important to give a child so s/he can have a good life?"; (4) "Who has the better life?" [Tsimane living far from town, close to town, those living in town, or non-Tsimane living in town]; and (5) "Where would you prefer to live?" [town, close to town, or far from town]. For "What is important to give a child so s/he can have a good life?" women ranked 10 skills from most to least important: traditional skills of hunting, fishing and farming; non-traditional skills of Spanish fluency, literacy, education, access to wage labor and access to San Borja; and the uncategorized skills health and influence in the community. These questions were included to better understand how status and cultural success are viewed by Tsimane, and to assess the lifestyle options that Tsimane women believe are available to them.

Body mass index (BMI) was measured using a portable stadiometer and Tanita weigh scale, and body fat percentage (based on bioelectric impedance) using the same weigh scale. These measures were taken in the same year as demographic interviews. Women pregnant at the time of interview were not included in this study; only non-pregnant weights and body fat percentages are used.

Data analysis

Descriptive statistics summarize IFS and TFR. Tsimane women's age and parity are strongly correlated, therefore, relationships between age, IFS and parity are assessed by partial correlations.

Table 1 summarizes key variables, measurement techniques, predicted directions, and observed effects on IFS controlling for parity, according to the schema from Figure 1. Socioecological variables include: *proximity to town*,

*TABLE 1. Description of variables utilized in our linear regression model and predicted direction of effect on IFS. A positive correlation is represented by +, a negative correlation by –, N/A is used for Region as it is a categorical variable and must be assessed separately, and NS indicates for Observed Direction where the correlation was non-significant. For the means * indicates a ranked mean and ** a categorical mean*

Variable		Description	Predictions	*N*	β	S.E.	Direction	
							Exp.	Obs.
Dependent variable								
Woman's IFS		Woman's stated IFS from demographic interviews	Declines with market integration	305	4.621	0.137		
Independent variables								
(1) Socioecology								
Ecological and Socioeconomic	Proximity to town	Resident village was binary coded as 1 = near town, 0 = far from town. Far from town is further divided into three regions based on geographic proximity to the Mission, and whether the village was accessible by road or river.	Women living near town will be more acculturated and have correspondingly lower IFS	305	N/A	N/A	N/A	N/A
Economic	Women's schooling index	Principle component of literacy and highest school grade	Women who are better educated and more able to communicate with Bolivian nationals will have smaller IFS	305	0.369*	0.035	–	–
	Literacy	Self-reported reading & writing ability						
	Highest School Grade	Self-reported highest school grade completed		305	1.175	0.097	–	–
	Spanish fluency	Spanish linguistic skills assessed by interviewer		305	0.580*	0.039	–	–
Social	Surviving sibship Size	Total number of surviving maternal siblings assessed from reproductive histories	Women with more siblings have larger support networks and more alloparents and may consequently have larger IFS.	299	5.920	0.162	+	–
(2) Reproductive history								
Age at first birth	Calculated from women's reproductive histories	In a natural fertility population older women have higher parity and due to post-rationalization bias may have larger IFS		283	18.24	0.157	–	NS
Parity	Total number of living children assessed from reproductive histories	Due to post-rationalization bias women will enlarge their IFS to match their parity.		305	4.80	0.199	+	+
Offspring sex ratio	Sex ratio	Ratio of sons to daughters	Daughters may be a lower cost to maternal energetics and family economics (alloparents & brideprice). Also, sons are highly valued. Women with many daughters may state larger IFS to allow for new sons.	238	1.268	0.071	–	+
	Sex of oldest surviving child	Sex of the oldest surviving child assessed from reproductive histories (0 = female, 1= male)		280	0.52**	0.030	–	NS
Total number of marriages at interview	The total number of times a woman had been married assessed from reproductive histories	Women who remarry may have greater autonomy and be less likely to enlarge their IFS to accommodate husbands' larger IFS.		305	1.20	0.030	–	+
(3) Maternal condition								
Age at interview	A woman's age at time of interview based on her year of birth	Women who have been reproducing for longer will have larger parity and due to post-rationalization bias have correspondingly higher IFS		305	29.282	0.528	+	+

TABLE 1. Continued.

Variable	Description	Predictions	*N*	β	S.E.	Direction	
						Exp.	Obs.
Age at menarche	Self-reported age started menstruating	Women who have a positive energy balance may be more willing to have large families as they can better afford the cost of reproduction.	289	13.420	0.059	+	+
Maternal energy stores	Principle component of BMI and body fat percentage						
BMI	BMI calculated from height & weight data.		223	23.005	0.246	+	NS
Body fat percentage	Body fat percentage, from bioelectric impedance.		213	24.995	0.473	+	NS
(4) Husband's IFS							
Husband's IFS	Husband's stated IFS from demographic interviews	Women, dependent on their husbands' for socioeconomic support, may inflate their IFS to accommodate their husbands' larger IFS, and avoid spousal conflict	216	5.520	0.245	+	+
Husband's capital	Husband's schooling index	Principle component of literacy and highest school grade Men's IFS are influenced by their education. Better educated men have smaller IFS and encourage their wives to have smaller IFS.					
	Literacy	Self-reported reading & writing ability	294	0.656	0.046	–	NS
	Highest school grade	Self-reported highest school grade completed	294	2.193	0.192	–	NS
	Spanish fluency	Spanish linguistic skills assessed by interviewer	294	0.996	0.040	–	–

used as a proxy for degree of market integration, access to healthcare and market-derived foods, and wage labor opportunities; *women's schooling index*, derived using principle components analysis of highest grade completed and literacy, used as a proxy for investment in embodied capital; *Spanish fluency* for women and their husbands, used as a proxy for interaction with non-Tsimane Bolivians; and *number of surviving siblings*, a proxy for availability of social support. Reproductive history variables are dated to when women stated their IFS unless stated otherwise in Table 1. Maternal condition and husbands' IFS are dated to the year women stated their IFS. *Maternal energy stores* is an index derived using principle components analysis of BMI and body fat percentage. *Husband's schooling index* is derived using principle components analysis of highest grade completed and literacy.

To test predictions outlined in Figure 1, multiple linear regression was used with IFS as the dependent variable. Women's age, age^2, proximity to town, parity and a parity-by-age interaction term were controlled for. Terms associated with significance levels < 0.10 were retained in the final model.

The three hypotheses for why fertility preferences and outcomes may differ are tested as follows:

(H1) Low female reproductive autonomy: To assess whether women or their husbands exert greater influence on fertility outcomes (P1.1), we correlate IFS discrepancy between husbands and wives with the difference in wives' parity and IFS using multiple linear regression. To assess the directionality of the relationship between proximity to town and the discrepancy between IFS and parity at interview, we use Pearson partial correlation and multiple regression (P1.2, P2.3, and P2.4). Analysis of variance (ANOVA) is used to compare the discrepancy between women's IFS and parity at interview across regions. Discrepancies between spousal IFSs by region are compared using ANOVA and paired *t*-tests (P1.3).

(H2) Improved maternal condition: To address P2.1, we assess how maternal condition varies with proximity to town and if age at menarche affects parity at interview using Pearson partial correlation. We test whether maternal energy stores predict likelihood of reproducing within three years of being interviewed using logistic regression. Whether maternal condition affects offspring mortality rate is assessed using Pearson partial correlations.

Whether women in better maternal condition are more likely to exceed their IFS (P2.3) is assessed using both logistic and linear regression. To test P2.4 and P2.5, only women in villages near town are considered and linear regression is used. We test whether women are able to control their fertility (P2.6) by considering the predictive power of women's IFS on subsequent fertility. Excluding women who were at their IFS (IFS = parity at time of interview), we divide women into two groups: "women who did not want more children" (IFS $\leq$ parity at time of interview); and "women who wanted more children" (IFS $>$ parity at time of interview). The relative risk of having additional children by 2008, which was at least three years post-interview for all women, was considered across these two groups and by region using Pearson chi-square.

(H3) Low returns on embodied capital investments: To separate P3.1 from P2.3, we assess whether the discrepancy between IFS and parity varies with distance to town controlling for maternal energy stores using

multiple linear regression. To assess the perceived importance of somatic versus human capital components to success (P3.2), and perceptions about the benefits of investing in human capital and the attractiveness of greater market integration (P3.3), LM's ethnographic interviews are used. For the open-ended questions "Who in your village is a good woman and why?" and "Who in your village is a good man and why?" we examined qualities of people named by respondents as worthy of respect and emulation. For other semi-structured questions, participants either ranked choices or selected one response from forced choice scenarios.

RESULTS

Comparison between IFS and TFR among Tsimane and throughout Beni

Mean ± SD IFS for Tsimane women is 4.62 ± 2.40 children compared with a TFR of 9.1. This gap between IFS and TFR is much greater than that reported at the regional level of the Beni department in 2003, where both mean IFS (3.2) and TFR (4.2) are lower (Demographic and Health Surveys, 2012). On average, Tsimane women reach their IFS in their late 20s/early 30s, and exceed their IFS by their mid-30s (Fig. 2).

Determinants of women's ideal family size

Age and age^2 account for 11.2% of the variation in women's IFS ($P < 0.001$). Controlling for age and age^2, parity ($\beta = 0.372$, $P < 0.001$) and proximity to town ($\beta = -0.254$, $P < 0.001$) are highly significant predictors of women's IFS [$F(4, 300) = 20.610$, $P < 0.001$]. Figure 3 presents women's mean IFS by region; women living in villages near San Borja have smaller IFS than women living in riverine and forest villages or near the Mission [$F(3, 301) = 6.692$, $P < 0.001$].

Table 2 presents the relationships between additional variables and women's IFS controlling for age, age^2, parity, parity-by-age and proximity to town. These variables are considered individually due to the high number of missing values for some subjects. Of the remaining socioecological variables women's schooling index, Spanish flu-

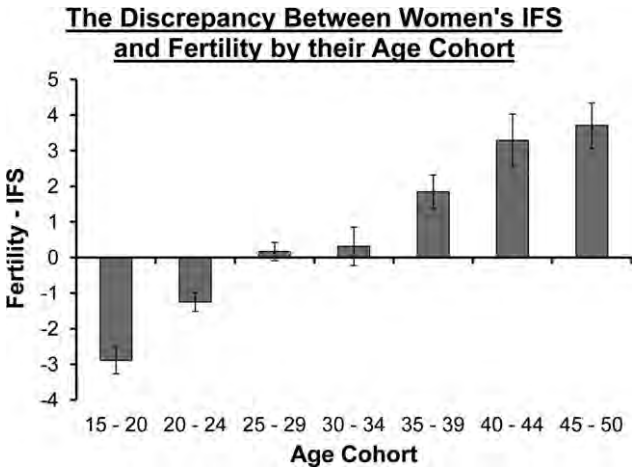

Fig. 2. The discrepancy between women's IFS and fertility by women's age with the standard error of the mean shown.

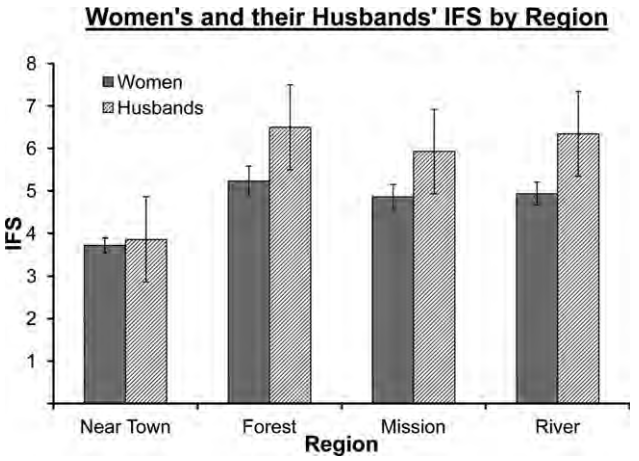

Fig. 3. Mean IFS for women and their husbands' by region with the standard deviation of the mean shown.

TABLE 2. Linear regressions of factors hypothesized to influence women's IFS, controlling for age, age^2, parity, parity-by-age and proximity to town

Variable	Standardized β	S.E.	*P*-value	*N*	R^2 change
(1) Socioecology					
Economic					
Woman's schooling index	**−0.122**	0.131	**0.027**	305	0.013
Women's Spanish fluency	**−0.095**	0.201	**0.097**	305	0.007
Social					
Surviving sibship	−0.122	0.044	**0.020**	299	0.015
(2) Reproductive history					
Age at first birth	−0.023	0.062	0.742	283	0.001
Sex ratio of offspring	0.051	0.132	0.420	238	0.002
Sex of oldest surviving child	−0.003	0.253	0.962	280	0.000
Number of marriages	**0.122**	0.246	**0.023**	305	0.013
(3) Maternal condition					
Age at menarche	0.030	0.143	0.609	289	0.001
Maternal energy stores	**−0.168**	0.149	**0.008**	213	0.027
(4) Husband's IFS					
Husband's IFS	**0.261**	0.046	< **0.001**	216	0.049
Husband's capital					
Husband's schooling index	−0.062	0.131	0.261	294	0.003
Husband's Spanish fluency	**−0.108**	0.197	**0.056**	294	0.010

ency, and surviving sibship are significant predictors of women's IFS. Of the remaining reproductive history variables only number of marriages was a significant predictor of women's IFS. Of the remaining maternal condition variables only maternal energy stores was a significant predictor of women's IFS. Of the husbands' IFS variables husbands' IFS and husbands' Spanish fluency were significant predictors of women's IFS. Within a single regression model [$R^2 = 0.344$, $F(11, 145) = 7.281$, $P < 0.001$] the variables bolded in Table 2, with the aforementioned control variables, explain 34% of the variation in women's IFS. However, women's schooling index and Spanish fluency are no longer significant predictors.

