

Human Rights, Biomedical Science, and Infectious Diseases Among South American Indigenous Groups*

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*We dedicate this chapter
to Manuel Bepurangi
(1947–2003, Chupa Pou,
Canindeyú, Paraguay).

Key Words

South America, indigenous peoples, global health initiatives, prevalence rates, hepatitis, HTLV, parasites

Abstract

Despite the efforts of international health agencies to reduce global health inequalities, indigenous populations around the world remain largely unaffected by such initiatives. This chapter reviews the biomedical literature indexed by the PubMed database published between 1963 and 2003 on South American indigenous populations, a total of 1864 studies that include 63,563 study participants. Some language family groupings are better represented than are others, and lowland groups are better represented than are highland groups. Very few studies focus on major health threats (e.g., tuberculosis, influenza), public health interventions, or mestizo-indigenous epidemiological comparisons. The prevalence rates of three frequently studied infections—parasitism, human T-cell lymphotropic viral infection (HTLV), and hepatitis—are extraordinarily high, but these facts have been overlooked by national and international health agencies. This review underscores the urgent need for interventions based on known disease prevalence rates to reduce the burden of infectious diseases in indigenous communities.

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The International Decade of the World's Indigenous People (1995–2004) was proclaimed by the General Assembly in its resolution 48/163 of 21 December 1993 with the main objective of strengthening international cooperation for the solution of problems faced by indigenous people in such areas as human rights, the environment, development, education, and health. (United Nations 1995)

INTRODUCTION

High rates of mortality and poor health among South American native populations during and since conquest have been documented in many books and articles (Am. Friends Brazil 1974, Arens 1976, Black 2004, Bodard 1974, Brooks 1972, Coimbra & Santos 2004, Cook 1981, Davis 1977, Dostal 1972, Goodland & Irwin 1973, Gross 1973, Hames & Kuzara 2004, Hemming 1978, Hurtado & Salzano 2004, Lewis 1974, Hill & Hurtado 1996, Ribeiro 1967). Ribeiro reports that 87 out of 230 native groups in Brazil went extinct between 1900 and 1957, and studies estimate that the current native population in Brazil is only 5% of its estimated size in the 1500s (Ribeiro 1967). This dismal picture did not end with the period of conquest. Indigenous groups of South America today continue

to be vulnerable to all sorts of diseases. In the 1950s, groups like the Southern Kayapo lost 99% of their original population in 50 years. And, in the 1950s and 1970s, some Xikrin and Yanomamo communities declined in numbers by more than 20% within 10–15 years (Hurtado & Salzano 2004 and references therein). Equally baffling is the finding that in the 1990s the infant mortality rate among the Xavante was three times higher than among other nonnative Brazilians and that life expectancy at birth in 2000 was frequently 20+ years lower among indigenous groups when compared with their nonindigenous counterparts in most countries of South America. In fact, the life expectancy of indigenous peoples in Brazil and Venezuela is lower than that for the United States population in 1900 and lower than in Sierra Leone in 2000, which has the lowest reported national life expectancy in the world today (Hurtado & Salzano 2004 and references therein). What are international agencies doing to help ameliorate the large discrepancy between the health of indigenous peoples and those of other populations? And, what should biomedical scientists contribute to this process?

The International Decade of the World's Indigenous People declared by the United Nations in 1995 has ended with little evidence that the international community is prepared to solve the health problems of indigenous peoples of South America (Ring & Brown 2002). Although health is mentioned as one of the areas of main concern, activities specifically designed to protect indigenous health rights were not an intrinsic part of the United Nations' International Decade's plans of action for 1995–2004 (United Nations 2004).

A second important initiative, the Pan American Health Organization's Health of Indigenous Peoples (PAHIP) program, ended its first decade in 2003 and focused entirely on the health of indigenous peoples in the Americas (Pan Am. Health Organ. 1993). In 1993, the Pan American Health Organization drafted the first Health of Indigenous Peoples resolution in response to testimonies

presented by representatives of indigenous groups at the Working Meeting on Indigenous Peoples and Health held in Winnipeg, Canada, in April of that year. The first item on the resolution states that “the living and health conditions. . .of indigenous persons in the Region of the Americas are deficient, as reflected in excess mortality due to avoidable causes [e.g., infectious diseases] and in reduced life expectancy at birth, which demonstrates the persistence and even the aggravation of inequalities among indigenous peoples in comparison with other homologous social groups” (Pan Am. Health Organ. 1993).

Indeed, rights to health and to the benefits of scientific progress are rarely realized in indigenous communities of South America. More specifically, most indigenous peoples of South America have been denied the right to benefit from the scientific progress that allows societies to create conditions conducive to the attainment of a highest standard of physical and mental health (United Nations Popul. Fund 1994).

Since the early 1900s, health interventions that have had the greatest impact on the attainment of healthy states throughout the life span have been those that successfully eradicate parasites and pathogens that cause infectious diseases (Folch et al. 2003, Turkington 2003). Such interventions are not equitably present in all human populations today, allowing pathogens and parasites, as agents of natural selection, to continue to influence human biology in devastating ways. One of the main objectives of public health is to prevent pathogens from having such influence by monitoring the number of infected cases and intervening before one or more pathogens or parasites invade too many hosts. Consequently, a prevalence or frequency rate of 1 infected person per 100 individuals, or 1%, is cause for great concern and justification for the mobilization of public health resources (Daly & Gani 1999).

The protection of populations from infectious pathogens and parasites requires close collaboration between scientists who under-

stand the biology of pathogens and hosts and policy makers who commit sufficient public resources to contain or eradicate infectious pathogens. In the public health sciences, this approach is called evidence-based public health. Evidence-based public health is defined as “a public health endeavor in which there is an informed, explicit and judicious use of evidence that has been derived from any variety of science and social science research and evaluation methods” (Sackett et al. 1996). Such an approach is sorely lacking in programs that provide, or that should but do not provide, services to indigenous communities of South America. But when, how, and who should take on the responsibility? And what should be the role of biomedical and social scientists who know South American indigenous communities better than do the vast majority of those practitioners who implement indigenous health policy at the international, national, and regional levels?

Scientists could take three straightforward steps in their work among indigenous communities, and these steps require determination, persistence, and cooperation: (a) identify the most pressing health problems that indigenous communities face; (b) gather information on solutions to those problems; and (c) implement solutions in partnership with the governments, agencies, and community organizations that are in charge of public health programs in indigenous populations.

The main objective of this chapter is to address the first step by reviewing biomedical studies published from 1963 to 2003 of South American indigenous groups. This information was obtained using the PubMed search engine (Natl. Libr. Med. 2004). We characterize in epidemiological terms the biomedical literature on indigenous health by establishing (a) the extent to which the information is representative of all linguistic family groupings, geographic regions, and health conditions; and (b) whether the published studies include adequate comparative information on the health of nonindigenous neighbors. After identifying potential gaps and biases in the

Evidence-based public health: public health interventions that use evidence derived from scientific and evaluation methods

Prevalence rate:

the number of persons who are diagnosed with a health condition divided by the total number of individuals sampled in the study and multiplied by 100

HTLV or human T-cell

lymphotropic

viruses: HTLV I causes adult T-cell leukemia; HTLV I and II cause inflammation of nervous tissue in the spinal cord, eyes, joints, muscles, lungs and skin

Hepatitis:

inflammation of the liver when infected with one of five viruses—A, B, C, D, and E

HTLV: human T-cell lymphotropic viral infection

PAHO: Pan American Health Organization

literature, we summarize the population-based prevalence rate data on infectious diseases that occur in South American indigenous populations and that were the three most frequently studied between 1963 and 2003: (a) intestinal parasitism, (b) human T-cell lymphotropic viral (HTLV) infection, and (c) hepatitis infection.

