Shiwiar Health Risk and the Evolution of Health Care Provisioning

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ABSTRACT

Humans experience lower extrinsic mortality than other hominoids. This fact may underlie the evolution of long human lifespan, delayed maturity, exceptional intelligence, and intra and intergenerational resource transfers. Understanding why humans have low mortality is therefore critical for understanding basic human traits. One explanation is that the evolution of food provisioning to individuals suffering health crises reduced mortality. This brings up the questions of whether selection produced adaptations for producing or eliciting this behavior, and what functional attributes those adaptations are expected to embody. Health risk is hypothesized to have selected for adaptations motivating individuals to generously and recurrently provide beneficial goods and/or services to others, because this had the effect of motivating the recipients to provide costly health care to their provider when s/he was sick or injured. Conversely, adaptations motivating individuals to value those who generously and recurrently provide them with important benefits such that the former are willing to provide costly care when a valued person is disabled have been put forth. These hypotheses are contingent upon health risk having constituted a significant and specific kind of selection pressure for our ancestors, and health-care provisioning having significantly reduced mortality and increased fitness. Evidence of such selection pressure may be searched for in the fossil record and among extant forager populations. Here I report the causes, distribution, and duration of injuries and illnesses suffered by Shiwiar forager-horticulturalists based on physical evidence and informant reports. I find that (a) most individuals suffer pathology during their lifetimes that would be lethal without help from others, (b) these periods are temporally unpredictable (c) not primarily attributable to impacts from the Western/Industrial world and (d) the fitness effects of surviving these episodes are high, suggesting that selection could favor adaptations motivating individuals to the pay long term costs associated with maintaining relationships that yield health care altruism.

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Key Words: health risk; bankers paradox; altruism; costly signaling; disability; cooperation

Introduction

A fundamental difference between the life history of humans and other hominoids is that humans experience lower extrinsic mortality (e.g., Blurton Jones & Marlowe 2002; Hawkes et al. 1998; Hill et al. 2001). Human life history is distinguished by long lifespan (e.g., Alvarez 2000; Hawkes et al. 1998, 2000; Hill et al. 1999; Hill et al. 2001; Hill & Kaplan 1999; Kaplan et al. 2000), delayed reproduction (e.g., Blurton Jones & Marlowe 2002; Hill et al. 2001; Hill & Hurtado 1996; Hill & Kaplan 1999; Kaplan et al. 2000; Pereira 1993; Pagel & Harvey 1993), intergenerational asymmetric benefit transfers from adults to juveniles and between adults (e.g., Bogin 1999; Gurven et al. 2000; Gurven & Kaplan 2002; Hagen et al. 2001; Hawkes et al. 1997, 1998, 2000, 2001; Hewlett 1992; Hill & Hurtado 1996; Kaplan & Hill 1985; Kaplan et al. 2000; Marlowe 1999, 2001; Winterhalder 1996), and a large brain able to engage in unprecedented levels of learning, reasoning, and insight (e.g., Byrne 1997; Bogin 1999; Geary & Flinn 2001; Hill & Kaplan 1999; Kaplan et al. 2000; Tooby & DeVore 1987). The evolution of each of these traits depends on relatively low human mortality because the probable payoffs for each is diminished by the probability that one will not live long enough to reap their benefits (e.g., Charnov 1993; Fisher 1958; Hamilton 1966; Hawkes 1998; Hill & Kaplan 1999; Kaplan et al. 2000; Medawar 1952; Pagel & Harvey 1993; Pereira & Fairbanks 1993; Sugiyama in press; Williams 1957). As Hill and Kaplan (1999) point out, understanding why humans experience low mortality may therefore "hold the key for understanding a variety of evolved human features and … the evolutionary history of our species" (Hill & Kaplan 1999:413).

Hill and Kaplan (1999) summarize that humans may have achieved low mortality via the evolution of (1) reduction of predation via increasingly effective use of weapons and/or coalitional defensive tactics (Hill & Kaplan 1999), (2) slow growth combined with adult protection that insulated juveniles from foraging competition or (3) potentially lethal mating competition with adults (e.g., Bogin 1999, Janson & van Shaik 1993), (4) increased investment in immune function, pathogen and parasite resistance (Aiello & Wheeler 1995; Hill & Kaplan 1999), and/or (5) care and provisioning for sick and injured individuals (Gurven et al. 2000; Hill & Kaplan 1999; Kaplan et al. 2000; Sugiyama 2002, in press). The latter explanation -- that the evolution of food provisioning during periods of health crisis increased survival from serious health insults -- leads to the questions of whether or not health care aid reduces mortality under evolutionarily relevant conditions (see e.g., Sugiyama 2003), whether humans have adaptations functioning to elicit aid from others, and whether we have adaptations motivating us to provide aid to temporarily disabled individuals under specific conditions (e.g., Gurven et al. 2000; Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming).