The discrepancy between women's ideal family size and fertility

(H1) Low female reproductive autonomy: There is a significant difference between husbands' and wives' IFS ($t = -3.682$, $df = 216$, $P < 0.001$). As presented in Figure 4, greater spousal disparity in IFS is associated with greater excess fertility for women [controlling for women's age, age^2 and proximity to town: $\beta(3, 212) = 0.330$, $P < 0.001$]. Both women's IFS (Partial $r = 0.238$, $df = 301$, $P < 0.001$) and their husbands' IFS (Partial $r = 0.309$, $df = 212$, $P < 0.001$) are positively correlated with parity. However, when both partners' IFS are considered simultaneously, parity is more strongly related to women's IFS than their husbands' IFS for those living near town and the Mission (Table 3); this pattern is reversed for forest and riverine women. P1.1 is thus not supported in villages near town and near the Mission. Furthermore, couples in which the husband wants more children while the wife does not are no more likely to have another child than couples that agree on whether to have more children or not (logistic regression controlling for proximity to town: $\beta = -0.422 \pm 0.370$, $P = 0.643$).

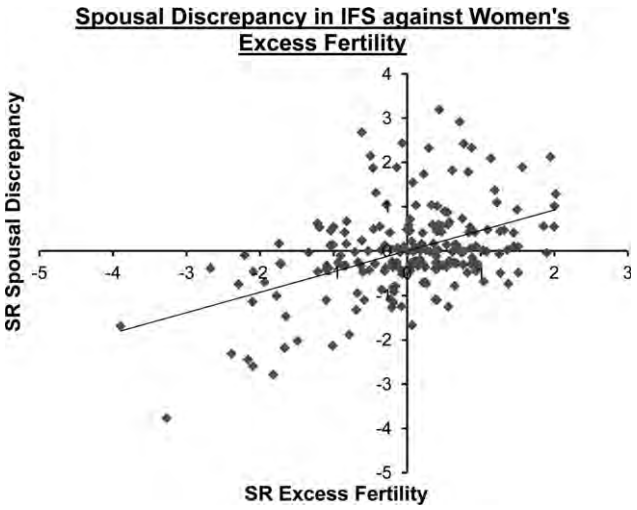

Fig. 4. Standard residuals of women's excess fertility (women's parity at time of interview—women's IFS) controlling for age and distance to town against the standardized residual of spousal disparity (husband's IFS—wife's IFS) controlling for age and distance to town.

Controlling for age and age^2, women living near town have smaller IFS (Partial $r = -0.253$, $df = 301$, $P < 0.001$), but higher parity (Partial $r = 0.139$, $df = 301$, $P = 0.015$) and offspring survival (Partial $r = 0.113$, $df = 301$, $P = 0.049$). Among women aged 30–50 years—most Tsimane women exceed their IFS in their mid-30s—there is regional variation in excess fertility [$F(3, 186) = 3.877$, $P = 0.010$]. Excess fertility is greatest among women living near town (2.50 ± 2.50), followed by women living near the Mission (1.24 ± 2.05), in the forest (1.12 ± 3.85) and in riverine villages (0.70 ± 3.51). P1.2 is not supported, while P2.3 is supported.

Proximity to town is negatively correlated with IFS for both sexes. Controlling for age, age^2, parity, and parity-by-age the estimated marginal mean IFS ± SE for women living near town is 3.71 ± 0.26 compared with 5.11 ± 0.17 for women living far from town ($P < 0.001$), and 3.82 ± 0.39 compared to 6.26 ± 0.25, respectively, for their husbands ($P < 0.001$). As presented in Figure 3, couples living near town show no significant discrepancy in spousal IFS [$t(66) = -0.371$, $P = 0.712$], however, couples living in other regions do show discrepancies (forest [$t(45) = -2.745$, $P = 0.009$], Mission [$t(44) = -2.741$, $P = 0.009$], riverine [$t(57) = -2.268$, $P = 0.027$]).

Furthermore, contrary to the prediction generated by H1, husbands also exceed their IFS. There is a significant difference between husbands' IFS and their wives' parity [$F(3, 210) = 8.640$, $P < 0.001$]. Tukey post-hoc comparisons indicate that men living near town (1.47 ± 3.55) exceed their IFS more than men living in the forest (-1.57 ± 3.62, $P < 0.001$), near the Mission (-0.47 ± 2.55, $P = 0.026$) or in riverine villages (-1.18 ± 4.09, $P < 0.001$). P1.3 is thus not supported.

(H2) Improved maternal condition: Women living in villages near town experience menarche at an average of 10.37 ± 1.23 months earlier ($P < 0.001$). Controlling for proximity to town, for every year menarche is delayed women marry 6.50 ± 2.16 months later ($P < 0.001$) and give birth 5.72 ± 2.10 months later ($P = 0.007$). Consequently, parity-for-age is larger in women with earlier ages at menarche (Partial $r = -0.126$, $df = 286$, $P = 0.033$). Furthermore, women living in villages near town have larger maternal energy stores (controlling for age, age^2, parity, and parity-by-age: Partial $r = 0.121$, $df = 206$, $P = 0.082$). Women with larger maternal energy

TABLE 3. Regression of women's and their husband's IFS against women's parity controlling for women's age

	Women			Husbands			
Region	Standardized β	S.E.	*P*-value	Standardized β	S.E.	*P*-value	R^2 change
Near town	0.164	0.153	0.039	0.017	0.090	0.819	0.025
Forest	0.020	0.134	0.837	0.218	0.123	0.033	0.044
Mission	0.227	0.154	0.066	0.026	0.157	0.843	0.052
River	0.061	0.126	0.481	0.293	0.064	0.001	0.079
Total	0.069	0.065	0.126	0.140	0.043	0.002	0.028

TABLE 4. Risk of giving birth within three years post interview by whether women had exceeded their IFS or were below their IFS at time of interview. The Pearson Chi-Square compares women with IFS less than parity (did not want more children) and women with IFS greater than parity (wanted more children) for each region

	All women interviewed			Women with IFS < parity			Women with IFS > parity				Pearson Chi-square	
Region	No. women	No. births	New birth (%)	No. women	No. births	New birth (%)	No. women	No. births	New birth (%)	Relative risk	χ^2	*P*-value
Near town	91	56	61.54	47	30	63.83	30	16	53.33	0.84	0.216	0.402
Forest	64	27	42.19	28	12	42.86	24	10	41.67	0.97	0.009	0.563
Mission	64	40	62.50	21	8	38.10	23	19	82.61	2.17	7.943	0.006
River	86	40	46.51	28	9	32.14	37	20	54.05	1.68	3.445	0.051
Total	305	163	53.44	124	59	47.58	114	65	57.02	1.20	2.886	0.057

stores trend towards being more likely to have another child within three years of the interview (logistic regression controlling for age, age^2, parity, parity-by-age, and proximity to town and whether a woman wants more children: OR = 1.31, $P = 0.081$). P2.1 is marginally supported.

Women's age at menarche bore no relationship to offspring survival (controlling for age, age^2 and proximity to town: Partial $r = 0.050$, $df = 192$, $P = 0.488$). However, women with larger maternal energy stores at interview had experienced fewer miscarriages and stillbirths (Partial $r = -0.143$, $df = 198$, $P = 0.043$). P2.2 is supported.

Women with greater maternal energy stores are more likely to exceed their IFS within three years of the interview (OR = 1.63, $P = 0.011$, controlling for age, age^2, parity, parity-by-age, and proximity to town). Maternal energy stores are also positively correlated with excess fertility (regression model [$F(6, 205) = 50.455$, $P < 0.001$] controlling for age, age^2, parity, parity-by-age, and proximity to town: β (6,205) = 0.109, $P = 0.017$). P2.3 is supported.

Among women living near town, women with greater maternal energy stores have smaller IFS (regression model [$F(5, 50) = 5.237$, $P = 0.001$] controlling for age, age^2, parity, and parity-by-age: $\beta(5,50) = -0.283$, $P = 0.020$). P2.4 is therefore not supported. P2.5 is also not supported: among women living near town, women with larger maternal energy stores have greater excess fertility (regression model [$F(5, 50) = 25.082$, $P < 0.001$] controlling for age, age^2, parity, and parity-by-age: $\beta(5,50) = 0.174$, $P = 0.029$).

Despite the absence of effective contraceptive use, we find evidence of fertility control among the Tsimane. 51% of couples who did not want more children ($N = 111$) had another child within three years of the interview compared with 65% of couples who wanted more children ($N = 105$). Furthermore, regional comparisons of women who had exceeded their IFS with those who had not reveals that: (1) women living in riverine villages and near the Mission who want more children have a significantly greater relative risk of having another child by 2008 than women who did not want more children; while (2) near town and forest women regardless of whether they have exceeded their IFS or not experience no significant difference in risk of having another child by 2008 (Table 4).

(H3) Low returns on embodied capital investments: Controlling for the larger maternal energy stores of women living near town, age, age^2, parity, and parity-by-age, women living near town still have smaller IFS [estimated marginal mean IFS ± SE of women living in villages near town is 3.78 ± 0.33 compared to 5.11 ± 0.20 for women living far from town ($P = 0.001$)], but higher parity (Partial correlation $r = 0.183$, $df = 207$, $P = 0.008$) and lower offspring mortality (Partial correlation $r = -0.113$, $df = 301$, $P = 0.049$). Consequently women living in villages near town have 1.07 ± 0.29 more surviving offspring than women living in villages far from town ($P < 0.001$), and exceed their IFS by 2.05 ± 0.37 children more than women living in villages far from town ($P < 0.001$). P3.1 is thus supported.

Supporting P3.2, there is some evidence that women continue to prefer somatic markers of success over extrasomatic markers. When asked to identify the "influential" or "model" women in their village, respondents chose women with large families. Of 79 women residing near town over age 18 at the time of interview, only 16 were identified by respondents as "influential" or "model" women, and 46% of respondents chose one of two sisters both with family sizes one greater than the mean for their age cohort. When asked why these women were chosen 81% of women listed traditional attributes (e.g., good at gathering food, good mother, and has many children) before novel attributes (e.g., educated, speaks Spanish). Furthermore, when asked to name "good men", 76% of respondents chose men whose wives' parity was greater than the mean parity of their wives' age cohorts. When asked why these men were chosen 67% of women listed traditional attributes (e.g., good hunter and farmer) before novel attributes (e.g., does a lot of wage labor, educated, speaks Spanish).

Prediction 3.3 is supported. When asked whether they thought Bolivian nationals or Tsimane living in various locales had a "better life," more women reported that Tsimane living in remote villages had a better life than Tsimane living near or in town, while nationals were believed to have relatively good lives regardless of where they lived ($P < 0.005$). Bolivian nationals in town were believed to have significantly better lives than Tsimane living in town ($P = 0.004$). Consistent with their reports about the "good life," both forest and near town women said they would prefer to live far from town rather than in or near town (Fig. 5). Moreover, embodied capital, in the form of formal education, Spanish fluency and literacy, did not appear as salient resources to invest in children. For all women, traditional skills such as fishing, hunting, and farming were deemed most important. Two or more of these traditional skills were selected within the top three choices by 87% ($N = 76$) of women ($\chi^2 = 27.240$, $df = 3$, $P < 0.001$), with 49% of women listing hunting, fishing, or farming skills as their primary selection ($\chi^2 = 13.04$, $df = 2$, $P = 0.001$). Education, ability to speak Spanish and literacy, if chosen, were listed after traditional skills by 64% of women,

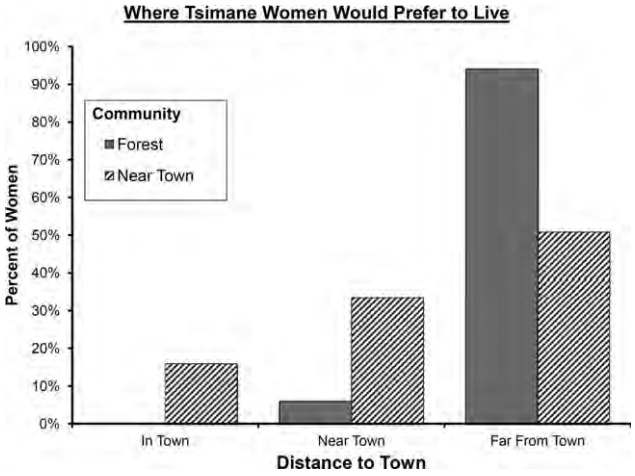

Fig. 5. Comparing where Tsimane women from a forest village (N = 17) and a near town village (N = 57) would prefer to live.

appearing as primary selection for only 29% of women. Moreover, women's schooling index and Spanish fluency had no affect on women's parity-for-age (residual of age and age^2 regressed on parity) when controlling for proximity to town [$F(3, 301) = 0.923$, $P = 0.430$].