The magnitude and the distribution of the frequency of indigenous persons infected with these pathogens lead us to conclude that, in spite of a rather unsystematic approach to the study of indigenous health, research to date clearly shows that a large percentage of indigenous groups are infected simultaneously with multiple pathogens and that the rates of infection are exceedingly high. Most of the rates in our review far exceed the 1% level that justifiably leads to press releases and the mobilization of resources for public health programs in the First World (Voelker 2001). And yet, to our knowledge, parasite, HTLV, and hepatitis infection rates ranging as high as 100% of indigenous adults or children sampled have never elicited such a response from the international public health community. Instead, this information has been accessible only to academics for the past four decades, and unintentionally, but nevertheless, hidden from the indigenous organizations and the regional, national, and international agencies whose charge it is to provide protection.

INDIGENOUS HEALTH

The future of an effective global approach to improvements in health among South American indigenous peoples lies in the hands of the Pan American Health Organization. However, the need for health initiatives specific to indigenous peoples of the Americas was not recognized internationally until 1993 when the Directing Council of the Pan American Health Organization (PAHO) passed Resolution V—Health of Indigenous Peoples. The resolution clearly identifies the role of infectious diseases as a major threat to the well-being of indigenous groups and concludes that

the disease profile that characterizes the indigenous peoples of the region features many of the same conditions that plague other socioeconomically disadvantaged groups. The resolution also states

[v]iral diseases (influenza, measles, dengue, poliomyelitis, arboviral respiratory diseases, hepatitis B, etc.) frequently explode into epidemics, particularly among groups with low levels of immunity. The prevalence of diseases endemic to tropical and subtropical areas (e.g., leishmaniasis, onchocerciasis, cysticercosis, Chagas' disease, etc.) remains high, and especially affects those human settlements where indigenous people are a majority. Other communicable diseases such as tuberculosis and malaria are on the rise again. Primary health care workers frequently report high incidence rates and lethality of cholera in indigenous populations, as well as considerable increase in the occurrence of sexually transmitted disease. The spread of AIDS poses an added and very grave risk for the indigenous people who live in areas with high rates of HIV infection. (PAHO 1993)

The resolution also identifies ecological complexities that programs must consider to be effective. Culturally, South American indigenous groups are numerous, fragmented into small communities, and very diverse. Epidemiologically, they are unable to produce the "appropriate" immunological response or to "make the necessary sociocultural adjustment" (PAHO 1993) when faced with pathogenic disease. Consequently, they are extremely vulnerable to infectious diseases because they are generally at the very fringes of outreach programs. Indeed, even those programs that do extend into indigenous areas may fail because racist attitudes among health care providers greatly limit access to services and because the programs are designed with the incorrect assumption that human groups are culturally and biologically homogeneous.

If, as PAHO's resolution suggests, control of infectious diseases and their effects on the biology of indigenous groups should be one of the most pressing public health objectives of PAHO's member states, the actions taken by PAHO officials were not planned with this goal in mind. Up to 1998, control of infectious diseases is not mentioned in any of the areas in which progress was made (PAHO 2000): (a) Member states successfully designated individuals responsible for implementing Resolution V in their respective countries; (b) indigenous health units in the ministries of health were created in several countries; (c) a total of 41 manuscripts were produced, but not a single one was dedicated to the control of infectious diseases; and (d) a Web site with information on PAHIP-related activities was created (PAHO 1998).

In spite of a call for collaboration from scientists in Resolution V, the documents gathered during the first years of the initiative do not include publications on biomedical research among South American indigenous groups. Because Resolution V endorses an evidence-based approach for finding solutions to indigenous health problems, it would have been appropriate for PAHO officials to rely on at least the 1,399 articles that had been published on some aspect of indigenous health or biology by 1996 and which can be found through PubMed, as well as the many other articles and reports that PAHO officials have access to and which are not indexed by PubMed.

The Wrath of Infectious Diseases

The biomedical literature well establishes that the quality of life of humans is greatly impaired by infectious diseases. Infectious diseases drain hosts of important energy and nutrients, and weakened hosts in turn are unable to work as productively as are hosts free of disease. This synergistic relationship has been best studied in persons infested with macroparasites (Stephenson & Holland 1987). Ascariasis has been found to corre-

late with decreases in growth rate, nitrogen absorption and retention, fat absorption, D-xylose absorption, lactose intolerance, and structural abnormalities of the mucosa of the small intestines (Stephenson & Holland 1987). In a recent review of the literature published since 1975, the authors conclude that among *Ascaris*-infected children growth rates are slower than among other children (Hlaing 1993). Moreover, intestinal nematode parasites have deleterious effects on host nutritional status, and malnutrition in turn is a predisposing factor to intestinal nematodes. Patients can quickly recover their nutritional reserves after deworming treatment, but they can also very quickly lose them on reinfection. Similarly, individuals who suffer nutritional losses because of parasitic infection or for other reasons are in turn very susceptible to macroparasitic infection (Scrimshaw & Giovanni 1997). Some studies report more significant negative impacts of infection on nutrition than do others, but overall, it is clear that macroparasites drain their hosts of essential nutrients, diminish their ability to perform effectively, and thus, greatly impair their quality of life.

Macroparasitic infestation also promotes the dominance of immune cells—known as T-helper 2 or Th2—that specialize in macroparasitic threats. Th2 dominance implies that an individual produces fewer of the Th1 immune cells that specialize in fighting viral and bacterial infections. Recent work on the interplay of Th1 and Th2 cells suggests that the balance between these two types of cells in hosts is critical to understanding the variation in resistance to a wide range of intracellular infectious pathogens. In particular, Th2 dominance is associated with lower resistance to intracellular bacteria and viruses such as HTLV and hepatitis (Borkow et al. 2001). Consequently, individuals in communities with high worm burdens tend to be Th2 dominant, which dampens the Th1 response, and puts them at risk of bacterial and viral infections. A marker in the blood, known as immunoglobulin E (IgE), indicates Th2

T-helper 2 cell dominance: macroparasitic infestation promotes the dominance of T-helper 2 cells

Th2: T-helper 2

IgE:
immunoglobulin E

Developmental instability:
imprecise expression of developmental design in-utero and during infancy and childhood

dominance, and studies show that in some indigenous groups of South America IgE levels are some of the highest ever reported for healthy individuals who do not suffer from allergies or other autoimmune diseases (Hurtado et al. 2003, Kaplan et al. 1980, Kron et al. 2000, Larrick et al. 1983). Thus, indigenous peoples who are Th2 dominant are probably less immunologically able to fight these pathogens than are most peasant populations, who are Th1 dominant (Beyers et al. 1998, Brady et al. 1998, Johnson et al. 2000, Luty et al. 1999, Sam & Stevenson 1999), and they also have less energy to combat infectious pathogens because macroparasites drain hosts of important nutrients.

Macroparasites also put individuals at risk of developmental instability, and this is associated with poor physiological performance including cognitive function (Furrow et al. 1997 and review therein). Developmental instability is the imprecise expression of developmental design in utero and during infancy and childhood owing to parasites and other pathogens, mutations, toxins, and other stressors. All organisms are exposed to these stressors, and hence, none develop perfectly according to design. But those who experience greater negative exposure, or who have less ability to respond because of variation in genetic heterozygosity, will exhibit more instability. The primary measure of developmental imprecision used by biologists is fluctuating asymmetry or the absolute asymmetry in bilateral traits (symmetrical on average in the population) due to random errors in the development of the two sides of the body (e.g., see Gangestad & Thornhill 1999).