Of particular concern here is the hypothesis that selection pressure from health risk shaped psychological adaptations motivating individuals to attempt to generously and recurrently provide beneficial goods and/or services to others because it signaled coalitional intent and made the provider a valued resource, and thus motivated beneficiaries to provide costly health care to benefactors when the latter were grievously sick or injured to retain access to the individual (Gurven et al. 2000; Sugiyama 1996; Sugiyama & Chacon 2000; see also Tooby & Cosmides 1996). A corollary posits that adaptations allow individuals to recognize those who recurrently provide them with important benefits, and the relative costs that others pay to provide them. In other words we have adaptations that track "reputations for generosity" (Gurven et al. 2000). Recipients of generosity provide care to valued generous individuals when disabled, with the effect that the recipient(s) retain access to the generous individual when s/he recovers (Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming). These motivational adaptations could help account for the frequent apparent altruism observed in human society (Gurven et al. 2000; Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming; Tooby & Cosmides 1996). Apparently altruistic behavior is common among humans; it appears to be central to the human foraging lifeway (Kaplan et al. 2000) or what has been called the "cognitive niche" (Tooby & Devore 1987). Humans are so dependent on complex networks of social cooperation that psychological evidence suggests they exhibit what Hill (2002) has called a "general propensity to cooperate" (e.g., Hill 2002), beyond having specific adaptations for identifying and excluding cheaters in direct contingent exchange (e.g., Cosmides & Tooby 1992; Stone et al. 2002; Sugiyama et al. 2002).

Here I review a set of hypotheses about adaptations for health risk buffering via aid to sick and injured individuals, and the assumptions about health risk upon which they are based. I then present data on 678 injuries and illnesses suffered by 40 Shiwiar forager-horticulturalists of the Ecuadorian Amazon to begin testing these assumptions. Data is based on physical evidence and informant reports. A subsample of 17 individuals provides data on incidence and duration of disability for 215 incidents, and genealogical and census data are used to examine some of the demographic and fitness effects of provisioning and protection during health care crises.

Evidence for human health risk and associated adaptive problems for social relations

In humans, the results of health risk are seen among historic and prehistoric populations (e.g., Alejandro 1996; Aufderheide & Rodriguez-Martin 1998; Berger & Trinkaus 1995; Bush & Zvelebil 1991; Grauer & Stuart-Macadam 1998; Lambert 1995; Martin & Frayer 1997; Owsley & Jantz 1994; Rothschild & Martin 1992; Steckel et al. 2002; Trikaus 1983; Tyson 1997; Walker 1989; Webb 1994). Osteological evidence presents a potentially biased view of pathology prevalence because incidents leaving only soft-tissue damage, or those that did not have time to heal are not osteologically visible (e.g., Wood et al. 1992; but see Steckel et al 2002). This "osteological paradox" means that much of the pathology pre-dating the evolution of extensive health-care provisioning may not show up in the hominid record, whereas there may be evidence of many injuries and illnesses after the evolution of health-care altruism. Even where there is visible pathology, the duration of disability attendant to a case of illness or injury is difficult to estimate based on osteological evidence alone (e.g., Steckel et al. 2002). Ethnographic evidence indicates that people may continue to work while suffering from injuries that could appear debilitating in the fossil record (e.g., deformed foot, severe arthritis, loss of limbs [Sugiyama 1996; Sugiyama & Chacon 2000; and see Steckel et al. 2002]), and are disabled by incidents that might not be osteologically visable (e.g., exposure to caterpillar or scorpion toxin, or postpartum complications [see below and Sugiyama in press]). The result is that we do not know the relative frequency with which pathology leaving only soft-tissue (i.e., osteologically invisible) damage occurred in prehistoric populations, nor do we know the relative probability with which these are likely to cause disability or the duration of disabilities that did occur. Data from extant small-scale populations with limited access to modern medical care provide a useful source of comparative ethno-bioarchaeological data on these issues (e.g., Lukacs 1998; Sugiyama in press; Walker et al. 1998).