DISCUSSION

Tsimane women have high fertility and indications among the youngest cohort are that fertility may increase further. These patterns exist even though women state preferences for lower fertility. Most Tsimane women exceed their IFS by their mid-30s and young women living near town are predicted to exceed their IFS the most. Young women living near town have the lowest IFS (<25 years old = 3.03 ± 1.69) but highest TFR (9.58) and lowest IMR (<10%); they are therefore predicted to exceed their IFS by up to six children. In contrast, women residing in the interior forest have larger IFS (<25 years old = 4.30 ± 2.80), lower TFR (8.01) and higher IMR (up to 25%); they are predicted to exceed their IFS by only two children. The Tsimane's high fertility and associated 3% annual population growth is unsustainable, especially closer to town where environmental degradation and competition for land and resources with Bolivian nationals is greater. Therefore, among Tsimane women, as with many South Amerindian women, determining why IFS and fertility rarely coincide is an important question.

Determinants of women's ideal family size

Tsimane women's IFS is influenced by components of their socioecology, reproductive history, maternal condition, and husbands' IFS.

1. Socioecology: Women living in villages near town prefer smaller families than women living far from town. Near town, educational opportunities and quality of schools are greater. Education encourages a desire for reduced reproduction either directly, by highlighting economic, social, and health benefits of a smaller family, or indirectly by encouraging women to delay reproduction and invest more in their own education and that of their children (Cleland and Van Ginneken, 1988; Jejeebhoy, 1995; Leonetti et al., 2007; Newson et al., 2007; Riley, 1997). This broad association is supported here, as women with more schooling have smaller IFS after controlling for town proximity. Women near town also interact more with non-Tsimane—individuals that may be considered to have good and successful lives (Fig. 5). Tsimane women may wish to emulate non-Tsimane and adopt similar preferences for lower fertility if this is perceived to facilitate success. Women living near town may also have had more exposure to NGO-sponsored workshops on reproductive health and family planning, and family planning advice from medical professionals working in town.

Women with larger surviving sibships were expected to have larger IFS due to greater access to allocare reducing the cost of childrearing. However, among our Tsimane sample, women with larger surviving sibships have smaller IFS. Women's sibship size may affect their childhood experiences of resource access and perceptions of how difficult it is to raise a large family (Belsky et al., 1991). In future research residential proximity, closeness in age, and relationship quality should be factored in for each sibling, as these affect women's perceived access to kin support.

2. Reproductive history: Women's parity has the strongest positive association with IFS. Women rarely state IFS lower than their current parity, consistent with post-rationalization bias (Kent and Larson, 1982).

Women who have remarried have higher IFS. Although remarriage rates among Tsimane women are low (10%, unpublished data), a remarried woman presumably includes in her IFS her children from previous marriages and expectations for more children in a new union. Although multiple marriages may often lower fertility outcomes, as among Pimbwe women of Tanzania (Borgerhoff Mulder, 2009), compared to Tsimane women, Pimbwe women are less dependent on men for resources because of strong maternal kin support and greater integration into the market economy. Alternatively, divorcees and widows of reproductive age who are pro-natalist may be more likely to remarry.

Women's age at first birth does not affect their IFS, suggesting women do not take into account the length of their potential reproductive life span when considering their IFS. Moreover, having more "helpers at the nest" (oldest child being female or a female biased offspring sex ratio) had no significant affect on IFS. These results, coupled with the finding that larger surviving sibships were associated with smaller IFS, suggests that availability of alloparents may not influence women's IFS.

3. Maternal condition: Women in better maternal condition have larger IFS. Women with higher BMI and body fat percentage are likely in better health and better able to support infant growth; their better condition may increase their willingness to have larger families.

4. Husband's IFS: Husband's IFS is significantly correlated with women's IFS, suggesting assortative mating. Assortative mating among the Tsimane has been shown for some personality traits (Godoy et al., 2008), and work effort independent of parity (Gurven et al., 2009). Alternatively, Tsimane women may have low reproductive autonomy and adjust their IFS to match their husbands' IFS. Whether Tsimane women have low reproductive autonomy is discussed below.

Women with Spanish-speaking husbands have lower IFS. Men more fluent in Spanish may be less traditional

and allow their wives more autonomy. Also, men more fluent in Spanish are more likely to engage in wage labor, which is associated with paternal disinvestment (e.g., extra-marital affairs) (Stieglitz et al., 2011). Paternal disinvestment may encourage women to reduce their IFS. Factors that predict men's IFS will be analyzed in a forthcoming article.

The discrepancy between women's ideal family size and fertility: evaluating the three hypotheses

(H1) Low female reproductive autonomy: Hypothesis 1 is not supported. Parity for women living in villages near town is more strongly correlated with wives' IFS than with husbands' IFS (P1.1, see Table 3). Furthermore, couples in which the husband wants more children but the wife does not are no more likely to have another child within three years of interview than couples in accordance. However, Tsimane women are more likely to exceed their IFS as the discrepancy between their IFS and their husbands' IFS increases, suggesting low reproductive autonomy for some Tsimane women.

Excess fertility is greatest in women living near town (P1.2 is not supported while P2.3 is supported). However, near town spousal disparity does not explain variation in extent of excess fertility above women's IFS (P1.3). Moreover, women and their husbands have smaller and more similar IFS near town. Therefore, while low female autonomy and husbands' larger IFS may explain why women living away from town exceed their IFS, they do not explain excess fertility among couples living near town.

(H2) Improved maternal condition: Hypothesis 2 is weakly supported. Women in better condition have higher parity (P2.1), are more likely to have another child within three years of the interview (P2.1) and have fewer miscarriages and stillbirths (P2.2). However, women in better condition have smaller IFS and thus exceed their IFS more than women in poorer condition (P2.3).

Women living in villages near town are in better condition than their remote-dwelling peers. However, in contrast to P2.4 and P2.5, among women living near town, those in better condition have the smallest IFS and greatest excess fertility. Education, interactions with non-Tsimane, and other factors associated with proximity to town, may outweigh the affect of maternal condition on IFS.

Although infanticide is increasingly condemned among educated Tsimane, women have numerous sanctioned pre-conception and post-conception methods of fertility control. "*A woman can take care of herself, she can get an injection. She can drink herbal concoctions to not have children…and her husband knows*" (woman living near town). Women living near town have easier access to modern contraceptives as well. One might therefore expect Tsimane women living near town to have lower fertility, despite their improved condition. However, women near town show no evidence of effective fertility control (P2.6), while women living near the Mission and in riverine villages showed significant control over their fertility. The greater fertility control of women living in riverine villages and near the Mission may be due to better access to herbal methods of fertility control: "*Women (in villages) near town… they have forgotten about the plants of the forest and their mothers do not teach them. And, near town you have to grow the plants in your house garden if you want them, the forest is too used* [exploited for agriculture and logging] *to find the plants easily. So, they cannot help but have many babies*" (woman living in a riverine village). Despite potentially greater fertility control farther from town, women and their husbands in these regions still exceed their IFS. The historic demographic transitions in Europe began before the advent of modern contraceptives (Preston et al., 2000). So while access to modern contraceptives may assist women in reducing fertility, access per se may not be fundamental to the process. Family planning programs that focus on improving access to modern contraceptives may thus be less effective than those focusing on truly reducing IFS first, e.g., those that increase perceived benefits of investment in human capital (Bledsoe et al., 1998; Pritchett, 1994; Schultz, 1969).

(H3) Low returns on embodied capital investments: Hypothesis 3 is supported. The larger discrepancy between IFS and fertility in women living in villages near town holds even after controlling for maternal condition (P3.1). Interviews suggest that Tsimane women: (1) recognize that small families are easier to manage, but, as success and security are still defined in terms of family and social connections, the predilection to have large families persists, even amongst those living under more modern conditions (P3.2); (2) Tsimane women still believe their children need traditional skills more than education or Spanish fluency, suggesting that the desire to invest heavily in these non-traditional forms of human capital for themselves or their children may still be low (P3.3); and (3) Tsimane women believe that life in town, where non-traditional human capital and life ways are important, is not ideal, and is also unavailable, and express a preference for more traditional life ways (P3.3). However, Tsimane women do rate non-Tsimane as having the better life and perhaps wish to emulate those lives. This may help explain smaller stated IFS near town despite the continued belief that large families are important for success.

A few quotes from female participants living near San Borja lend additional support for H3. The value of children in terms of household economics and desirability is a salient theme: "*Large family is good so children can work for the family, daughters can help make chicha and sons can hunt and fish*" (16 year old woman). As is the difficulty of life in San Borja for Tsimane: "*Napos* [non-Tsimane] *do not like Tsimane in San Borja and the work is hard. San Borja is expensive and* [Tsimane] *make little money…*" (adult woman). Tsimane do emphasize the value of learning Spanish, but not of formal education: "*It's important that sons and daughters can speak Spanish… so they can sell [agricultural products] to Napos. If you cannot speak Spanish the Napos cheat you…*" (adult woman); and wage labor is acknowledged as a male domain: "*Women who work [for money], they are not respected, they are not good mothers…good Tsimane women look after children and clean the house*." (adult woman).

As of yet lives outside of the Tsimane territory are not feasible options for the Tsimane, who like many other indigenous populations, face discrimination and have cultural norms and egalitarian traditions regarding resource distribution that limit the accumulation of individual wealth and private security (Hern, 1994; Jackson, 1975; Lu, 2007; McSweeney and Arps, 2005; Ribeiro, 1967; Terborgh et al., 1995). Hypergyny is uncommon and outmigration is only 7.1% of the population (Godoy et al.,

2007b). Therefore, the Tsimane continue to live fairly traditional lives, and continue to measure success predominantly in terms of somatic wealth, i.e., physical size and family size. However, for Tsimane men, non-traditional and novel skills increasingly beget community leadership, although influence, prestige and reproductive success are still highly correlated with traditional skills (von Rueden, 2008). Greater access to market goods and services, and improvements in maternal condition enable women to increase their fertility, potentially increasing their status within their village. Tsimane who have pursued interests in education, wage labor, and the local market economy may soon be at a crossroads: move to town and enter at the lowest rung of an aggressive economy, or stay within their traditional territory, have many children and be considered highly successful.

This article has begun to address why natural fertility populations do not follow the standard path to low fertility in the early stages of demographic transition. Pre-transition increases in fertility have been extensively documented (e.g. Dyson and Murphy, 1985; Hirschman, 1994) but rarely explored in depth. We propose that it is the continued preference for somatic markers of success, and the lack of perceived and actual returns on investments in schooling that contribute to a desire for high fertility. A similar pattern has been documented among the Arsi Oromo of Ethiopia undergoing development initiatives but increased fertility (Gibson and Mace, 2002, 2006). This implicit desire for high fertility, coupled with higher fecundity due to improved maternal condition, may explain Tsimane high fertility and rapid population growth. Modernization may not improve Tsimane women's long-term nutritional and health status if extra energy is used to invest in more offspring. Moreover, while effective birth control options now exist, they may be inaccessible for many, and the desire to obtain them remains weak. Therefore, women may increase their social status by continuing to invest in high fertility.

The prospect for future demographic change in the Tsimane is uncertain. Tsimane children today receive more education than their parents did, and the gender inequality in educational attainment has decreased substantially. For example, Tsimane girls and boys aged 10–19 now have an average of 3.2 and 3.5 years of schooling, respectively, compared with 0.4 and 1.3 years of schooling among women and men aged 40+. However, the quality of Tsimane schools remains low compared to schools in San Borja and higher education is too expensive for most Tsimane to attend. Moreover, the benefits of a good education continue to be low as employment opportunities are predominantly low wage, short term, male biased, and require limited schooling.

Our model attempts to explain women's reproductive decision making by focusing not only on schooling and wealth but also on beliefs about current and future conditions, social support, and pressure from spouses. Future studies would benefit from gathering explicit data on fertility preferences and variation in spousal discrepancy in IFS, and qualitative data on perceptions and beliefs pertaining to why women in high fertility populations may exceed their IFS. There is a great need for broader studies that focus on multiple factors and for attention placed particularly on the discrepancy between fertility preferences and outcomes among high fertility indigenous populations in developing countries. Gaining a better understanding of how women internalize and integrate traditional ideas from respected peers, novel ideas about reproductive technologies, expectations of future conditions and social support, and the value placed on investments in human capital is critical to best understand how the pace of fertility will change in the near future. It is also important to investigate mechanisms for reducing fertility without use of contraceptives, as these methods may have greater efficacy with marginalized indigenous populations.