Parasites also exacerbate intergenerational cycles of growth failure through intrauterine growth retardation (Stephenson et al. 2000). It follows, then, that interventions that successfully reduce parasite loads in pregnant women and infants will reduce Th2 dominance, fluctuating asymmetry, and failure to thrive in childhood and later in life, thus thwarting the negative intergenerational transmission of poor health.

In conclusion, any investments by international agencies, governmental and non-governmental organizations, and communities made to improve the quality of life of indigenous peoples must target first the control of infectious diseases. Interventions that fail to do so will be much less effective because, simply put, to make significant improvements in all aspects of life—maternal and child health, parental care, social networks, subsistence work, learning, community work—human hosts need to be free of lifelong, chronic infectious disease loads.

DATA COMPILATION

Review of the literature involved downloading abstracts from PubMed search results and creating a spreadsheet with data on each abstract (“PubMed”), name of indigenous group, macro-family language affiliation and population size (coded from the SIL, Inc., “Ethnologue”), country and ecozone of study population, and prevalence rates of infectious diseases (“macroparasites,” “HTLV,” “hepatitis”). Data analysis was carried out with MINITAB (Minitab Inc.). The objectives of the data analyses were to determine (a) whether the published studies include adequate comparative information on the health of nonindigenous neighbors; (b) the extent to which the information is representative of all linguistic family groupings, geographic regions, health conditions, and areas of public health; and (c) whether differences in infection rates of macroparasites, HTLV, and hepatitis between South American indigenous populations are statistically significant.

Search Methods

First, we ran a search through the PubMed Mesh database (<http://www.pubmed.org>). The Mesh system extracts records by using terms that are manually assigned to every article published in journals indexed by PubMed. For example, if an article includes information on any South American indigenous

group, regardless of the term that the authors use to refer to that group, members of the PubMed staff assign to it the term South American Indians. The PubMed Mesh system is the only electronic search engine that works in this way. All other search engines rely on key words found in the title, abstract, and text of published papers. Thus, literature search problems can be avoided, including those introduced by the heterogeneity of terms used to refer to indigenous groups (linguistic affiliation, geographic location, the name of communities or autochthonous names or the names given to communities after contact, or general terms such as “indigenous” or “indigenous population,” or “ethnic or minority group”). The Mesh system greatly increases the probability that every article that has been published in medical, public health, clinical, and biological journals in the United States or overseas since 1963, the year of PubMed’s creation, was included in the search results.

The PubMed search through the Mesh system using the category “South American Indians” generated a total of 1,864 references published between September 1963 and December 2003—four decades. We then created a database (the PubMed database) in Microsoft Excel (Microsoft Corp.) with data fields for identification numbers for each abstract, the last name of the first author, the first author’s institutional affiliation and the institution’s location, the year of publication, the term given in the study to the indigenous population/s sampled, the disease, the health or biological indicator of interest, whether the study’s focus was health or human biology, whether the research was applied (i.e., description or evaluation of a health intervention) or basic research (i.e., description of a health outcome and/or examination of its causes), whether nonindigenous populations were sampled, and the major finding of the study. Multiple entries were made for articles that included two or more ethnic groups.

Of the initial 1864 studies extracted from the database, 221 were excluded from further

analyses, leaving a total of 1643. Items excluded were on topics such as travel accounts, behavior unrelated to health, prehistory, paleopathology, mythology, literacy, hunting, human locomotion, economic development, and cognitive tests.

A second database using Ethnologue (<http://www.ethnologue.com>, SIL Int.) was created (the Ethnologue database) that includes the autochthonous and other names used to refer to different ethnic groups of South America, the country or countries where their territories are located, their linguistic affiliation, and their geographic location (lowland and highland). These data allowed us to substitute a single primary ethnic denomination provided in the Ethnologue database for multiple terms used to refer to the same ethnic group by different authors (e.g., Cuiba is the primary denomination for Cuiva, Jiwi, Jigui, Chiricoa, Amaruwa, Amorua, Masiguare, Siripu, Yarahuuraxi-Capanapara, Mella, Ptamo, Sicuane, and Sicuari).

The PubMed database allowed us to identify the three health conditions with the highest numbers of publications during the past four decades in the biomedical literature on South American Indians: macroparasites, HTLV, and hepatitis. We then created additional databases specific to these three conditions with data fields on group name, prevalence rate (expressed as a percent), sample size, abstract identification number, first author’s last name, and year of publication. In this study, prevalence is calculated by dividing the number of persons diagnosed with a health condition by the total number of individuals sampled in the study multiplied by 100. Females and males participated in all studies, but only adults participated in some studies, and in others children participated as well.

Characteristics of the Data

Because decisions about what research questions to study and which indigenous populations to sample have been made by individual biological anthropologists or biomedical

scientists and funding agencies without a global research design for all indigenous groups of South America, it is important to determine whether much of what has been published about indigenous health comes from a few or many groups. Owing to the large number of indigenous communities in South America, for this initial analysis of the data published in the literature, we grouped communities according to their linguistic affiliation.

Linguistic family groupings. To this end we created three tables with data on linguistic family groupings and grouped the data further into lowland, highland, and lowland versus highland groups. “Lowland” refers to groups found in the inland and coastal lowlands. Each table lists the names of linguistic family groupings identified in the Ethnologue database, the population size of each linguistic family grouping obtained from the Ethnologue database, the number of studies generated by the PubMed database for each linguistic family grouping, the percentage of the total population size that the family grouping represents, the percentage of the total number of studies done on that linguistic fam-

ily grouping, the number of studies that we expect to have been done on the basis of population proportions, the additional number of studies that would have to be done to meet the expected, and the p-value for the Chi-Square statistic resulting from a comparison between the proportions of the actual and the expected number of studies. Large numbers of additional expected studies indicate that biomedical researchers should have done many more studies on that linguistic family grouping, and large negative numbers indicate that biomedical researchers did too many studies on that population, that is, on the basis of population proportion criteria. Numbers closer to zero indicate that groups were sampled as expected on the basis of population criteria.

In the lowlands, a large percentage of the linguistic family groupings have been sampled as expected from population proportions (see **Supplemental Table 1**. Follow the Supplemental Material link from the Annual Reviews home page at <http://www.annualreviews.org>). The differences between the proportions of actual and expected number of studies were not statistically significant for 23 out of 36 (64%) of the groupings. The remaining 36%, by comparison (that

Table 1 Comparison of expected versus actual number of studies conducted among indigenous groups of Highland South America from 1963–2003

Linguistic family (<i>n</i> = 38)	Population size ^a	Number of studies	Percent of population	Percent of studies	Number of expected studies ^b	Additional expected studies ^c	Chi-square p-value
Quechuan	8,889,298	95	76	33	218	123	0.000
Paezan	118,845	2	1	1	3	1	0.656
Uru-Chipaya	2008	3	0	1	0	−3	0.084
Barbacoan	30,000	21	0	7	1	−20	0.000
Chibchan	64,301	24	1	8	2	−22	0.000
Aymaran	2,136,219	86	18	30	52	−34	0.009
Araucanian	440,000	56	4	20	11	−45	0.000
Total	11,680,671	287	100	100	287		

^aBased on estimates found in the Ethnologue Web site (<http://www.ethnologue.org>).

^bNumber of expected studies is calculated by multiplying the proportion of expected studies (which here is measured as the percentage of the population divided by 100) times the total number of studies.