Little is known however, about the causes, frequency, and duration of disabling illness and injury among forager and forager-horticulturalist populations who live without consistent access to western medical attention (Kaplan et al. 2000), whether health care altruism reduces mortality in these populations (Hill & Kaplan 1999), or what the probable fitness benefits of receiving care are (Sugiyama in press). Among forager and forager-horticulturalist populations for which we have evidence, disabling health insults appear to be common (see, e.g., Bailey 1991; Baksh & Johnson 1990; Chagnon 1975, 1979, 1997; Gurven et al. 2000; Hill & Hurtado 1996; Sugiyama & Chacon 2000; Truswell & Hansen 1976). Bailey (1991), for instance, reports that the Efe of central Africa sought medical treatment on 21% of man days. Among the Machiguenga, lacerations from *cana brava* cost on average three weeks of work per individual per year (Baksh & Johnson 1992). Among the Ache of Paraguay, adults required care at a health clinic on 6% of all person days, and children required care on 3.5% of person days (Kaplan et al. 2000). Among the Yora of Peruvian Amazonia, individuals were observed to be sick or injured on approximately 5% of person days overall, with male heads of household suffering illness or injury on 10% of man days (Sugiyama & Chacon 2000). These disabling conditions may occur for prolonged periods: among the Yora, one hunter refrained from hunting for eight weeks, over a month of which was unambiguously due to injury disability (Sugiyama & Chacon 2000). Once they occur, severe illness or injury may form a significant adaptive bottleneck to survival.

When an adult is temporarily disabled, both that individual and his/her dependents face fitness costs from lowered nutritional intake, particularly of the rich but difficult-to-acquire game which is a key component of the human foraging diet (e.g., Kaplan et al. 2000; Kelly 1995; Sugiyama & Chacon 2000; Tooby & Devore 1987). When an average Yora hunter was injured, average per capita protein intake within the food-sharing group dropped approximately 18%. If the best hunter were injured, however, average per capita protein intake would have dropped approximately 37%--well below USRDA guidelines (Sugiyama & Chacon 2000). Costs of poorer nutrition have been observed in a variety of primates and other mammals. They include shorter reproductive lifespan, delay of menarche and onset of puberty, fewer offspring, a lower proportion of live births, lower infant survival and body weight, and increased juvenile mortality (see, e.g., Allen 1984; Altmann 1991; Buzina et al. 1989; Fritch & McArthur 1974; Green et al. 1986; Hill & Hurtado 1996; Kohrs et al.; Manocha & Long 1977; Prasad et al. 1993; Prentice et al. 1987; Riley et al. 1993; Schwartz et al. 1988).

Health risk thus appears to pose a number of adaptive problems for social relations. Unlike those who are experiencing a temporary slump in foraging returns (which may be buffered by day-to-day food transfers of high-variability food items between a few individuals [e.g., Winterhalder 1996]), severely sick or injured individuals are not only unable to forage, but are incapable of defending themselves and their interests. They are dependent upon others to do so. And, within a wide range of parameters, illness and injury are expected to be temporally unpredictable; it is difficult or impossible to forecast when one will be injured or temporarily disabled. These factors suggest that to be selected for, adaptations designed to increase the likelihood and/or quality of health care provisioning and/or protection received must be engaged prior to the health crisis, and on a relatively consistent basis.

Critically sick or injured individuals also face a formidable “bankers paradox”--it is when they are in greatest need that they are least likely to be able to repay investment directed to them (Tooby & Cosmides 1996). Expectations of future repayment based on the logic of reciprocal altruism are therefore problematic, because the probability that any investment in a disabled individual will reap future fitness returns diminishes as need becomes critical: as probable mortality increases, probability of repayment decreases to a point where the relative benefit to potential providers of investing their resources elsewhere outweighs the value of return from the disabled, devalued by the probability that the disabled individual will die (Sugiyama & Chacon 2000; Sugiyama and Scalise Sugiyama in press; Tooby & Cosmides 1996). Contrary to expectations of foraging risk reduction models, in which transfers are expected to balance through time (e.g., Bliege Bird and Hawkes 2002), one cannot rely on tit-for-tat reciprocity to buffer health risk: if one did, one would risk finding oneself obligated to others at the time of disability, rather than their being obligated to oneself (Sugiyama & Chacon 2000).