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INFORMES PASADOS

INFORME: TRABAJO REALIZADO 2002-2004

PREPARADO PARA EL GRAN CONSEJO TSIMANES

POR

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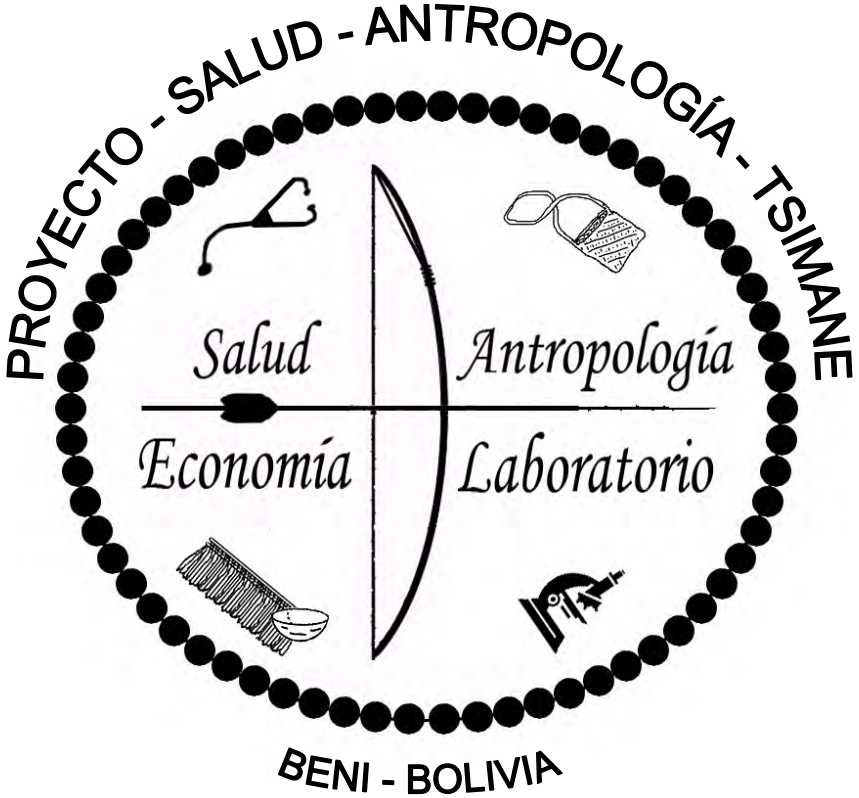


Resumen del proyecto

El programa de investigación propuesto se concentra en varios aspectos de la salud en una población indígena en Amazonia. Se enfoca en importantes preguntas teoréticas dentro de la biología evolucionaria, la economía doméstica y la antropología. Componentes aplicados del proyecto se enfocan en aspectos del desarrollo de la comunidad mediante el establecimiento del fundamento en que se puede basar un programa de salud sostenible.

El componente de salud pública tiene tres objetivos. El primero es documentar la frecuencia y distribución de las enfermedades que afligen a los hombres y mujeres Tsimanes. También pretende describir el cambio de esta distribución a través de la vida. Las explicaciones de los Tsimane por la ocurrencia y propagación de la enfermedad serán investigadas al mismo tiempo. El segundo objetivo es servir a las necesidades de salud de las distintas comunidades con la ayuda de un equipo de médicos. Por medio de esto, pretendemos establecer el fundamento de un sistema de salud sostenible, en el cual los Tsimanes mismos serán entrenados a distinguir, tratar y evaluar las enfermedades comunes en sus pueblos. Nuestra tercera meta es explorar la relación entre la salud y la educación, la dieta y el acceso a los mercados económicos modernos. Esta examinación pretende identificar las maneras en que la interacción con la sociedad nacional y la aculturación pueden llegar a tener impactos negativos en la salud de estas comunidades.

Muestreo

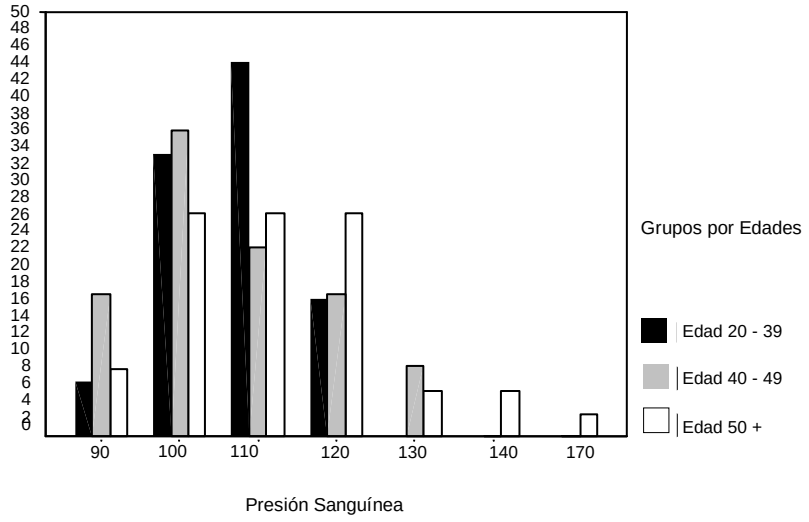
El muestreo consiste en 18 comunidades Tsimanes con una población aproximada de 2,300 individuos. Las comunidades mas aculturadas son las de La Cruz, Tacuaral de Matos y San Miguel con un total de 293, 310 y 290 habitantes respectivamente. Las comunidades de Anachere, Aperecito, Boreyo, Cachuela, Catumare, Cosincho, Cuverene, Donoy, Emeya, Fatima, Moseruna, Munday, Nuevo Mundo, Jamanchi 1 y Vishiricansi están mas alejadas de los mercados y por lo tanto menos aculturadas y con menos acceso a servicios de salud.

De junio del 2002 a Julio del 2003, el equipo trabajaba en las comunidades menos aculturadas de Cuverene, Aperecito, Munday y Cosincho. Estudios antropológicos fueron conducidos en esas cuatro comunidades principales mientras que información acerca de la salud y demografía fue recolectada en un muestreo mayor que incluyo el total de las 18 comunidades, excepto Jamanchi 1. El equipo trabajó con 3 médicos que repartiendo su trabajo de la siguiente manera: una trabajando en las comunidades de Cosincho y Munday, otra en Cuverene, Aperecito y el circuito San Miguel, Nuevo Mundo y Moseruma; y un último medico haciendo un gran circuito por todas las comunidades, enfocándose en las comunidades del río arriba de Munday. Llegado el 2003, las comunidades han sido visitadas por un equipo de dos médicos un mínimo de tres veces contando con una visita cada seis meses.

Datos Preliminares

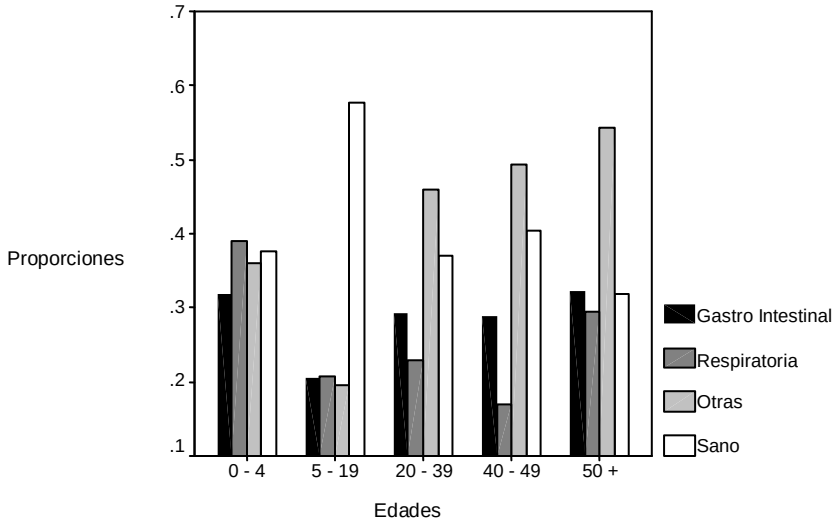
Salud La figura 1, indica que el índice de hipertensión es muy bajo; el promedio de presión arterial en un muestreo de 167 adultos fue de 107,106 y 113 mm/hg para individuos entre las edades de 20-39, 40-49 y 50+. Estos resultados junto con los datos antropométricos, los cuales demuestran que hay una baja incidencia de obesidad, indican que los Tsimanes no sufren de las enfermedades crónicas modernas.

Fig. 1. Presión Sanguínea por Edad



La figura 2, ilustra la probabilidad de que un individuo sea diagnosticado con enfermedades respiratorias, gastrointestinales u otro tipo de enfermedad. Las enfermedades gastrointestinales y respiratorias afectan a un 30-40% de los bebes y niños. Este índice decae de manera significativa en el grupo de edades de 5-19 años, y luego sube en el grupo de individuos mayores de 50 años. La frecuencia de otras enfermedades es también alta entre niños de 0-4 años pero desciende precipitadamente en el grupo de 5-19 años. Se ve un ascenso rápido de la frecuencia en los adultos mayores. No se han encontrado casos de diabetes. La probabilidad de que un individuo se encuentre sano es de un 35% para niños de 0-4 años, de un 65% en individuos de 5-19 años y de un 30-40% para adultos. El porcentaje de niños menores de cuatro años sanos es de un 38%, esta cifra sube a un 58% en el grupo de 5-19 y se mantiene en un 40% durante la adultez. Para adultos mayores este porcentaje decae de forma progresiva.

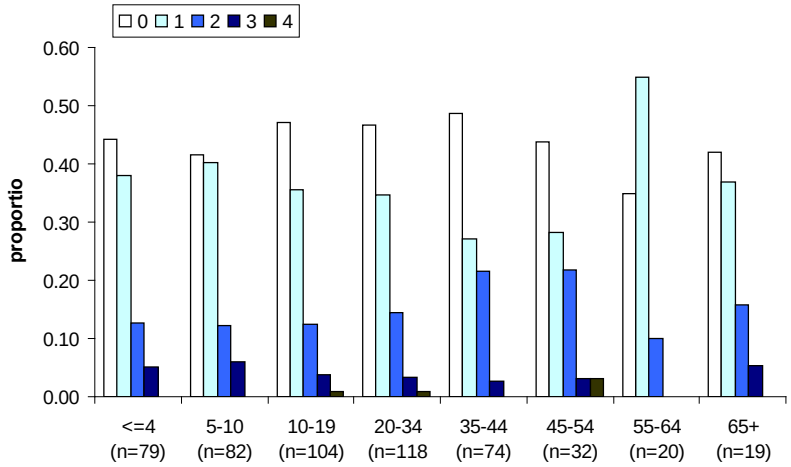
Figura 2. Incidencia de Enfermedades



Los siguientes gráficos muestran la incidencia de parásitos, nivel de hemoglobina y proteína c-reactiva. El grafico 3.a., ilustra la incidencia de cuatro tipos de parásitos estudiados. Estos resultados se han extraído de una sola muestra dándonos un estimado mínimo de los resultados. Creemos necesario hacer tres repeticiones por individuo de manera de obtener un estimado más preciso. De todas formas, se puede ver que más del 50% de la población se encuentra afectada al menos por una especie

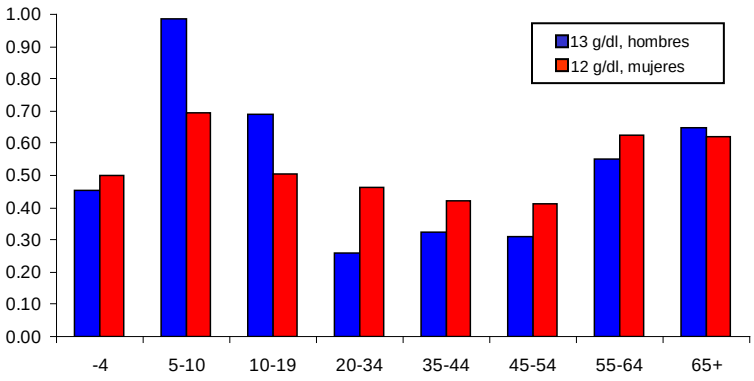
de parásitos. La incidencia de parásitos múltiples es más elevada en los mayores de edad.

Figura 3.a. Parasitismo Elevado



El grafico 3.b., nos muestra la incidencia de anemia en las comunidades. Un “cut-off” o línea de corte menor que 13g/dl en los hombres y menor que 12g/l en las mujeres demarca un nivel insuficiente de hemoglobina. Un 50% del muestreo tiene la hemoglobina baja.