^cAdditional expected studies is calculated by subtracting the actual number of studies from the expected number of studies.

is, Arawakan, Jivaroan, Choco, Cahuapanan, Guahiban, Peba-Yaguan, Chibchan, Panoan, Barbacoan, Macro-Ge, Carib, Araucanian, and Yanoman), were subject to under- or oversampling, as indicated by statistically significant differences between the expected and actual proportions of studies (p-values in bold). An example of how we interpret these findings is that researchers would have had to conduct 107 studies more than were done from 1963 to 2003 among Arawakan communities, in addition to the actual 57 studies conducted, to meet the expectation set by the population proportion criteria. In contrast, researchers conducted an excess of 73 studies in Yanomam communities over the same time period and using the same criteria.

In the highlands (**Table 1**), a large percentage of the linguistic family groupings has not been sampled as expected from population proportions. The differences between the proportions of actual and expected number of studies were statistically significant for 5 out of 7 (71%) of the linguistic family groupings (the Quechuan, Barbacoan, Chibchan, Aymaran and Araucanian, p-values in bold). The remaining 29%, that is, two linguistic family groupings, were not subject to under- or oversampling, as indicated by the lack of statistically significant differences between the expected and actual proportions of studies. One example of how we interpret these findings is that researchers would have had to conduct 123 studies more than were

done from 1963 to 2003 among Quechuan communities, in addition to the actual 95 studies conducted, to meet the expectation set by the population proportion criteria. In contrast, researchers conducted an excess of 45 studies in Araucanian communities over the same time period and using the same criteria.

Finally, when we examine the data on the frequency of studies conducted according to geographical location lowland versus highland, we find that many more studies should have been done among the highland groups (816), and much fewer studies in the lowlands (-816), on the basis of expectations set by population proportions (**Table 2**), and the statistical differences between expected and actual proportions of studies are significant. This suggests that most of what we know about South American indigenous health stems from studies conducted among lowland groups.

In summary, during the past four decades, using the biomedical information published in the United States and abroad in journals indexed by PubMed, lowland groups have been more evenly sampled than have highland groups. In addition, the number of studies done on the indigenous population of the lowlands is greater than one would expect from population proportions and lower in highland indigenous populations. Thus, the published information is biased in favor of lowland groups.

Table 2 Comparison of expected versus actual number of studies conducted in Highland versus Lowland indigenous groups of South America from 1963 to 2003

Geographical location	Population size ^a	Number of studies	Percent of population	Percent of studies	Number of expected studies ^b	Additional expected studies ^c	Chi-square p-value
Highland	11,680,671	287	92	24	1103	816	0.000
Lowland	963,297	907	8	76	91	-816	0.000
Total	12,643,968	1194	100	100			

^aBased on estimates found in the Ethnologue Web site (<http://www.ethnologue.org>).

^bNumber of expected studies is calculated by multiplying the proportion of expected studies (which here is measured as the percentage of the population divided by 100) times the total number of studies.

^cAdditional expected studies is calculated by subtracting the actual number of studies from the expected number of studies.

Intestinal parasites:

Ascaris lumbricoides,
Necator Americanus,
Trichuris trichuria,
and *Strongyloides*
stercoralis are
pathogenic
nematodes

Indigenous versus nonindigenous comparisons. One important, although not exclusive, way to determine whether indigenous populations are at greater risk of health problems and are more severely affected than other ethnic groups during the past four decades would have been for investigators to include in their studies samples of control mestizo populations. But for the most part they did not, and the number of studies with a nonindigenous component was therefore very low in the PubMed database.

Of 1,643 studies, 50 (3%) included a comparison of data on indigenous versus nonindigenous populations. Of these, 0.1% of the studies ($n = 1$) were on environmental pollution, 0.4% ($n = 7$) were on anthropometry, 0.7% ($n = 12$) were on chronic diseases, 0.9% ($n = 15$) were on infectious diseases, and 0.9% ($n = 15$) were on genetics. This does not mean that the universe of publications is biased in favor of indigenous groups. One would have to compare the actual versus expected number of biomedical studies for indigenous versus homologous nonindigenous groups during the same time period to determine if such bias is present in the biomedical literature. It does tell us that the inclusion of the comparison of nonindigenous groups was not a research design criteria required by funding agencies or members of proposal review committees.

Areas of interest. Table 3 shows the number and percent of studies grouped according to area of research interest. More studies focused on health ($n = 958$, 58.3%) than on other aspects of human biology related to health ($n = 685$, 41.7%), and more of the health-related studies focused on basic research ($n = 735$, 77%) than on applied research ($n = 223$, 23%). Applied research refers to studies that describe or evaluate some component of health care interventions. For example, research on chloroquine-resistant *Plasmodium falciparum* strains found among the Yanomamo would be considered basic science research, whereas a study on the ef-

fects of mosquito nets on the prevalence of chloroquine-resistant *Plasmodium falciparum* strains found in Yanomamo communities is considered applied research.

Infectious diseases were the focus of the majority of basic research. Among the applied studies, the most popular area was ethnomedicine, followed by articles on health care programs, research ethics, vaccinations, and environmental health. Because these three components of public health are indispensable for the control of infectious diseases, it is troublesome that, during four decades of publication, health care programs, vaccinations, and environmental health were the focus of only 45 articles out of a total of more than 1600. When we consider publications addressing the biology of indigenous populations, we find that studies on population history (e.g., genetics, blood groups) are the most numerous, followed by papers on morphology, adaptation, anthropometry, and energy expenditure. In fact, the number of studies done on population history are more numerous ($n = 459$) than the number of studies in the two major areas of basic health research, infectious diseases ($n = 333$) and chronic health conditions ($n = 112$). Thus, a disproportionate number of the biomedical studies published between 1963 and 2003 were not designed to determine why indigenous peoples are in such poor health and what we can do about it.

Infectious diseases. Table 4 shows the number and percentage of studies on infectious diseases in the database. Studies on contact diseases cover more than one pathogen and were grouped into a separate category ("contact diseases"). Intestinal parasites ($n = 57$, 16.5%), HTLV ($n = 52$, 15.3%), and hepatitis ($n = 42$, 12.3%) have been studied more extensively than any other pathogens. Because these three categories account for almost half of all the studies ($n = 151$, 44.1%), we created three databases that would allow us to examine the magnitude of population rates of infection as well as differences

Table 3 Comparison of the number and percent of studies on indigenous groups in South America in the biomedical literature from 1963–2003

	Health-related studies		Percent of health-related studies
	Number	Percent of total	
Applied			23.0
Environmental health	2	0.1	
Vaccinations	5	0.3	
Development and health	14	0.9	
Research ethics	18	1.1	
Health care	38	2.3	
Ethnomedicine	146	8.9	
Subtotal	223	13.6	
Basic research			77.0
Trauma and injuries	1	0.1	
General health	14	0.9	
Health behavior	16	1.0	
Genetics of health	30	1.8	
Mental health	33	2.0	
Reproductive health	34	2.1	
Immunology	34	2.1	
Dental health	47	2.9	
Nutrition	81	4.9	
Chronic conditions	112	6.8	
Infectious diseases	333	20.3	
Subtotal	735	44.7	
	Human biology studies		
Energy expenditure	3	0.2	
Anthropometry	43	2.6	
Adaptation	68	4.1	
Morphology	112	6.8	
Population history	459	27.9	
Subtotal	685	41.7	
Total	1643.0	100.0	

in prevalence rates between linguistic family groupings.