Health risk thus poses three critical adaptive problems: (1) how to subvert the short-term cost-benefit psychology of potential sources of aid such that they are more rather than less likely to invest, even though the current probable payoff of doing so is low relative to other potential uses of the investment; (2) how to stimulate this investment at a time when one lacks defensive or enforcement credibility (i.e., risk of punishment to enforce interests is low or uncertain); and (3) how to circumvent the temporally unpredictable nature of severe health crises. Task analysis suggests that the cognitive and emotional systems necessary to provide an adaptive solution to these problems are complex, and could arise only after the psychology underlying direct and delayed social exchange and cooperative food sharing had evolved (Sugiyama & Chacon 2000; Tooby & Cosmides 1996), and the foundations of a dietary strategy rich enough to allow adequate provisioning had emerged (Kaplan et al. 2000).

In foraging societies food transfers are often characterized by asymmetric flows of food from some adults to others (e.g., Bliege Bird et al. 2002; Hawkes 1993, 1995; Kaplan & Hill 1985; Sugiyama 1996; Winterhalder 1996). At least some of the variance in these apparently altruistic food transfers defy standard explanations based on kin selection, reciprocal altruism, tolerated theft or foraging risk reduction (e.g., Bliege Bird et al. 2002; Blurton Jones 1987; Cashdan 2002; Gurven et al. 2000; Hawkes 1993, 1995; Hawkes et al. 1998, 1999; Kaplan & Hill 1985; Sugiyama 1996; Sugiyama & Chacon 2000; Smith & Bliege Bird 2000; Winterhalder 1996). Food sharing often entails costly transfers to others: some hunters consistently contribute more to the diets of non-nuclear family members than they receive in return, even taking into account the need to buffer day-to-day foraging risk via food-sharing (e.g., Bliege Bird et al. 2002; Blurton Jones 1984, 1987; Cashdan 1985, 1990; Hawkes 1990, 1991; Kaplan & Hill 1985a, 1985b; Kaplan et al. 1990; Sugiyama & Chacon 2000; Winterhalder 1996). The application of costly signaling theory shows promise in explaining some of the variance in asymmetric resource transfers, and researchers have suggested that hunting of various kinds may serve as a costly signal of phenotypic quality and/or coalitional intent or value (e.g., Bliege Bird & Smith 2001; Gintis et al. 2002; Gurven et al. 2000; Sosis 2000; Sugiyama & Scalise Sugiyama forthcoming).

Following a suggestion by Kaplan and Hill (1985), and using Tooby and Cosmides arguments about the "bankers paradox," I suggested that evolution shaped adaptations motivating long-term, consistent, hard to replace conferral of benefits to specific others because at least in part, this behavioral strategy yielded critical protection and health care during times of temporary disability for individuals who deployed it, and that this could account for some of the unexplained variance in food and other benefit transfers for which compensatory benefits are difficult to identify (Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming). A formal model expanding upon these and related ideas was supported with data from the Ache (Gurven et al. 2000). Gurven et al. (2000) argue that the relative proportion of an individual's kills transferred to a recipient provides a clear signal of the provider's "generosity," which can be seen as an indicator of the generous individuals commitment to the interests of the recipient (see too e.g., Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming). Zahavi and Zahavi (1997) argue that, the more costly a signal, the more confidence can be placed in its "honesty" because the very cost of the signal makes it unprofitable to fake. Recipients of the signal benefit because they have reliable information about the quality being signaled, the signaler benefits to the degree that having others accurately assess the quality may be to one's benefit. Individuals of lesser quality must also engage in the display, because failing to do so indicates ones lack of competitive ability within the signaled domain.

Gurven et al. (2000) argue that the proportion of available resources transferred from a given individual (*i*) to each other recipient individual or household (*j…n*) during times of individual *i's* good health provides an honest signal of the degree to which *i* is committed to each recipient's welfare: the higher the relative cost of the transfer (in this case, the higher the proportion of the kill transferred), the greater the signaled commitment. Thus, when *i* is incapacitated and dependent upon others for subsistence, each recipient (*j…n*) of individual *i*'s past largesse is expected to provide health-care aid to *i* as a function of the relative cost of previous food transfers received from (*i*), because committed allies are valuable ones in time of crisis (Gurven et al. 2000; Sugiyama 1996; Tooby & Cosmides 1996). Total aid to *i* is the sum of the aid provided from individuals (*j…n*) (Gurven et al. 2000).