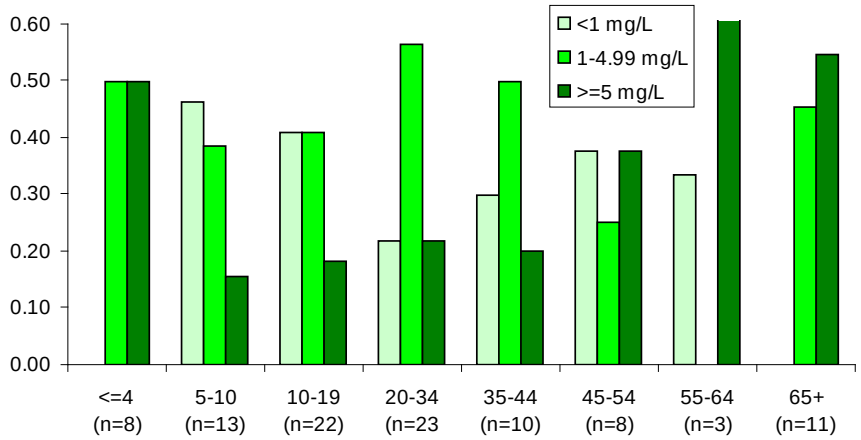
Figura 3.b. Hemoglobina baja (anemia)



El grafico 3.c., revela la proteína c-reactiva en los distintos grupos de edades. Utilizamos la proteína c-reactiva como marcador del proceso inflamatorio. Hemos usado tres niveles de medición; menor a 1mm/l (normal), 1-4.99mm/l (elevado), mayor a 5 (muy elevado). La mayoría de los niños menores de 5 años tienen la proteína c-reactiva muy elevada (la muestra es pequeña). Lo mismo sucede para los individuos mayores de 55 años. En general los Tsimanes muestran una incidencia de proteína c-reactiva muy

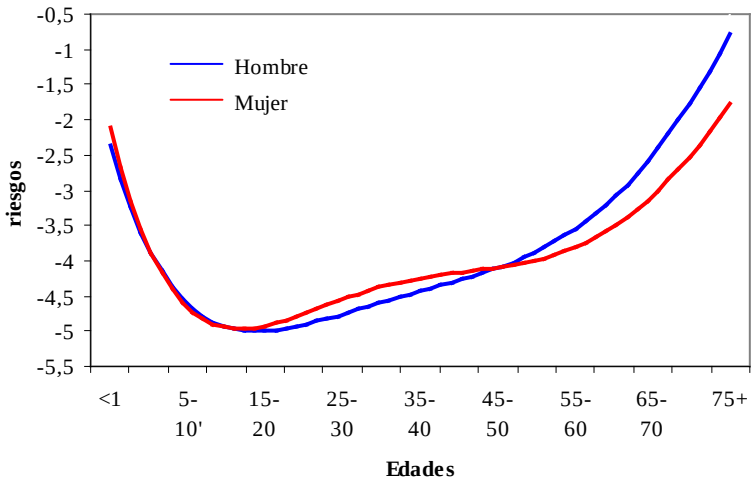
elevada, especialmente si comparamos estos resultados con los de países mas desarrollados. Aunque las comunidades no presenten las enfermedades clásicas de los países mas desarrollados, se ve en las figuras 2 y 3 que si sufren mayormente de enfermedades infectuosas como parasitismo, y otras infecciones bacterianas y virales.

Figura 3.c. Proteína c-Reactiva Elevada



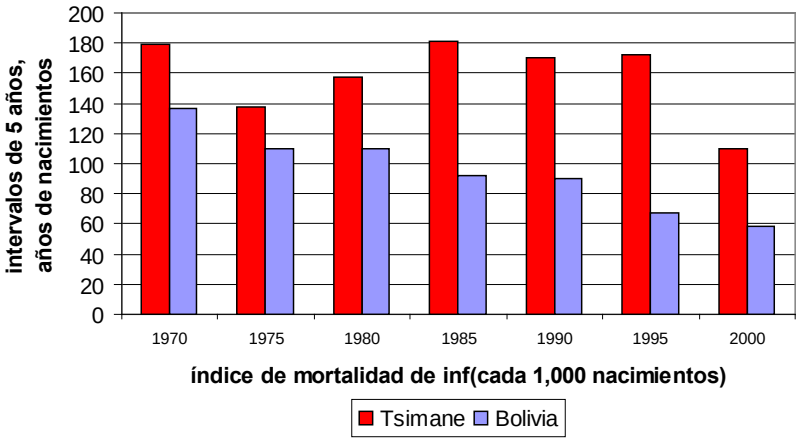
Demografía La figura 4, nos presenta el logaritmo de la probabilidad de mortalidad de cada grupo de edad. Esta probabilidad que es alta al nacer baja de forma precipitada hasta aproximar los diez años. Durante el periodo de adolescencia y adultez la curva asciende de forma gradual pero al entrar en la vejez este ascenso se manifiesta de manera abrupta. Al considerar todas las tasas de mortalidad por grupo de edades se nota una expectativa de vida al nacer de 42 años, esta siendo menor al resto de la población boliviana.

Fig. 4. Incremento proporcional en mortalidad por riesgos



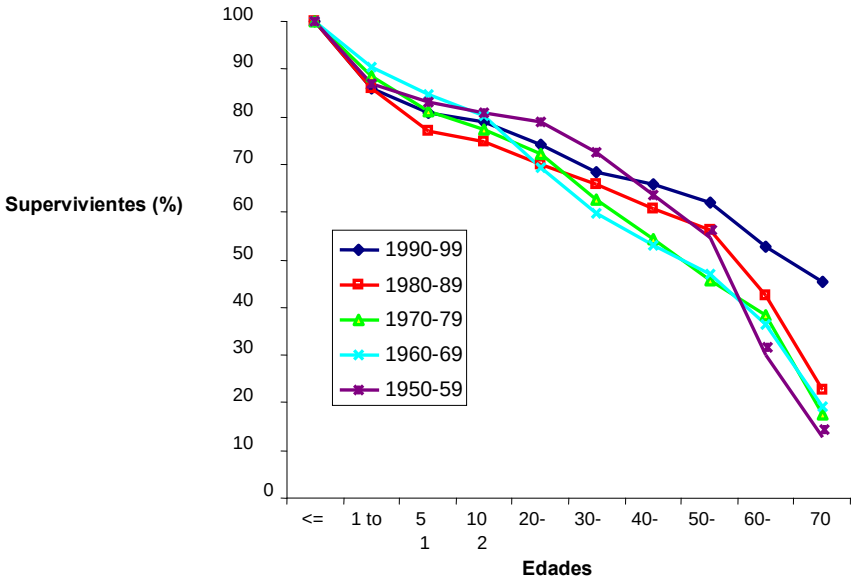
La figura 5, compara la tasa de mortalidad infantil entre los Tsimanes y el total de la población boliviana en el periodo de 1970-2000. Aunque la mortalidad infantil de los Tsimanes ha sido reducida en estos últimos años, probablemente por la introducción de asistencia médica de nuestro equipo, esta sigue siendo más elevada que la del resto de la población boliviana.

Fig. 5. **Índice de Mortalidad de infantes, 1970+, n=1,684 nacimientos**



La figura 6, demuestra cambios ocurridos en las distintas décadas en la probabilidad de sobrevivir con el paso de los años. En general, se presenta una constante en la expectativa de vida por década para la mayor parte de los grupos estudiados salvo en los años '90 con la categoría de mayores de 50 años.

Fig. 6. Supervivencia por década



La figura 7, muestra una tabla con las causas de mortalidad en niños menores de 10 años basado en los síntomas descriptos por los familiares del fallecido. Aunque estos resultados no se han basado en un diagnostico medico nos da de igual manera una idea general de lo que esta ocurriendo con la mortalidad infantil. Esta dividida en tres categorías; niños menores de 1 año, de 1-5 años y de 5-10 años. Se ve claramente que la neumonía, influenza y enfermedades diarreicas agudas (EDA) son las principales causas de muerte en niños menores de 5 años. El sarampión y paperas son causas de mayor importancia en la mortalidad en niños de 5-10 años ya que no están muriendo de las otras causas respiratorias y gastrointestinales

.

Fig. 7 Causas de mortalidad de infantes y niños

N	346		134		54
Causa	<1		1 to 5		5 to 10
neumonía / influenza	0,17	diarrea	0,19	sarampión/paperas	0,24
desconocido	0,15	neumonía / influenza	0,14	desconocido	0,15
diarrea	0,15	sarampión/paperas	0,14	herida involuntaria	0,13
peri natal	0,12	desconocido	0,12	parasitosis	0,11
maltrato / abuso	0,09	herida involuntaria	0,10	diarrea	0,07
malnutrición/descuido	0,05	parasitosis	0,07	neumonía / influenza	0,07
herida involuntaria	0,05	tos ferina	0,06	apendicitis/obstrucción intestinal	0,06
fiebre	0,05	fiebre	0,05	tos ferina	0,04
tos ferina	0,05	malnutrición/descuido	0,02	anemia	0,04
sarampión/paperas	0,03	infección, otras	0,02	respiratoria crónica	0,04
SUM	0,90		0,93		0,94

La figura 8, explica las causas de mortalidad en adultos de edades avanzadas. En general, la mayor tasa de mortalidad esta causada por razones respiratorias.

Fig. 8. Causas de mortalidad en adultos

N	42		38		29
Causa	50-60		60-70		70+
desconocido	0,17	tuberculosis	0,18	vejez	0,28
saramp/paperas/rubeola	0,17	repiratorio cronico	0,13	tuberculosis	0,14
abuso	0,14	saramp/paperas/rubeola	0,11	desconocido	0,10
respiratorio cronico	0,12	desconocido	0,08	infeccion, otras	0,10
fiebre	0,10	herida involuntaria	0,08	herida involuntaria	0,07
meningitis	0,10	neumonia-influenza	0,08	neoplasma maligno	0,07
tuberculosis	0,07	fiebre	0,05	appendicitis/obstruc. intestinal	0,07
nefritis/riñon	0,02	neoplasma maligno	0,05	sarampion/paperas/rubeola	0,03
appendicitis/obstruc. intestinal	0,02	diarrea	0,05	lepra	0,03
higado	0,02	vejez	0,05	abuso	0,03
	0,93		0,87		0,93

Conclusiones

Los resultados de estudios médicos y demográficos preliminares denotan una alta incidencia de enfermedades infecciosas en el grupo Tsimane. De todas formas se ha notado un decaimiento de la curva de mortalidad en estos últimos años, especialmente en los infantes y adultos mayores. Estos cambios se deben en gran parte gracias a la introducción de medicina en las comunidades y al mayor acceso a la salud pública en San Borja. A pesar de este leve mejoramiento, las tasas de morbilidad y mortalidad siguen siendo mucho más altas que las del resto del país. Esto se debe principalmente a la falta de agua potable, letrinas, conocimiento de higiene y a la escasez de recursos económicos por parte del gobierno boliviano para ofrecer un programa de salud pública y atención medica apropiada a las necesidades de estas comunidades.

INFORME TRABAJO REALIZADO 2005-2009

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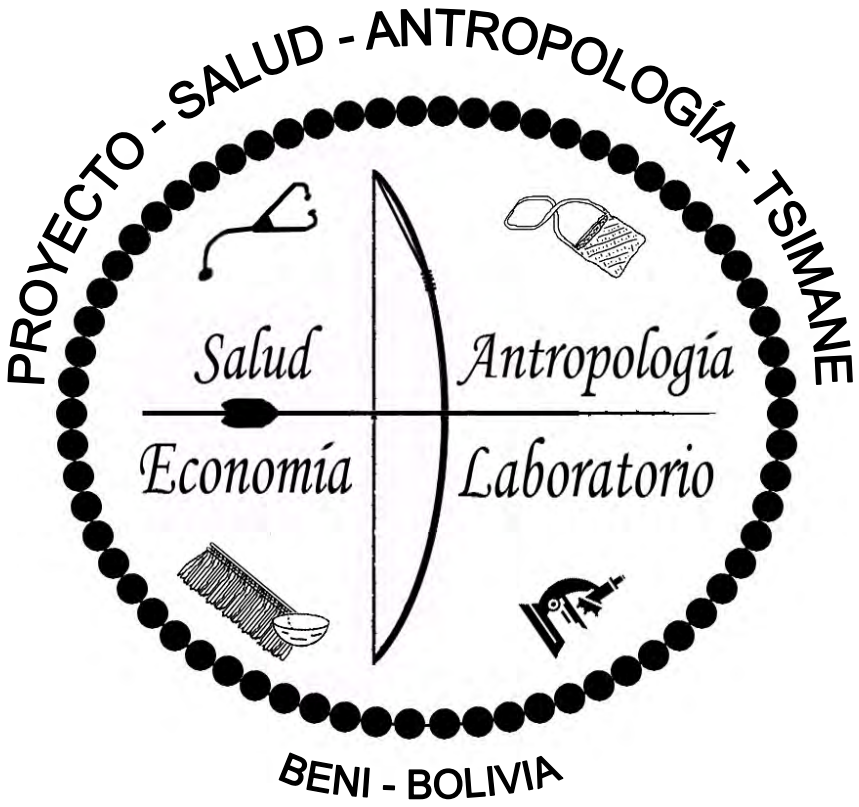

http://www.unm.edu/~tsimane

INTRODUCCIÓN

El proyecto de Investigación Salud y Antropología “Tsimané” es una iniciativa que nace de la carrera de Antropología de las universidades de Nuevo Mexico y Santa Barbara California en los Estados Unidos, como un intento de aprender sobre culturas indígenas que se mantienen conservadas y soportan los cambios de la modernidad. Desde el año 2002 hasta la fecha actual, muchos investigadores y profesionales han recolectado información sobre sus costumbres, estilo de vida, relaciones humanas y económicas;información que sentara un sólido precedente que describa la cultura Tsimane´ para conocimiento de las futuras generaciones y otros grupos del país que no los conocen.