The total numbers of research participants for each of these areas was 12,676 (macroparasites, mestizos: 367; indigenous: 12,309; mean sample size: 116), 68,629 (hepatitis, mestizos: 43,055; indigenous: 25,574; mean sample size: 294), and 49,228 (HTLV, mestizo: 23,548; indigenous: 25,680; mean sample size: 182). A total of 63,563 indigenous persons were sam-

pled, or 1589 persons per year out of a population size of 12,643,968 indigenous South American persons, or 12.6 indigenous persons per 10,000 South American persons per year.

DISEASE BURDEN

Intestinal parasitic, HTLV, and hepatitis infection are ubiquitous in communities that lack public health infrastructures such as

Table 4 Number and percent of studies on infectious diseases grouped by pathogen/parasite. Studies on contact diseases address two or more pathogens

Pathogen/area	Number of studies	Percent	Pathogen/area	Number of studies	Percent
Anthrax	1	0.3	Tetanus	3	0.9
Chlamydia	1	0.3	Herpes	5	1.5
Hanta virus	1	0.3	Mansonella	6	1.8
Kala-azar	1	0.3	Syphilis	6	1.8
Rubeola	1	0.3	Measles	7	2.1
Shigella	1	0.3	Toxoplasma	7	2.1
Streptococcus	1	0.3	Tuberculosis	9	2.7
Trachoma	1	0.3	Chagas	11	3.3
Norwalk virus	2	0.6	HIV	12	3.6
Pinta	2	0.6	Onchocercosis	15	4.5
Pneumococcus	2	0.6	Fungi	17	5.1
Staphylococcus	2	0.6	Contact diseases	27	8.1
TT virus	2	0.6	Malaria	28	8.4
Yellow fever	2	0.6	Hepatitis	42	12.6
Influenza	3	0.9	HTLV	52	15.6
Leishmaniasis	3	0.9	Intestinal parasites	57	17.1
Polio	3	0.9	Total	333	100.0

clean, running water and sewage systems, as is the case in the vast majority of indigenous communities.

Intestinal parasites are the single most studied health problem among South American native populations. We examined the prevalence rates for four of the most common intestinal pathogens found in rural and indigenous communities of South America: *Ascaris lumbricoides* (large roundworm), *Necator Americanus* (hookworm), *Trichuris trichuria* (whipworm), and *Strongyloides stercoralis* (threadworm). These parasites are transmitted through the oral-fecal route in areas with soils contaminated with fecal matter. They reach adult stages in the host's intestines where they embed themselves in the mucosa and drain the host of important nutrients (Camil 2005).

HTLV refers to human T-cell lymphotropic viruses, and there are two types: I and II. HTLV I is associated with adult T-cell leukemia (a rare form of cancer of

the blood), and both HTLV I and II are associated with inflammation of nervous tissue in the spinal cord, eyes, joints, muscles, lungs, and skin. HTLV is transmitted through blood transfusion, sexual contact, drug needles, and breast-feeding (Strickland 1991). Some studies show that individuals infected with HTLV I or II experience decreased survival (Orland et al. 2004), and co-infection with HTLV I is associated with faster HIV 1 disease progression (Schim et al. 2003). HTLV infection may contribute to impaired immunological resistance to other viruses and bacteria among indigenous peoples of South America. However, most of the research done in this area has been designed primarily to make inferences about population history or to learn more about retroviruses related to HIV. None of the research was designed specifically to determine how HTLV could adversely affect indigenous populations and what should be done to mitigate those effects.

Hepatitis refers to inflammation of the liver when it is infected with one of five viruses: A, B, C, D, and E. These viruses can cause chronic or acute disease with symptoms such as jaundice (yellowing of the eyes and skin), extreme fatigue, nausea, and vomiting. Hepatitis A, D, and E are transmitted through contaminated water or food. Hepatitis B is transmitted through contact with body fluids or blood, and Hepatitis C is transmitted only through blood.

The methods used to assay for levels of intestinal parasites, HTLV, and hepatitis in fecal and blood samples are described elsewhere (Sheehan 1997).

Intestinal Pathogens

Table 5 shows the distribution of the prevalence of four major intestinal pathogens in indigenous populations and mestizo comparison groups. Ninety-two percent (81 of 88) of the groups had prevalence rates over 1%, and 67% (59 of 88) had rates over 25%. Evidence for *Ascaris* infection was found in all the groups sampled, and the prevalence of infection was 1% or greater in all the samples (range = 12%–100%, median = 57.73%, $n = 30$). Linguistic groups with reported infection rates of more than 80% include the Aymaran (91%), Quechuan (82.6%, 91%), Yanomam (90%, 100%), and Jivaroan (92%). The differences between lowland ($n = 23$, mean = 55.4% \pm 25.5) and highland groups ($n = 3$, mean = 88.2% \pm 4.9) are statistically significant [R-sq(adj) = 13.1%], but the highland sample is small. The differences between indigenous ($n = 26$, mean = 59.2% \pm 26.25) and mestizos ($n = 4$, mean = 48.2% \pm 31.7) are not statistically significant [ANOVA, $p = 0.452$, $n = 29$, R-sq(adj) = 0%], but again the sample of nonindigenous groups sampled is very small ($n = 4$).

Table 5 also shows the distribution of *Necator* (range = 0–96%, median = 72%, $n = 25$). In one Quechuan and one mestizo sample, researchers did not find evidence of hookworm infection. However, in studies

of indigenous communities, the prevalence was more than 1%. Groups with the highest levels of infection include groups that belong to the Maku language family grouping (96%, 95.9%); a language isolate (96%); and Arawakan (82.6%), Yanomam (74.2%, 76%, 78%), and Aymaran (72.8%) linguistic family groupings. One highland group (Aymaran) had high levels of infestation whereas the other had no infestation (Quechuan). None of the studies included a comparative mestizo sample.

The levels of *Strongyloides stercoralis* infestation are lower than *Necator* and *Ascaris* (range = 0–37%, median = 10.5%, $n = 18$). Only three groups sampled (Katukinan, Panoan, and one mestizo rural group) showed no evidence of infection with *Strongyloides*. The remaining groups had prevalence rates of more than 1%. Linguistic groups with reported infection rates of 10% or greater include various lowland mixed groups (11%, 26%, 36.4%, 37%), Yanomam (10%), Tupi (16%, 33.3%), Maku (12.2%), Xavante (11.7%), and one language isolate (20%). Only one mestizo urban group was sampled as mentioned, and none of the indigenous groups sampled were from highland areas.

Finally, the levels of *Trichuris* infestation are higher than that of *Strongyloides* and similar to *Ascaris* and *Necator* (range = 0%–100%, median = 43.4%, $n = 23$). *Trichuris* was not found in the only Arawakan group sampled, the Yawalapiti, a mixed sample of lowland groups, and in one mestizo group. Linguistic groups with reported infection rates of more than 80% include Panoan (100%), Jivaroan (98%), Quechuan (95%), Yanomam (96%), Katukinan (78%), and Tupi (77%). Only one highland group (Quechuan, 95% prevalence), and two mestizo groups are in our sample (0% and 45% prevalence).

Table 6 shows a comparison of the levels of helminth infestation across the indigenous language groups and mestizos. For these analyses, we calculated for each of the groups the standard deviation from the sample mean

MRP: mean relative prevalence

prevalence averaged across the four parasite types. Groups that have a mean relative prevalence (MRP) close to zero have prevalence rates close to the mean for the sample. Groups with a MRP higher than zero have prevalence rates higher than the sample mean (i.e., are

considerably more infested), and those below zero have lower rates than the sample mean (i.e., are considerably less infested).

The data show that the Jivaroan, Aymaran, and Quechuan language groupings are worse off than several other lowland groups.