The "signaling generosity" (Gurven et al. 2000) model accounts for slightly more than half the variance in food transfers to temporarily disabled individuals among the Ache, but measures only food transfers directly. There are other benefits one can provide to others for which people may be willing to pay high short-term costs in order to retain long-term access, for example foraging and technological expertise, political savvy, medical aid, and alliance partnership in warfare (Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming). Benefits that can be provided by one individual but not by others (or less well by others) are expected to be especially valued (Sugiyama & Chacon 2000; Tooby & Cosmides 1996): generous provision of these not only signals coalitional intent, but does so by providing the difficult to replace benefit used in the signal. Social niche cultivation (i.e., the cultivation of socially recognized useful abilities/roles within the social group) is thus one hypothesized outcome of the selection pressure exerted by health risk, yielding interlacing networks of cooperative endeavors encompassing numerous benefit classes, (Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming; Tooby & Cosmides 1996).

Taken together, these ideas can be expressed as a four-factor model in which relative cost to the provider, reliability of provision in relation to need, frequency of provision (all three of which signal commitment to the welfare of the recipient), and relative benefit provided (including how difficult the benefit would be to obtain elsewhere) can vary independently for each potential provider-recipient combination. From this perspective, the generous consistent conferral of benefits to others does not reap enhanced health care provisioning based on the logic of reciprocal altruism. Rather, those who honestly signal positive coalitional intent are for that very reason important individuals for those to whom they signal: reliable allies or "true friends" are a real benefit (e.g., Sugiyama 1996; Tooby & Cosmides 1996). Additionally, those who receive signals of generosity gain not only a coalitional signal, but the benefits conferred as a signal of coalitional intent, and should therefore be even more highly motivated to retain access to those benefits if they are threatened. A major threat to future access to those benefits occurs when their provider is grievously injured. The recipient receives these benefits in a manner closer to byproduct mutualism than to reciprocal altruism per se. This is because the value of benefits conferred loses signal value if they are "repaid."

Can selection maintain the high cost of generous conferral of benefits to others?

While it is clear that health risk forms a potentially potent adaptive problem: how potent a problem and thus how costly a solution can be and still be selected for are difficult to estimate at this time. A myriad of human health risk buffering adaptations have been identified though, and it is hard to imagine that they are not costly to maintain. Many are either homologous or analogous to mechanisms in other species, others more specifically human. Examples include, of course, sexual reproduction (as a response to co-evolving pathogens [Hamilton 1980; Tooby 1982]), the immune system, skin, mucosal membranes, pain, nausea, pathogen respondent anemia (e.g., Profit 1991; Ewald 1994; Hurtado et al. 1999; Nesse & Williams 1994; Weinberg 1984;), fever (Doran et al. 1989; Graham et al. 1990; Kluger 1990; Nesse & Williams 1994), "pregnancy sickness" (Profit 1992), menstruation, fear (Marks 1987; Marks & Nesse 1994) and fear acquisition devices (Tomarken Mineka & Cook; Mineka & Cook 1992), disgust mechanisms (Hait et al. 1997; Rozin & Fallon 1987; Rozin et al. 1999), and food preference adaptations (Nesse & Williams 1994; Rozin 1976, 1996). Many health risk buffering adaptations rely at least in part on a social component. These include precautionary reasoning systems (Fiddick 1999; Fiddick et al. 2000; Stone et al. 2000), and reasoning mechanisms about threat (Rutherford et al. 1996), compassionate emotions (for discussion see e.g., Detwyler 1991; Trinkaus 1983), fear acquisition devices dependent on social learning (Tomarken, Mineka & Cook; Cook & Mineka 1988), and assessments underlying distribution of polygynous marriage (Low 1988). Human mate choice is based in part on cues to, and advertisements of, health (e.g., Buss 1989, 1994; Gangestad & Thornhill 1997; Symons 1979, 1989, 1995; Singh 1993, 1995). Clearly the production and maintenance of these systems are costly both in the short and long term, and yet selection is believed to have produced them nonetheless. The adaptations motivating generous, consistent, non-reciprocal benefit transfers hypothesized to help buffer health risk that are proposed here (Gurven et al. 2000; Kaplan & Hill 1985; Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming; Tooby & Cosmides 1996), can not therefore be excluded from consideration simply on the basis of their day-to-day cost, nor on a hypothetically large discount rate for future health care aid. If the evolutionary benefits of surviving periodic adaptive bottlenecks of health care crises were sufficiently large, then as illustrated with the examples of health risk buffering mechanisms listed above, selection could produce health risk buffering mechanisms that entail high recurrent costs. If generosity itself serves as an honest signal of coalitional intent because of its cost, then even higher costs to asymmetric benefit transfers may be maintained.