Información demográfica también ha sido recolectada, lo que nos permite conocer el ritmo de crecimiento de la población, sus movimientos en la zona geográfica, los factores sociales y ambientales involucrados en las enfermedades que influyen más en su mortalidad, y los grandes cambios que se dan en estos años sobre su mortalidad.

Se reconoce que muy pocos Tsimane alcanzaban edades de 60 años o más, porque morían de muchas enfermedades; pero el mayor acceso a los servicios de salud, el mayor contacto con San Borja esta cambiando este proceso de envejecimiento y cada vez más gente alcanza los 60 años o más, pero con un costo, ya que enfermedades que antes no tenían y solo estaban en la gente de San Borja, también están comenzando a afectar a los Tsimanes; esto pudimos aprender gracias a los análisis de sangre, caca, orina, y corazón.

Toda esta rica información disponible de la etnia ha afectado el trato que se recibe de parte de las autoridades y los responsables de salud. El proyecto Tsimane ha censado al 90% de la población Tsimane, y ha impulsado acuerdos con la Alcaldía, el hospital San Borja, ONG´s para que tengan una participación activa en la atención de las necesidades de la etnia.

Gracias los acuerdos realizados con la Alcaldía de San Borja y el Hospital de San Borja. En el Hospital de San Borja se atienden de 3 a 5 pacientes por semana en los servicios de internación casi sin costo alguno para los pacientes.

Los casos de pacientes que requieren cirugías se han resuelto en gran parte gracias a acuerdos con la ONG Solidaridad Médica Canaria, con ellos se han realizado más de 170 operaciones, principalmente de hernias abdominales y enfermedades ginecológicas; con todos los gastos pagados para la etnia, incluyendo alimentación y alojamiento.

Nuestro equipo móvil en los 7 años atendió a más de 3500 pacientes al año, visitando con nuestra brigada médica a 26 comunidades, y ofreciendo servicios de asistencia primaria con medicación gratuita y laboratorio. Entre las actividades de la brigada médica móvil cabe destacar el comienzo de la búsqueda de Cancer cervicouterino entres las mujeres Tsimane, desde el 2008 encontramos 29 casos de mujeres con lesiones precancerosas(que se convertirán en cáncer con el tiempo) y dos casos de cáncer in situ, que al ser intervenidos oportunamente recuperan las opciones de supervivencia ante una enfermedad altamente mortal.

También en un convenio realizado con la ONG “Solidaridad” del Arzobispado de Cochabamba y la ONG Mano a Mano, se pudo realizar el traslado de 27 pacientes graves a Cochabamba con resultados alentadores que salvaron y devolvieron la calidad de vida a los pacientes.

Ahora, con la experiencia y la confianza ganada en las comunidades, además del aprecio que tenemos a la cultura y la gente de la etnia Tsimane´ es que decidimos iniciar una nueva fase para profundizar el estudio del proceso de envejecimiento en la etnia, estructurado sobre la base de un equipo medico y antropológico con su base en San Borja, que ofrece y realiza estudios más completos como ecografías, exámenes de laboratorioe incorpora en su estructura un sistema de coordinación con el hospital para la atención de pacientes más complicados.

Esta apuesta por mejorar la calidad de vida de los tismanes y aumentar el conocimiento de su cultura no seria posible sin el compromiso de sus autoridades, y la comunidad que facilitan nuestro trabajo; su tolerancia y paciencia para recibirnos cuando les pedimos de su tiempo es importante para conseguir nuestro resultados.

Pero también hemos tenido problemas con personas que a pesar de la ayuda brindada trata de desprestigiarnos y dificultar nuestro trabajo perjudicando los alcances tanto en investigación como atención médica para la gente.

Para esta nueva etapa nos definimos comprometidos con la gente y su cultura y esperamos de la misma forma su apoyo en las comunidades como de sus autoridades para que al final de la jornada tengamos unos resultados que nos alienten y enseñen más sobre la vida.

A continuación, se detalla un informe completo de los resultados con rigurosidad científica para los fines de los interesados.

Misión:

Comprender como las enfermedades, el estado nutricional y el comportamiento afectan la salud y proceso del envejecimiento en varias poblaciones del mundo, incluyendo indígenas de la cuenca Amazónica y ciudadanos de otros países

Metas del Proyecto:

1. Documentar las enfermedades y problemas que afligen los Tsimanes (infantes, niños, adultos y mayores; varones y mujeres) en lugares diferentes de su territorio
2. Hacer un estudio integrado de crecimiento, desarrollo, envejecimiento, producción, redes sociales, salud y la mortalidad con los Tsimane'
3. Examinar el efecto de integración, educación, y acceso al mercado sobre la salud y bienestar de los Tsimanes y comparar a los Tsimanes con otras poblaciones del mundo
4. Examinar relaciones entre la salud, flujo de recursos y redes sociales dentro y entre familias
5. Estimular investigaciones colaborativas sobre envejecimiento y desarrollo en lugares diferentes del mundo

Metas Operativas:

1. Proveer atención medica y mejorar las condiciones de vida de los indígenas de las tierras bajas de Bolivia

2. Facilitar la capacitación de responsables de salud en sus comunidades y la llegada de servicios de salud para poblaciones indígenas aisladas

MUESTREO

Desde el año 2002 al 2009 el Proyecto Salud y Antropología Tsimané ha trabajado en 26 comunidades, dando atención medica a cerca de 3, 900 personas(ver tabla). Nuestro equipo esta dividido en dos grupos:

Equipo móvil que consiste en 3 médicos, 2 bioquimicos con un laboratorio móvil, 5 asistentes tsimané, y 3 antropologos tsimané. Este equipo viaja a través de las comunidades recolectando datos sobre el estado de salud, el comportamiento con exámenes físicos, entrevistas, análisis de sangre, de orina y de heces además de la atención médica. Las visitas a las comunidades duran entre 2 días y 3 semanas dependiendo del tamaño de la comunidad.

Equipo Móvil visita cada comunidad aproximadamente una vez al año. Durante cada visita, los pacientes son vistos dos veces, en la primera reciben su atención y tratamiento, para la siguiente visita se les entrega los análisis de laboratorio además de realizar el seguimiento de la enfermedad y el tratamiento.

Equipo Fijo consiste normalmente en un grupo de estudiantes graduados del prof. Gurven de la universidad de Califormia y del profesor Kaplan de la universidad de Nuevo Mexico, también trabajan en este equipo varios antropologos Tsimane los cuales residen en las comunidades por períodos de hasta 6 meses a un año, recolectando información de mayor tiempo sobre salud, economía doméstica, y uso del tiempo.

TABLA 1. Muestra del Proyecto Salud y Antropología Tsimane'
Nota: * indica las actuales o anteriores comunidades "fijas")

Comunidad	Nº de habitantes
Anachere	72
Aperecito*	63
Boreyo	65
Cachuela	44
Campo Bello	205
Catumare	78
Cedral*	193
Chacal*	208
Cosincho*	230
Cuverene*	40
Donoy	29
Emeya	65
Fátima*	532
Jamanchi Uno*	125
La Cruz	362
Las Maras	34
Majal	97
Monte Rosa	96
Moseruna*	86
Munday*	73
Nuevo Mundo*	84
Puerto Trionfo	93
San Antonio	258
San Miguel	359
Tacuaral del Mato*	353
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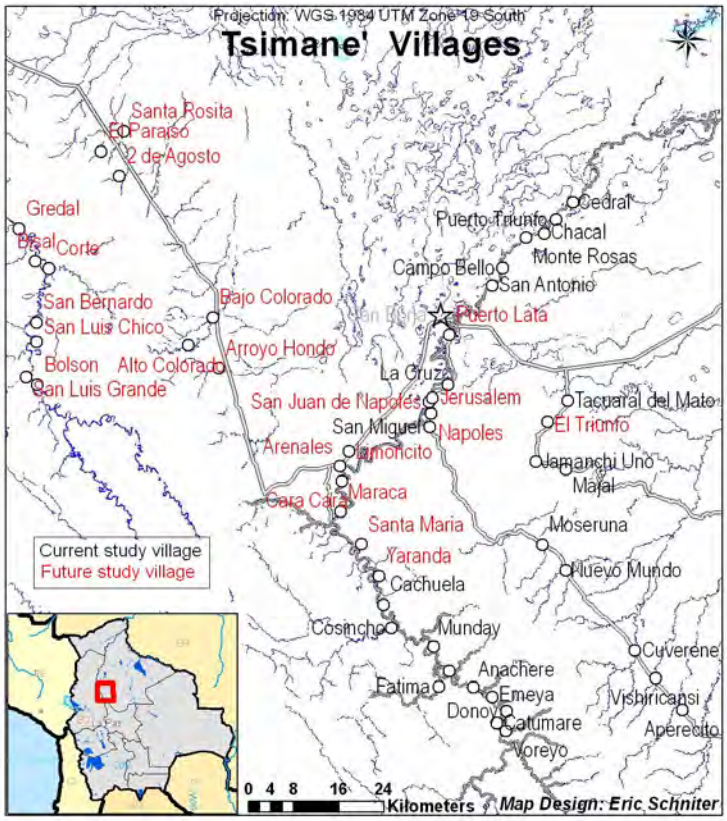


Asistencia Médica

El proyecto Tsimané a lo largo de su historia a tratado de mejorar el apoyo en salud a la gente enferma que participa en nuestro estudio, inicialmente solo se contaba con atención primaria en el campo limitada al manejo de infecciones y tratamientos paliativos para dolencias crónicas, ocasionalmente cuando los pacientes eran de gravedad se los trasladaba hasta el hospital de segundo nivel en San Borja; ya en el año 2007 a través de acuerdos con la ONG Solidaridad Médica Canaria de San Ignacio de Moxos, la organización de Solidaridad en Cochabamba y la organización Mano a Mano pudimos mejorar las opciones de tratamiento para algunos enfermos. En San Ignacio de Moxos con la ONG solidaridad Médica Canario se logro atender en los 3 años 167 pacientes, de los cuales 165 casos eran quirúrgicos, esencialmente problemas de hernias y prolapsos en las mujeres; enfermedades que eran discapacitantes y que aquejaban a los pacientes por muchos años.
El año 2007 se inicio el tamizaje de Cancer Cervicouterino con una cobertura de 450 mujeres muestreadas, de las cuales 29 presentaron lesiones premalignas y dos tenían cáncer. Estatarea de enorme importancia por la cantidad de mujeres Tsimane´que mueren de cáncer de cérvix, fue particularmente complicada dada la cerrada cultura de la gente a ese tipo de procedimientos, pero con logros incuestionables como fruto de la insistencia y paciencia del personal médico que nos apoya.
Con la ONG Solidaridad y Mano a Mano se tuvo algunos éxitos importantes como la recuperación de pacientes graves con accidentes como heridas de bala y fracturas graves, que en su caso, por la forma de vida que llevan es discapacitante. En total se enviaron 28 pacientes a Cochabamba, que es el nivel más especializado de atención y era donde trasladamos a los pacientes realmente graves, es por esa razón también que perdimos algunos casos que eran demasiado avanzados como ser los canceres terminales, insuficiencias cardíacas y renales, que aún con el mejor intento no pudimos salvarlos.

Colaboración con Instituciones Bolivianas

Gran Consejo Tsimane´: Jorge Añez Claros, Presidente (Convenio)

Hospital San Borja: Dr. Javier Jiménez, Director (Convenio)

O.N.G. “Solidaridad Médica Canaria”: Dr. José Rivera Director

Fundación “Solidaridad” Arzobispado Cochabamba: Hna. Adelina Gurpegui G. Directora

Universidad Mayor de San Simón (Convenio)

Universidad Autónoma Gabriel René Moreno (Convenio)

Centro Nacional de Enfermedades Tropicales (CENETROP) (Convenio)

Instituto Nacional de Laboratorios de Salud (INLASA) (Convenio)

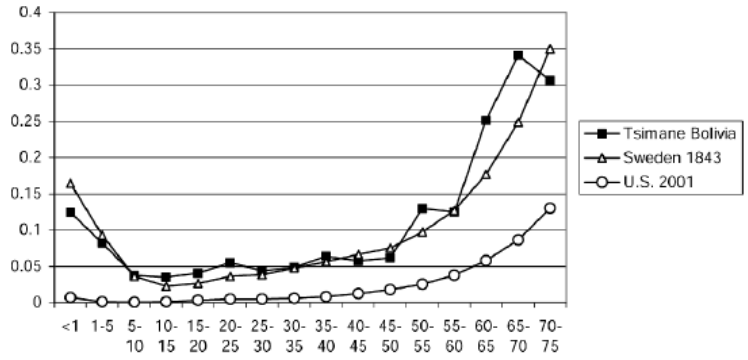
RESULTADOS

Demografía:

Mortalidad pasada y causas de muerte

Las entrevistas realizadas con los 1,097 individuos mayores de 16 años, abarcan historias de embarazos, historias maritales y patrones de residencia. Las historias de embarazos de los familiares y padres (vivos o muertos) fueron incluidas también en las entrevistas. Estas entrevistas demográficas nos sirven para averiguar la edad y las causas de muertes pasadas entre los Tsimanes.