Table 5 Prevalence of four major intestinal pathogens in indigenous populations and mestizo comparison groups of South America, sampled between 1963 and 2003: *Ascaris lumbricoides*, *Necator americanus*, *Strongyloides stercoralis*, and *Trichuris trichuria*. Lowland groups are denoted by plain text, highland groups are in italics, mestizo groups are in bold^a

Language, tribe	Prevalence (% infected)			
	<i>Ascaris lumbricoides</i>	<i>Necator americanus</i>	<i>Strongyloides stercoralis</i>	<i>Trichuris trichuria</i>
Arawakan, Yawalapiti	20.30	82.60	—	0.00
Carib, Maquiritari	77.00	16.70	—	19.30
Carib, Saluma	—	66.60	—	—
Jivaroan, Achuar	92.00	—	—	98.00
Katukinan, Kanamari	68.00	72.00	0.00	78.00
Language isolate, Ticuna	45.00	96.00	20.00	7.00
Macro Ge, Xavante	25.00	33.60	11.70	0.80
Maku, Maku	75.00	96.00	12.20	5.00
Maku, Maku	61.20	95.90	3.50	67.30
Panoan, Cashibo	55.00	72.00	5.00	55.00
Panoan, Kashinawa	60.00	60.00	0.00	100.00
Panoan, Shipibo	45.00	40.00	—	—
Tupi, Kaiwa	34.40	29.00	—	—
Tupi, Karitiana	18.90	0.90	—	0.90
Tupi, Parakana	42.80	33.30	5.60	77.00
Tupi, Surui	53.30	43.30	33.30	0.80
Tupi, Wayampi	—	—	16.00	—
Various lowland	81.97	81.00	36.40	37.00
Various lowland	75.50	—	—	—
Various lowland	70.00	95.00	26.00	13.10
Various lowland	52.00	32.00	11.00	0.00
Various lowland	18.00	91.60	37.00	91.00
Yanomam, Yanomamo	100.00	76.00	10.00	68.00
Yanomam, Yanomamo	90.00	74.20	3.30	43.40
Yanomam, Yanomamo	14.30	78.00	2.00	96.00
<i>Quechuan, Quechua</i>	<i>91.00</i>	<i>0.00</i>	—	<i>95.00</i>
<i>Quechuan, Quechua</i>	<i>82.60</i>	—	—	—
<i>Aymaran, Aymara</i>	<i>91.00</i>	<i>72.80</i>	—	—
Mestizo rural	76.00	—	—	0.00
Mestizo rural	—	—	—	45.00

(Continued)

Table 5 (Continued)

Language, tribe	Prevalence (% infected)			
	<i>Ascaris lumbricoides</i>	<i>Necator americanus</i>	<i>Strongyloides stercoralis</i>	<i>Trichuris trichuria</i>
Mestizo urban	12.00	0.00	0.00	—
Mestizo urban	73.63	—	—	—
Mestizo urban	31.14	—	—	—
Mean	57.73	57.54	12.94	43.37
SD	26.69	32.00	12.62	38.70

^aSources: *Ascaris lumbricoides*: Baruzzi 1970, Basset et al. 1986, Coimbra & Mello 1981, Confalonieri et al. 1991, Crofts 1977, De Muynck et al. 1977, Ferrari et al. 1992, Ferreira et al. 1991, Gaumerais 1984 cited in Basset et al. 1986, Knight & Prata 1972, Kroeger et al. 1992, Lawrence et al. 1980, Miranda et al. 1998, Miranda et al. 1999, Penot et al. 1978, Romano et al. 1988, Santos et al. 1995; *Necator americanus*: Baruzzi 1970, Coimbra & Mello 1981, Confalonieri et al. 1991, Crofts 1977, De Muynck & Silva de Lagrava 1977, Ferrari et al. 1992, Ferreira et al. 1991, Gaumerais 1984 cited in Basset et al. 1986, Knight & Prata 1972, Lawrence et al. 1980, Lynch et al. 1983, Miranda et al. 1998, Miranda et al. 1999, Penot et al. 1978, Santos et al. 1995; *Strongyloides stercoralis*: Baruzzi 1970, Carne et al. 2002, Coimbra & Mello 1981, Confalonieri et al. 1991, Knight & Prata 1972, Lawrence et al. 1980, Miranda et al. 1998, Penot et al. 1978, Santos et al. 1995; *Trichuris trichuria*: Baruzzi 1970, Basset et al. 1986, Coimbra & Mello 1981, Confalonieri et al. 1991, Ferrari et al. 1992, Ferreira et al. 1991, Knight & Prata 1972, Kroeger et al. 1992, Lawrence et al. 1980, Miranda et al. 1998, Penot et al. 1978, Santos et al. 1995.

Interestingly, the two highland groups are more affected by parasite infestation than most other lowland groups, even though they reside in the more temperate Andean region. Table 6 also shows that the two mestizo groups in the sample had MRPs below most other indigenous groups, although they were higher than the Macro-Ge.

In summary, the rates of infection with intestinal pathogens among indigenous groups of South America are extremely high regardless of geographical location (i.e., lowlands versus highlands) and higher than the infestation rates among mestizo groups in the sample.

HTLV

Supplemental Table 2 shows the distribution of HTLV I and II in indigenous populations and mestizo comparison groups. The range of variation in HTLV I infection is very high as was the case for intestinal parasites, but the mean for the sample is much lower because there are many more groups that are not infected with HTLV and have zero prevalence

rate, and the highest prevalence rates are below 40% (range = 0%–39%, mean = 2.28%, $n = 186$). Among 29% of the indigenous groups, the prevalence is 1% or greater. Thirty-two percent (78 of 238) of the groups had prevalence rates over 1%, and 7% (16 of 238) had rates over 25%. Populations with the highest levels of infection are the Macro-Ge (mean = 11.68% \pm 15.43, $n = 11$) and mestizo clinical populations (mean = 6.64% \pm 7.52, $n = 22$). The differences between them are not statistically significant [ANOVA, $p = 0.213$, R-sq(adj) = 1.9%]. Moreover, the differences between lowland (mean = 1.7% \pm 5.9, $n = 128$) and highland groups (mean = 1.6% \pm 2, $n = 22$) are not statistically significant [ANOVA, $p = 0.927$, R-sq(adj) = 0%, $n = 148$], whereas the differences between the Macro-Ge groups (mean = 11.7% \pm 15.4, $n = 11$) and the highland groups (mean = 1.6% \pm 2, $n = 22$) are significant [ANOVA, $p = 0.004$, $n = 32$, R-sq(adj) = 20.8%].

When prevalence rates of HTLV II were measured, and infection was present, the prevalence rates were higher than was the case

Table 6 Mean relative prevalence of intestinal pathogens in indigenous populations and mestizo comparison groups of South America, sampled between 1963 and 2003. Lowland groups denoted by plain text, highland groups are in italics, mestizo groups are in bold. For data sources, see Table 5

Language group	Mean relative prevalence ^a
Jivaroan	1.35
<i>Aymaran</i>	<i>0.86</i>
<i>Quechuan</i>	<i>0.60</i>
Various lowland	0.42
Yanomam	0.25
Maku	0.25
Katukinan	0.18
Language isolate	0.09
Carib	-0.05
Mestizo rural	-0.09
Panoan	-0.12
Tupi	-0.47
Arawakan	-0.58
Mestizo, urban	-0.64
Macro-Ge	-0.79

^aStandard deviation from the sample mean prevalence averaged across the four parasite types.

for HTLV I (range = 0%–57.9%, mean = 8.6%, $n = 92$). Among 53.2% of indigenous groups the prevalence is 1% or greater. Of the highland groups, only the Quechuan linguistic group was infected, but the prevalence was low (0.7%). Populations with the highest levels of infection are Alacalufan (34.8%, $n = 1$), Macro-Ge (range = 0%–41.75%, mean = 25.4% \pm 6.87, $n = 9$), Mataco Guaicuru (range = 1.4%–34.15%, mean = 22.2% \pm 4.33, $n = 14$), and Guahiban (range = 24.7%–31.5%, mean = 29.23% \pm 2.27, $n = 3$). There is a marked difference in prevalence rates between lowland (mean = 10.1% \pm 14.59, $n = 78$) and highland groups (mean = 0.07% \pm 0.22, $n = 10$), and the difference is statistically significant [ANOVA, $p = 0.033$, $n = 87$, R-sq(adj) = 4.1%]. The only mestizo group sampled did not show signs of infection (0% prevalence).