Expectations about health risk and the effects of aid during health crises

The question arises, is health risk one of the selection pressures leading to adaptations underlying the kind of asymmetric recurrent, costly benefit transfers at issue, or are these behaviors merely one subset of a more general set of adaptations for cooperation? To determine this, not only must we find that 1) the specific psychology proposed is a feature of the human cognitive architecture (e.g., Gurven et al. 2000; Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama and Scalise Sugiyama forthcoming), 2) the adaptations motivating behavior which buffers health risk are unlikely to evolve by other evolutionary pathways (Sugiyama 1996; Sugiyama & Chacon 2000; Tooby & Cosmides 1996), and 3) selection pressure from health risk has the features necessary to select for adaptations designed to generate the behavior in question: the consistent provisioning of asymmetrical benefits to others over the long-term, at a relatively high cost to the provider. To do this, we must examine the frequency, duration, and fitness effects of pathology in an evolutionarily relevant context.

For selection to have favored health-care provisioning, generosity signaling, and social niche differentiation, a number of predictions regarding health risk are expected to receive support. Firstly, life-threatening health risk which can be buffered by health-care provisioning is expected to occur across individuals throughout the lifespan, even though risk-taking behavior may show facultative lifetime variation and thus higher rates of injury during some life stages. Secondly, for a given individual, occurrence of disabling pathology is predicted to show (a) temporal uncertainty, (b) significant probability of occurring during the lifespan (although that probability may vary somewhat across individuals [Sugiyama & Chacon 2000]), and (c) sufficient duration such that survival would be unlikely without health-care provisioning. Thirdly, high average probable fitness benefits must be realized by health-care provisioning. More precisely, health-care provisioning by providers $j \ldots n$ must provide large enough fitness benefits to individual i to offset, on average, the costs of i's generous, reliable conferral of benefits when healthy: here I test the simpler prediction that health care provisioning reduces probable mortality (Sugiyama & Chacon 2000). Fourthly, strategic allocation of health care provisioning should be directed toward those most likely to contribute to the provisioners' ($j \ldots n$) future fitness (Gurven et al. 2000; Sugiyama 1996; Sugiyama & Chacon 2000; Sugiyama & Scalise Sugiyama forthcoming).

To begin testing these hypotheses, this study reports on the causes, distribution, and duration of injuries and illnesses suffered by Shiwiar hunter-horticulturalists of the Ecuadorian Amazon based on physical evidence and reported occurrence of pathologies. The aim of this study is to determine: (1) what pathologies this population suffers; (2) with what frequency they occur; (3) with what frequency and duration pathology causes disability severe enough to interfere with subsistence activities or necessitate survival assistance over the course of the lifespan; and (4) demographic and fitness effects of individuals having received long-term aid without which they are likely to have died. Data presented were gathered in two communities (resident populations 67 and 87, respectively) during separate field trips by the author in 1994 and 1995. Additional information from this area was collected between 1993-1998 in these and two additional villages.

Study Population

The Shiwiar are a Jivaroan speaking people of approximately 2000 people who live in the upper Amazonian neo-tropical forests of Ecuador and northwestern Peru. Unnavigable rivers form a geographic barrier into Shiwiar territory from the west (Ecuador). Shiwiar hostility toward outsiders has also been a deterrent to colonization dating back to the time of the Incas. Border conflict between Ecuador and Peru continues to limit contact between Ecuadorian Shiwiar and colonists in the east. Prior to the 1970s, Shiwiar lived in scattered households linked by marriage ties and the influence of big men or "juunt" (Descola 1988). Sometime in the 1920s-1930s, a main contingent of the study population pushed northeast into their current territory. Since missionary contact in the late 1970s, Shiwiar have made dirt airstrips around which houses now form loose clusters. Although these airstrips provide some access to medical and other facilities outside of Shiwiar territory via missionary light aircraft, Shiwiar subsistence is still based on foraging and horticulture, and they have severed religious ties with evangelical missionaries.