Antes de 1990, el promedio de años (expectancia de vida al nacer) de los indigenas Tsimané era de 43 años. En el período de 1990 al 2002 aumento a 53 años, esto significa que las condiciones de vida han cambiado. Las comunidades más alejadas del pueblo muestran de 2 a 4 veces más alta mortalidad que las comunidades cercanas al pueblo. Más de la mitad de las muertes eran debidas a enfermedades infecciosas, especialmente enfermedades respiratorias y gastrointestinales. Los accidentes y violencia producen el 25% de todas las muertes.



Desde 1990, se produjo una gran reducción en las tasas de mortalidad para los adultos pero no de la misma forma para los niños.Nosotros pensamos que esas diferencias se deben a las diferencias en el acceso a los servicios médicos para los adultos en comparación con los niños, ya que ellos tienen mayores opciones para buscar tratamiento que los niños que dependen de sus padres. Las creencias culturales de los Tsimané sobre las enfermedades y la muerte influyen en la búsqueda de atención médica. La mayoría de las comunidades Tsimane todavía carecen de servicios básicos, como acceso a agua potable, higiene, que son importantes para mejorar la salud del niño.

Fertilidad

La etnia Tsimané tiene alta fertilidad(Tasa Fertilidad total=9) y alta mortalidad en su población, donde 51% son jóvenes menores de 15 años, 35% están entre 15 y 40 años, 9% entre 40 y 60 años, y 4% corresponde a personas de 60 años o más. La tasa de fertilidad ha cambiado poco desde 1950 en todas las áreas del territorio Tsimane. La fertilidad es menor en áreas del bosque(TFR=8) y más alta cerca a San Borja(TFR=9,6). No ha habido disminución de la fertilidad características de una transición demográfica; aunque los cambios se dan en un ambiente de comunidades más aculturadas. La razón de sexos se ha desviado hacia los varones en la mayoría de las edades, excepto entre los 10 y 20 años, donde se desvía hacia las mujeres.

Salud

Los exámenesmédicos y físicos de nuestros médicos y laboratorio durante las visitas a las comunidades del equipo móvil nos dan información sobre diagnósticos actuales, enfermedades previas y discapacidad. Los Tsimané muestran altas tasas de infecciones, especialmente parasitosis. Durante la visita médica, más del 66% de los Tsimanes tuvo al menos un parasito, el más común es la uncinaria(48%), Ascaris (21%) y Trichuris(4%). Las infecciones parasitarias por protozoos son también comunes, especialmente Giardia Lamblia(19%) y Ameba Histolitica(5%). Cerca del 50% de los hombres y mujeres tenía anemia, con niños y adolescentes mostrando el riesgo más alto (56% niñas, 63% niños). Los individuos con uncinaria eran al menos dos veces más afectados por anemia. Más del 90% de los individuos se quejaba de alguna enfermedad durante nuestra visita. Las enfermedades gastrointestinales y respiratorias eran el diagnóstico más frecuente: 30-40% de los infantes y niños pequeños tenían alguna de estas, 30-40% de los adultos con enfermedades gastrointestinales y 20% con enfermedades respiratorias. Además, de que frecuentemente esas enfermedades venían juntas en una persona.

La probabilidad de ser diagnosticado con enfermedades respiratorias, gastrointestinales u otras se correlacionaba significativamente con tener otra en todas las edades.

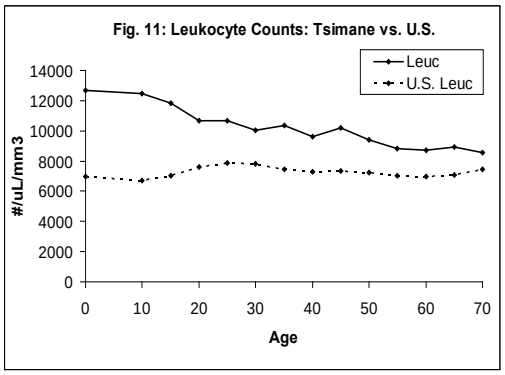
Análisis de sangre

Los análisis de sangre mostraron altos niveles de inflamación entre los Tsimane comparados con otras poblaciones. Esto sugiere que sus defensas (sistema inmune) gastan mucha energía defendiéndose de las constantes infecciones. Una proteína llamada PCR, se encontró mucho más alto que en otras poblaciones americanas. Las estimaciones del tiempo de vida con niveles altos de CRP para los Tsimane comparados con los Americanos, indican que para la edad de 34 años han pasado 15 años o 42% de su vida con niveles altos de CRP; mientras que en Estados Unidos el número de años se reduce a 6.8 años o solo 19% de su vida. Esto sugiere una larga exposición a los niveles de inflamación entre los Tsimané comparado con los norteamericanos u otras poblaciones. De hecho, los niveles de CRP son más altos en los Tsimane que en otras poblaciones muestreadas como Italia, México, Nativos americanos en USA y las Filipinas. Los Tsimané que viven más alejados del pueblo tienen más altos niveles de CRP que los que viven cerca, sugiriendo más alta exposición a enfermedades infecciosas en comunidades alejadas.

Otros análisis de sangre también indican altos niveles de actividad inmune de defensa a través de la vida. Los altos niveles de leucocitos son más frecuentes en los Tsimane que en otros americanos en todas las edades. En promedio, 20% de las células de defensa son eosinofilos, los cuales se presentan más en infecciones parasitarias, que normalmente no superan el 5%.

Los altos recuentos de glóbulos blancos disminuyen con la edad, probablemente por un rápido envejecimiento del sistema de defensa a pesar de tener infecciones menos frecuentes.

Otros indicadores de infecciones también son muy altos: el promedio de IgG es 1,971 mg/dL y IgE es10,719 IU/ml. Los rangos normales del adulto para poblaciones occidentales son para la IgG: 850-1,600 mg/dL ypara IgE: <100 IU/mL. IgE es de especial interes porque los niveles promedio son 100 veces más alto que en poblaciones occidentales, y esto se asocial a infecciones parasitarias.



Enfermedades Cardiovasculares

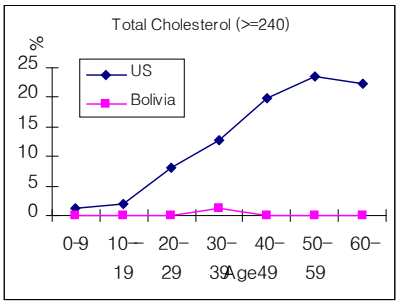
Los indicadores de riesgo para enfermedad cardiovascular entre los Tsimane difieren de los encontrados en otras poblaciones. La obesidad, el colesterol elevado, la presión arterial elevada son todos relacionados con enfermedad cardiovascular entre adultos de Norte América y otros países similares.

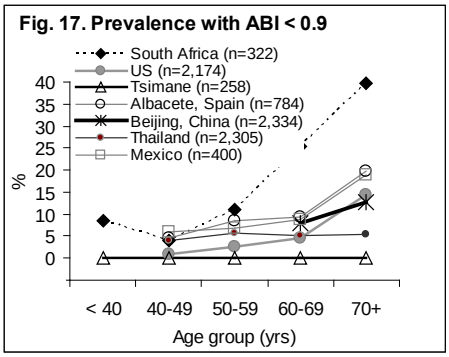
En los Tsimané menos del 2% son obesos (Indice de Masa Corporal >30), el colesterol total son menores que en los americanos.Nuestras investigaciones de enfermedad arterial periférica, que es un precursor de la aterosclerosis medido por el índice ABI indica que esta enfermedad esta ausente en los adultos Tsimane, no se encontró una persona en nuestra revisión de 258 adultosmayores de 40 años que mostrara evidencia de esta enfermedad (ABI<0.9).

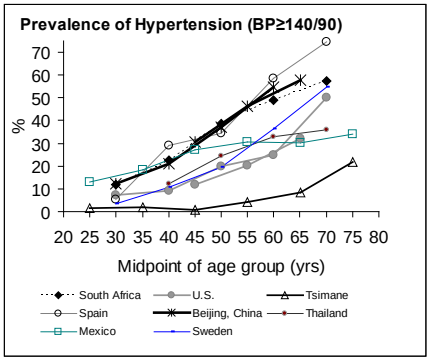
La enfermedad arterial periférica normalmente aumenta con la edad en todas las poblaciones, pero no entre los Tsimanes. La hipertensión es también muy baja entre los Tsimanes (menor a 5% de todos los adultos).

El índice de masa corporal y el colesterol bajo pueden proteger de enfermedades cardiovasculares por una reducción de la inflamación y mejoramiento del metabolismo. Nosotros pensamos que los bajos porcentajes de hipertensión, los altos niveles de actividad física, son responsables de los bajos niveles de enfermedad cardiovascular en los Tsimane.

Los varones y mujeres Tsimane de 40 a 49 años gastan en promedio 850 y 450 kcals/díamás, respectivamente en actividades físicas comparados con los americanos.En Estados Unidos, 66% de los adultos mayores a 18 años nunca realizan actividades físicas Fuertes que duren más de 10 minutos o más por semana, y solo 15% de los adultos realizan actividades físicas moderadas(trabajo y diversión combinados) por 30 minutos o más por día, En contraste, los hombres y mujeres tsimane gastan entre 4. 5 y 1.5 horas por día en estas actividades respectivamente.







Aunque esta es poca evidencia de enfermedades cardiovasculares en los Tsimanes, encontramos otros problemas de corazón. Nuestra muestra preliminar de electrocardiogramas en 357 adultos mayores de 40 años mostro daño auricular y ventricular con lesiones en cerca de 2% de los individuos. Esto puede indicar una historia de enfermedades del corazón debido a infecciones que aumenta los niveles de inflamación.

Enfermedades Renales

Encontramos también evidencia de que gran proporción de la población de la etnia Tsimanñe sufre de una enfermedad renal llamada cistinuria. Esta enfermedad es responsable de la formación de cálculos renales. Aunque la enfermedad es extremadamente rara en otras poblaciones(frecuencia de 1 en 2,500 a 1 en 10,000), los pocos matrimonios y reproducción con otros grupos étnicos aumento la probabilidad de tener esta enfermedad que esta en los genes de la gente de la etnia Tsimane´.

Papanicolao

Desde el año 2007 hasta el 2009 se hizo examen de Papanicolao para detección precoz de Cancer Cervicouterino a 457 pacientes, en colaboración conjunta con el Insituto Nacional de Laboratorios Salud (INLASA La Paz), donde encontramos 29 casos con lesiones premalignas, de las cuales 2 casos resultaron ser cáncer in situ. De los 29 casos, 14 correspondian a mujeres menores de 40 años, con un patrón de distribución similar entre regiones cercanas y alejadas de SB. De esas 29 mujeres por un acuerdo con la ONG Solidaridad Médica Canaria se logro realizar conización terapéutica por el método de asa fría a 14 mujeres que accedieron y acudieron para la realización del procedimiento.