Comparisons across linguistic family groupings and mestizo groups show that, in fact, the groups with the highest MRP are the Macro-Ge, the Alacalufan, the mestizo clinical groups, the Mato-Guaicuru, the Camasa, and the Guahiban (Table 7). The mestizo clinical group includes samples of individuals who were seen at hospitals or clinics and who were at risk of HTLV, mainly sex workers or HIV-infected individuals. It is indeed very troublesome that the Macro-Ge and Alacalufan communities are at much higher risk of HTLV infection than are those mestizos at highest risk of exposure to these retroviruses. At the same time, the Highland Aymaran and Quechuan communities, as well as most other lowland groups and rural mestizos, are at relatively lower risk of HTLV infection.

In summary, a high percentage of indigenous groups have prevalence rates of HTLV I and II infection (29% and 53.2%, respectively) that exceed one percent of the population. Again, the mestizo groups sampled were at relatively lower risk of infection, if they were not sampled in clinics or hospitals. And only a few of the Lowland groups are at extremely high risk of HTLV infection relative to most other Lowland groups. The Highland and nonclinical mestizo groups are also among the latter.

Hepatitis

Supplemental Table 3 shows the distribution of the prevalence of serologic responses (as measured by hepatitis-specific antibodies in blood, a measure of previous hepatitis infection) to various strains of hepatitis (A, B, C, D, and E) in indigenous populations and mestizo comparison groups. Hepatitis A ($n = 5$ studies), C ($n = 12$), D ($n = 5$), and E ($n = 7$) have been studied less extensively than has hepatitis B ($n = 59$ studies). As noted for intestinal pathogens and HTLV, the range of variation is also very high for hepatitis (range = 0%–100%, mean = 18.5%, $n = 73$). Few of the indigenous groups sampled had no evidence of infection (13%, $n = 11$ indigenous groups).

Table 7 Mean relative prevalence of HTLV I and II in indigenous populations and mestizo comparison groups of South America, sampled between 1963 and 2003.

Lowland groups denoted by plain text, highland groups are in italics, mestizo groups are in bold. For data sources, see Supplemental Table 2

Language group	Mean relative prevalence ^a	Language group	Mean relative prevalence ^a
Macro-Ge	1.44	<i>Quechuan</i>	-0.34
Alacalufan	0.75	Zamucoan	-0.36
Mestizo, clinical	0.72	Unclassified, Arara	-0.36
Mataco-Guaicuru	0.52	Chibchan	-0.38
Language isolate, Camsa	0.22	Panoan	-0.38
Guahiban	0.08	Barbacoan	-0.39
Carib	-0.02	Witotoan	-0.39
Araucanian	-0.06	Harakmbet	-0.39
<i>Aymaran</i>	-0.09	Katukinan	-0.39
Mascoian	-0.13	Peba-Guayan	-0.39
Yanomam	-0.16	Tacanan	-0.39
Language isolate, Yaghan	-0.17	Unclassified, Piajoa	-0.39
Mestizo, rural	-0.25	Uru-Chipaya	-0.39
Unclassified, Yaruro	-0.26	Tucanoan	-0.39
Choco	-0.26	Jivaroan	-0.40
Arauan	-0.30	<i>Paezan</i>	-0.41
Mapudungun	-0.31	Tupi	-0.44
Arawakan	-0.31	Salivan	-0.44

^aStandard deviation from the sample mean prevalence averaged across the two HTLV types.

That is, 87% of the groups sampled showed evidence of infection, whereby 1% or more of the populations sampled tested positive for at least one strain of hepatitis. Eighty-six percent (63 of 73) of the groups had prevalence rates over 1%, and 30% (22 of 73) had rates over 25%. Linguistic populations with the highest levels of infection were all from lowland areas: the Tupi (mean = 25.46% ± 6.1, $n = 23$), Yanomam (mean = 23.6% ± 15.3, $n = 3$), Carib (mean = 22.7% ± 5, $n = 20$), Macro-Ge (mean = 21.9% ± 4.45, $n = 13$), Arauan (17.9%, $n = 1$), Arawakan (mean = 13.5% ± 7, $n = 4$), and Chibchan (mean = 7.7% ± 7.7, $n = 2$). In contrast, the three highland groups in the sample, and all the comparison mestizo and indigenous urban groups, had lower levels of hepatitis infection (mean = 7.82% ± 6.7, $n = 18$) than the lowland groups (mean = 21.3% ± 22.8, $n = 70$), and the dif-

ferences are statistically significant [ANOVA, $p = 0.016$, $n = 87$, R-sq(adj) = 5.5%].

Table 8 shows the MRP of hepatitis infection across indigenous linguistic family groupings and mestizo groups. Groups belonging to the Yanomam, Carib, Macro-Ge, and Tupi language families have higher MRPs than do other groups as well as the mestizo clinical groups sampled. Mestizo urban and indigenous urban populations experienced lower rates of hepatitis infection along with several other lowland groups and highland Quechuan and Mapudugun groups.

In summary, the vast majority of indigenous groups (87%) show evidence of infection with at least one of the hepatitis strains, and the rates are higher among lowland and mestizo clinical groups than among highland groups, as well as mestizo urban and indigenous urban groups.

Table 8 Mean relative prevalence of serologic responses to Hepatitis A, B, C, D, and E in indigenous populations and mestizo comparison groups of South America, sampled between 1963 and 2003. Lowland groups denoted by plain text, highland groups are in italics, mestizo groups are in bold. For data sources, see Supplemental Table 3

Language group	Mean relative prevalence ^a
Yanomam, Yanomamo	0.90
Carib, Apalai	0.47
Mestizo clinical	0.35
Macro-Ge, Kayapo	0.28
Tupi, Arawete ^b	0.03
Arawakan, Palikur	-0.10
Arauan, Jamamadi	-0.11
<i>Quechuan, Inga</i>	-0.41
Mestizo urban	-0.58
Indigenous urban	-0.62
<i>Mapundugun, Mapuche</i>	-0.74
Language isolate, Arara	-1.10
Language isolate, Camsa	-1.17

^aStandard deviation from the sample mean prevalence averaged across the hepatitis types.

DISCUSSION AND CONCLUSIONS

On the basis of a review of publications in the National Library of Medicine's PubMed database, this chapter describes some of the most pressing health problems that indigenous communities of South America face. Because the governments of South America do not have data-gathering and -reporting systems in indigenous communities, and/or ethnicity data are not systematically entered in vital statistics forms and clinical questionnaires, the best we can do at this point is to bring together data on indigenous health that has been published during the past four decades by scientists in medical, clinical, biological, and anthropological journals. Such a compilation is presently inaccessible to native communities and regional and national public health workers.