Shiwiar life is in some ways similar to what we expect of human environments of evolutionary adaptedness: they live in small kin-based egalitarian communities in which some foods are shared; they rely on foraging by hunting and fishing for their dietary fat and protein, and plant products for fruits, starch, construction, and tool material; they have little easy access to western medicine; and they depend on relatively simple technology for their livelihood. Blowguns, muzzle-loading shotguns, and dogs are used in hunting, although single-shot cartridge shotguns are increasingly used when cash is available for the relatively expensive shells. A mixed strategy of blowgun, muzzle-loading shotgun, and hunting dog use yields relatively low failure rates (Sugiyama 2000; Sugiyama in press; Sugiyama & Chacon 2000). Fishing is done with hooks and line and fish poisons. In the rainy season, the bulk of protein comes from hunting, accompanied by fishing with hook and line. As the dry season progresses, fishing gradually increases as rivers become shallow and fishing with poison becomes increasingly efficient (Sugiyama 1998, 2000). Shiwiar do however grow a wide variety of horticultural products, the most important being manioc, plantains, yams, sweet potatoes and maize. The distance of gardens from the owner's house ranges from right next to the house to an hour's walk away. On a day to day basis, in some respects, the use of manioc horticulture may be similar to what would be expected among foragers with fairly reliable but work intensive access to tuberous plant resources; although horticulture involves higher start-up costs, but lower search and travel costs.

Cultural values and disability

Although in this study I operationally define disability as injury or illness preventing an individual from foraging or engaging in other subsistence work, locally accepted conditions under which it is valid to "call in sick" are expected to vary. If Shiwiar had a low threshold for staying home from work the results of this study would be difficult to interpret; this is not the case. *Shiir waras*, literally "good life" or "being," comprises key Shiwiar values. To live a good life is to engage in a set of practices expected of one's age and sex. A good life for men includes hunting, fishing, clearing gardens, hauling large logs for firewood, protecting one's family, being good to one's wife and children, speaking strongly in favor of one's interests, avenging transgressions against one's legitimate interests and those of one's kin group, fearlessness, and independence. For women living a good life means making and maintaining productive gardens, harvesting the produce, caring well for one's husband and children, preparing and serving food, keeping a clean house and house clearing, and, as an index of one's productivity, growing manioc sufficient to prepare and serve large quantities of *nihamanch* to family and visitors.

Kakaram, or power, is a complex concept referring to one's personal, spiritual, and/or political power acquired through and associated with various spiritual qualities (Mader 1999: 295-403). *Kakaram* may be used to refer to men recruited as mercenaries in warfare. However, the term is more generally applied to individuals who speak powerfully, don't complain about hardship, and are recognized as extremely hard workers in a society which values hard work. In behavioral terms, they do what is positively valued among Shiwiar faster, more efficiently, and with greater intensity than others. In this context, disability entails a high degree of injury or illness (see e.g. Sugiyama in press).

Methods

Participant observation, focal person follows, interviews and records of injuries and illness were used to provide an ethnographic context for Shiwiar reactions to injury. Genealogical and life-history data were gathered in formal interviews conducted between 1993 and 1998 in four Shiwiar and closely related villages. Age estimates for younger subjects are based on birth records, which are reliably accurate to the month and year for approximately the last 16 years. For older individuals, the accuracy of age estimates varies depending on the life circumstances of the individuals, whether or not they ever attended school, or the age at which they held a job for which official documentation was necessary. For individuals roughly 30 and older, ages were cross-checked or determined by calculating birth date in relation to significant historical occurrences (e.g., 1942 border conflict with Peru, first contact with missionaries, establishment of a mission) and the known age of other individuals.

A standard procedure was used to gather data on injuries and illness after the informant indicated their consent to participate in the study. Beginning with the right foot, the examination proceeded up the right leg as far as was comfortable for the subject, and then down the left leg. The left and then right arm were examined beginning with the fingers of the left hand, followed by the front and then rear of the torso, the neck, face, and head. Visible scarification and evidence of broken bones were noted on standardized forms depicting line drawing front and rear views of a human form, as well as enlarged views of the hands and feet. Each incident recorded was coded as visible, reported (by informant), current, or some combination of these in order to specify the evidence upon which the recording of each pathology was based. For each scar or evidence of a broken bone observed, the subject was asked to provide information about the cause, activity being engaged in and age at which the event occurred. Informants from one of the sample villages (n=17) were also asked the duration of disability if applicable, and this information cross-checked with other informants. A standard set of questions about past illnesses, injuries, and treatment received (either from a shaman or Western medical practitioner) was then administered.