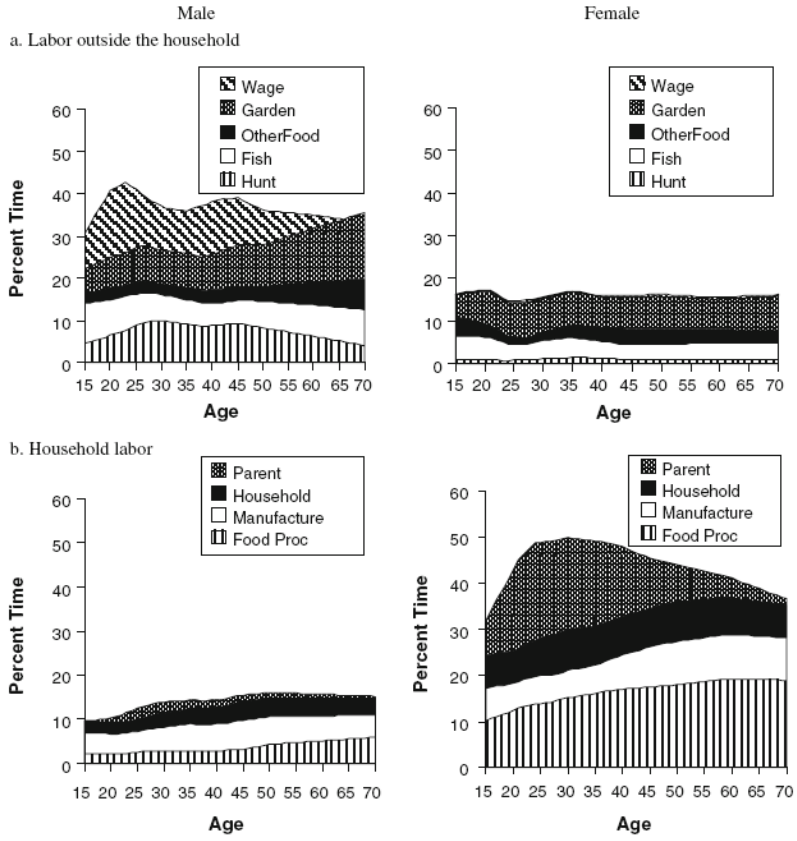
Habilidad Funcional

Desde 2005 hemos estudiado las condiciones físicas y el desempeño de los ancianos, como un intento de entender el envejecimiento entre los Tsimane. Hemos realizado una serie de entrevistas, tareas, y observaciones. Los análisis preliminares del estatus funcional de 260 adultos mayores a 40 años mostraron fragilidad aumentada y discapacidad importante a los 70 años. Más del 60% de los Tsimané mayores a 60 años se quejaron de perdida de la audición, más del 80% tenían problemas para ver a largas distancias, y más del 70% no podían derribar árboles grandes en sus chacos. Cerca del 50% de los hombres y 70% de las mujeres encima de los 70 años no podían caminar largas distancias, y se quejaron frecuentemente de dolor de articulaciones en sus piernas, espalda, y cadera. Más del 90% de los hombres mayores de 60 añosno podía llevar cargas pesadas una distancia de 50 metros. Más del 70% de los hombres no podía realizar cacerías largas a los 70 años. Los hombres se quejaron de sentirse demasiado cansados, dificultad paraver, perdida de audición y sentirse débiles. Vivir muchos años con esas discapacidades disminuye su calidad de vida y acelera el proceso de envejecimiento comparado con personas que viven en otros países. Por ejemplo, los Tsimane necesitan 91% más tiempo que los japoneses, y 29% más que los americanos en levantarse 5 veces consecutivasdespués de estar sentados, y son más lentos en caminar 3 metros de distancia.

Producción de comida y labores domésticas

Una combinación de observaciones del comportamiento y entrevistas mirando el uso del tiempo de la gente, producción de comida diaria, y la manera en que comparten la comida ha sido conducida en 8 comunidades desde que comenzó el proyecto. Estudiamos la división del trabajo entre esposos y otros familiares y miembros de la familia lejanos para ver como las necesidades diarias de comida son alcanzadas. Las mujeres gastan cerca de 2 horas por día en la producción de comida, y cerca de 5 horas por día en otras actividades de trabajo. Los hombres gastan 5 horas por día en producción de comida o trabajo asalariado, más del doble que las mujeres.

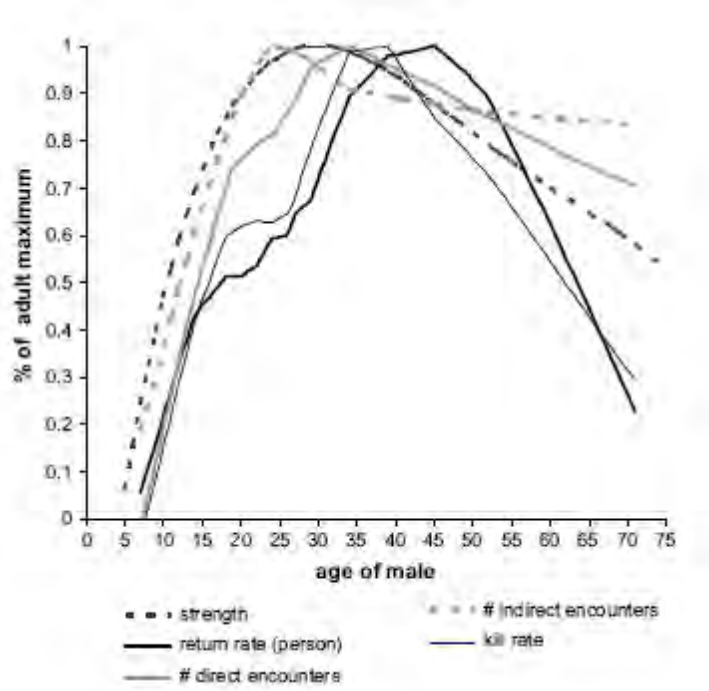
Sin embargo, los hombres gastan solo 1.5 horas por día en trabajo doméstico, menos de la mitad de las mujeres. Así que el tiempo total de trabajo es similar en hombres y mujeres. El tiempo total que un hombre y una mujer gasta en labores domesticas aumenta en edades tardías, con un gran aumento en procesamiento de la comida y manufactura. Los hombres las mujeres son productivas hasta los 60 años, con hombres ancianos que producen más calorías que los jóvenes menores de 20 años.



Cacería

Nosotros tambiénrealizamosestudios enfocados en el comportamiento en la cacería de los varones el 2002 y 2003. La máxima habilidad para cazar se alcanza a los 40 años, cerca de 20 años después de alcanzar el máximo de l tamaño y la fuerza corporal, indicando que existe todavía un largo período necesario de aprendizaje para ser un buen cazador. Dos componentes de la habilidad de cazar, indicadores indirectos (ej. Olores, sonidos, huellas) y tiro a blancos fijos, parecen mejorar al cazador, comparados con ser más grande y fuerte, que son además los componentes más difíciles de alcanzar, el encuentro directo con importantes ítems y la exitosa captura requieren bastante habilidad. Estas habilidades pueden tener 15 a 20 años adicionales para alcanzarse más que alcanzar el tamaño del cuerpo de un adulto. Los mejores cazadores tienen más alto estatus, reciben más apoyo social durante los conflictos, se cazan antes y tienen mayor supervivencia que los cazadores menos hábiles. Para hombres y mujeres, la habilidad de producir es altamente valorada por los esposos.

Figura. Perfil de esfuerzo, encuentros directos e indirectos con animales durante la cacería, rendimiento (calorías ganado por cada hora de trabajo) de cacería – en hombres a través de la vida



Estatus Social

También estudiamos los determinantes del estatus social y el prestigio entre los hombres Tsimane, Encontramos que el tamaño físico predice mejor la habilidad para pelear(evaluado por otros), mientras que el apoyo social predice mejor la percepción de la influencia y el respeto de los otros. Hay poca evidencia la aculturación, pero influye. Los hombres que hablan español y que son más educados tienen mayor probabilidad de ser vistos como influyentes(aunque no necesariamente reciben más respeto). Ser conocido como hábil productor de comida es asociado con más respeto aunque no más influyente.

Conocimiento cultural y experticia

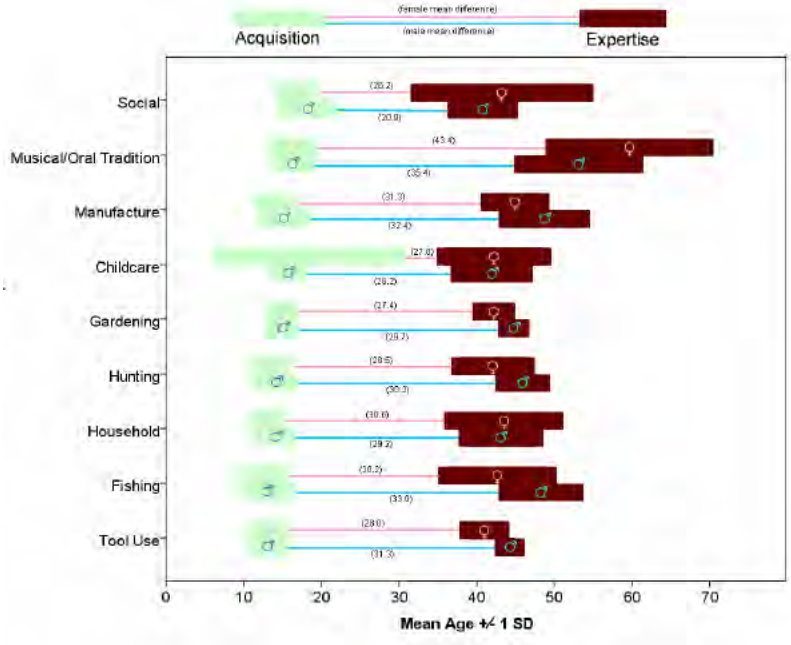
La figura siguiente muestra el promedio de edad que los tsimanes hombres y mujeres en que llegan a ser eficiente en diferentes habilidades que implican el repertorio cultural Tsimane. Esto también muestra el promedio de edad en que los Tsimanes se consideran expertos en varias categorías de habilidades. Estas categorías incluyen manufactura de herramientas, cuidado de los

niños, agricultura, cacería, pesca y otros. Los ancianos son frecuentemente considerados expertos en varias habilidades. El promedio de edad en que son llamados expertos en varias habilidades, basados en una muestra de 150 entrevistas con adultos de 3 comunidades, es mayor de 40 años.

Los expertos en conocimiento tradicional de plantas medicinales, frutas, y pescados, asi como, habilidades como tocar música, cantar cantos tradicionales y contar antiguas historias son todos por encima de 45 años.

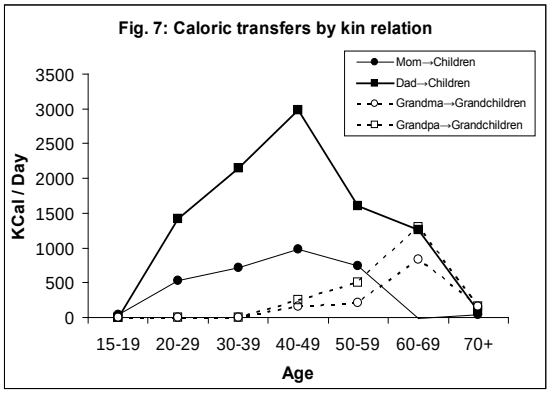
También encontramos que los padres contaron 50-60% de las personas llamadas influyentes por ayudar a enseñar una variedad de habilidades. Los abuelos contaron como 5-10%, y los tíos y tías, 10% de esos llamados como mentores influyentes o motivadores del aprendizaje. Estos resultados muestran que los parientes mayores tienen impacto sustancial en el desarrollo de habilidades cruciales que incluye el repertorio Tsimane.

Figura: Promedio de edad en que tsimanes hombres y mujeres alcanzan la eficiencia en la realización de diferentes habilidades



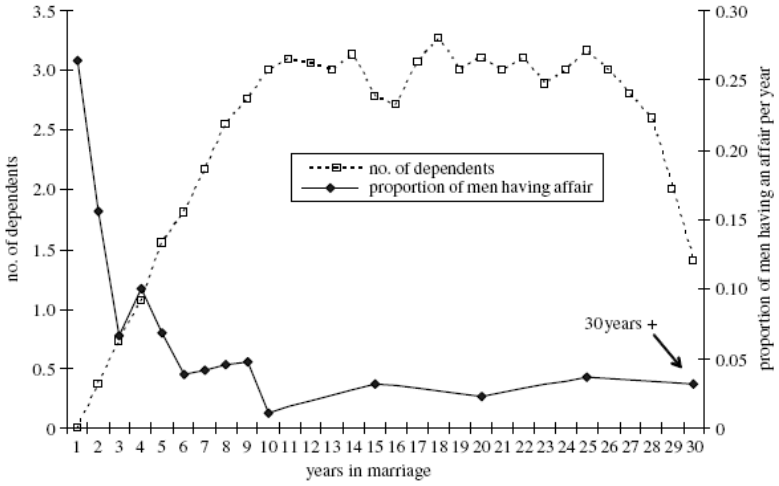
Compartir comida

Para la edad de máxima producción, hombres y mujeres comparten 50% de su producción con los niños. Para ambos, sin embargo, la producción disminuye entre los 60 y 70 años. Después del pico de producción la proporción de calorías dirigidas a los niños baja y más es dirigido a los nietos. Para los 70 años, los adultos no logran producir más de lo que consumen. Aunque los ancianos adultos no producen mucho, no son un problema para su familia



Matrimonio y emparejamiento

Analizamos la motivación tras el cuidado de los niños en los varones. Algunos piensan que los hombres cuidan a los niños para mejor su bienestar, otra idea es que los hombres cuidad a sus hijos para impresionar a su esposa y continúe reproduciéndose con ella en su matrimonio. Nuestros resultados muestran que los hombres generalmente ofrecen cuidado a los niños para darles bienestar a sus hijos y n para mostrarlo a sus mujeres. Por ejemplo, el hombre provee más cuidado a sus hijos cuando la mujer esta involucrada en el trabajo. También encontramos que los hombres eran menos probables de tener relaciones sexuales extra maritales como sus esposas ancianas y producir más hijos. Juntos, estos resultados respaldan la idea de que el objetivo del hombre en su compromiso familiar es para mejorar la calidad de vida más que perseguir sus propios intereses.



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