Before providing a summary of published patterns, we examined the extent to which the published information could be biased in favor of some linguistic family groupings or research questions. In developed countries, the underrepresentation of studies on specific health topics is kept in check by research funding committees created to identify gaps in health knowledge and to develop and implement funding programs to fill those gaps. But research carried out on the health of South American indigenous communities is not monitored in the same way, probably because developed countries fund it. Those who submit proposals to agencies that fund health research are generally given awards on the basis of the quality of the research and whether the research results could benefit the populations of U.S. and European countries, not those of South American countries. Only the Fogarty International Center and a handful of programs at the National Institutes of Health support health research that is specifically designed to benefit non-Western populations, but they are severely underfunded and not carefully monitored for gaps in knowledge (<http://www.nih.gov>).

The literature review shows that lowland language family populations, when compared with highland groups, are over-represented and that some lowland (e.g., Yanomam, Araucanian, Carib, and Macro-Ge) and highland language families (e.g., Uru Chipaya, Barbacoan, and Chibchan) have been studied much more than others in their respective regions. We also learned that basic research greatly predominates (77%) over applied research (23%) and that the number of genetic studies on population history is similar to the number of studies ($n = 459$) on infectious diseases and chronic conditions ($n = 459$). This indicates that scientific interest and funding is oriented toward academic/intellectual issues rather than practical solutions to urgent problems. The amount of information on effectiveness of programs designed to treat and prevent native health problems is dismal. And, from a public health

standpoint, the information on population history is excessive unless geneticists are able to demonstrate in the future that degree of relatedness between indigenous groups helps to explain disease patterns. If so, this fact must be taken into account by public health programs (e.g., Are Tupi-Guarani groups more susceptible to tuberculosis than are Macro-Ge groups?). In any case, to our knowledge, this is not one of goals of the historical/genetic studies published to date.

We also examined available literature on infectious diseases because infectious diseases are a significant cause of low quality of life, morbidity, and mortality, and effective control of infectious diseases is probably the single most important public health initiative that could greatly improve the quality of life of South American indigenous peoples. Again, we note that a large proportion of studies are carried out on pathogens that are at the center of theoretical and academic research in population history and health vectors of immediate concern in Western populations. Differences in HTLV strains have been used to trace the population origins of lowland and highland South American groups. In addition, the HTLVs are cancer-producing viruses that are distantly related to HIV. Although it is likely that sometime in the future cancer and HIV will be major health threats to indigenous peoples of South America, they are not major threats at the present time. We know a great deal more about HTLV among natives than we know about those health threats that cause most deaths and ill health (e.g., malaria, tuberculosis, sexually transmitted diseases, influenza, pneumonia and other respiratory infections, staphylococcal skin infections, Chagas disease, leishmaniasis, bacterial and viral intestinal infections, leprosy, trauma and injury, domestic violence, and alcoholism).

Published data on prevalence rates of infection by intestinal macroparasites, HTLV, and hepatitis viruses shows that in most indigenous groups, regardless of language family grouping, more than 1% of the popu-

lations were infected. These statistics stand in stark contrast to those of large epidemiologic surveillance surveys in the United States. The U.S. prevalence rates of hepatitis (<http://www.cdc.gov/ncidod/diseases>) and HTLV I/II infection were lower than 0.02% (CDC 1992), and of *Ascaris*, *hookworm*, *Trichuris trichuria* and *Strongyloides stercoralis* it was lower than 2% (CDC 1990). In indigenous groups fortunate enough to have low prevalence levels of infection of these diseases, the health threat is less urgent but latently explosive. The sudden shifts in disease ecology that plague indigenous groups (e.g., deforestation, forced resettlement or migration into a new region) can quickly lead to increased exposure, transmission, virulence, and high infection rates of a pathogen that had previously infected relatively few persons.

Groups with infection rates of more than 10% are seriously threatened, and when one pathogen thrives in a population, others do as well. For example, Macro-Ge groups have high rates of HTLV I/II (mean = 17.9%), hepatitis (mean = 23.7%), and macroparasitic infection (mean = 17.7%). The most studied group, the Yanomamo, have extremely high rates of macroparasitic infection (mean = 54.6%), lower levels of HTLV infection (mean = 2.7%), and high rates (mean = 33.1%) of hepatitis infection. The tendency to focus on single pathogens sometimes distracts scientists from observing and documenting frighteningly high overall disease burdens. Multiple infections drain hosts of energy and nutrients and cause complex symptomatological profiles that are difficult to treat. It is this burden that we must be able to track so that effective infectious disease control programs are implemented in indigenous communities of South America.

And finally, in most cases, indigenous groups had higher prevalence rates of infection than did homologous mestizo populations. But, infection rates of hepatitis and HTLV were disturbingly similar between some lowland groups and clinical mestizo populations.

The literature on health among South American indigenous peoples is insufficient in many areas, but the data that have been published on infectious diseases are sufficient to make the case that (a) infection rates are very high among indigenous peoples of South America and that policies and programs to control them are urgently needed, and (b) agencies like the PAHO and the United Nations must establish partnerships with biomedical scientists to find solutions based on the data they have in hand. Native peoples cannot afford to wait for the day that governments of South America decide to implement uniform and efficient health surveillance and reporting systems in indigenous communities.

PAHO's indigenous health initiative, Resolution V, is an important first step toward a global solution to the health problems that ail South American indigenous peoples. However, biomedical scientists and biological an-

thropologists who work with South American indigenous populations do not appear to be involved, even though they have information gathered, for the most part, with public funds that can help to guide policy and to establish contacts with indigenous communities. In addition, PAHO's health initiative calls for the use of limited resources in all areas of health rather than for investments into fewer public health projects, such as the control of infectious diseases, that if addressed promptly, will have a long-lasting effect on the work capacity and immunity of indigenous peoples. Concrete steps need to be taken by agencies like PAHO in partnership with scientists to ensure that indigenous peoples of South America do not continue to be denied the right to the benefits of scientific progress that allow societies to create conditions conducive to the attainment of the highest standard of physical and mental health.

SUMMARY POINTS

1. Because national epidemiologic surveillance systems do not reach indigenous communities, the only quantitative information on South American native health has been collected and published by medical scientists. These data are not accessible to native communities or regional and national public health practitioners.
2. In developed countries, numerous public health initiatives at the community, regional, state, and national levels help to ensure that the study of important health threats is routinely funded. In contrast, gaps in our knowledge about the health status of South American indigenous communities are not monitored by national or international agencies anywhere in the continent.
3. A very small number of the studies on indigenous health focused on the most serious health problems facing indigenous communities of South America such as malaria, tuberculosis, sexually transmitted diseases, viral and bacterial respiratory, diarrheal and skin infections, leprosy, trauma, domestic violence, and alcoholism.
4. Among the infectious diseases that have been more frequently studied, regardless of language family grouping, more than 1% of individuals sampled were infected by intestinal macroparasites, HTLV, and hepatitis viruses, and in 67%, 30%, and 7% of the communities, 25% or more individuals were infected with these pathogens, respectively. In U.S. national surveillance samples, the prevalence rates of these conditions were well below 2%.
5. The prevalence rates of hepatitis and HTLV infection in indigenous and homologous mestizo populations differed significantly but were similar to rates reported for mestizo clinical populations.

6. The data published to date by medical scientists are sufficient to make the case that the infection rates of co-occurring diseases are very high in South American indigenous communities and that programs to control them are urgently needed. Agencies like PAHO must establish partnerships with biomedical scientists to find immediate solutions by using data they have at hand and by implementing long-term epidemiologic surveillance and intervention solutions in partnership with local public health authorities.

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