Potential biases in data recording

Scars on the skin of young individuals are easily identified and their cause readily recalled. Numerous lacerations, abrasions, bites and infections over the lifetime mean that only the most prominent or most recent incidents can be accurately recorded on older individuals. The injuries recorded for adults therefore reflect only the most prominent cases: often the most recent or severe. The methods used in this study were also time consuming, and there may have been individual differences in tolerance for the study, as well as memory effects and reporting bias. These problems could not be entirely solved, but to the extent that they affect results they would result in under-reporting or missing data as opposed to over-reporting. In addition, sufficient independent means of cross-checking information were available such that overestimation or false reporting was highly likely to be exposed.

I addressed reporting bias by using physically observable evidence as the principle source of data. Disability duration and reports of health insults leaving no visible evidence were cross-checked with informants who were present when the incident occurred. Informants were often able to provide many details about the injuries or illnesses of their close kin. Their discussion of health problems or injuries, which shaman caused them, with what kind of *iwianch* (evil spirit), and other details indicated frequent correspondence between informants, particularly for major injuries. Informants asked others to clarify information about which they were unclear, suggesting they expected others to remember significant health insults that had occurred. On the other hand, informants had little interest in minor injuries, even when they could report the cause of the scar in question. Finally, informants joked about injuries that occurred which were considered preventable or foolish. This suggests that, at least for the health insults reported here, memory bias is not so problematic as to damage the general results of the study that emerges from data on long-lasting disability. In fact, memory systems are expected to have evolved to privilege some information over others based on ultimate fitness effects of doing so. Particularly “foolish” causes of injury (e.g., swinging a machete around in play and cutting oneself, jumping off the house floor and sustaining a fracture) may be well remembered specifically because they were clearly preventable. Severe injuries and illness may be well remembered because they can reveal prevention and healing strategies, as well as critical assessment of social support (i.e., separating true committed “friends” from “fair weather friends” [Tooby & Cosmides 1996]).

Results

Age/Sex Distribution of Sample

Physical examination of 19 male and 20 female Shiwiar individuals ranging in age from 3 to 50 was conducted. Table 1 shows the age/sex distribution of the sample. One male included in the 31-40 year old age cohort was not examined during the study because he was not present in the village. However, prior interviews documented the cause and duration of, healing practices used in, and his eventual recovery from a case of near-lethal snakebite. Because prior documentation of all relevant variables was available for this case, it was included in the analysis. The Kruskal Wallis test shows no significant differences between the ages of males and females in the sample overall (X2=28.6, df=28, p=.42) or by ten-year age cohorts (X2=1.514, df=4, p=.82). Removing the aforementioned individual from the sample does not significantly change this result.

Figure 1: Age/Sex Distribution of Sample

Shiwiar core pop: 497; sample 10%
Sample Vils. pop.: 166; sample 24%
Disability vil. pop. 103; sample 16.5%

K-W test for sex differences in age
overall: $X2$=28.6, df=28, p=.42
ten-year cohorts: $X2$=1.514, df=4, p=.82

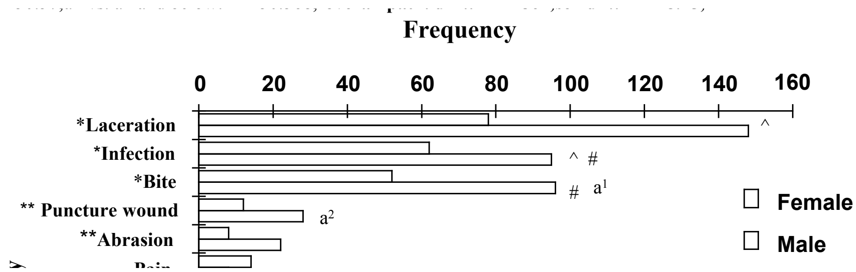
What health insults do Shiwiar suffer, and with what frequency do they occur?

678 injuries and illnesses were recorded among the 40 individuals examined. Significant differences were observed in the relative frequencies with which different kinds of health insults were observed. The most commonly observed were lacerations, followed by infections (including infectious disease), bites and stings, puncture wounds, abrasions, pain (either chronic or periodic), broken bones, and burns (X^2=1861, df=16, p<.000). Figure 2 provides an overview of the relative frequency of different classes of health insults by sex of victim.

Sex differences in health insults suffered:

Shiwiar males suffered significantly more health insults than females (n=430 and 248 respectively; X^2=48.855, df=1, p<.000). This was true for all types of health insults for which there were adequate sample sizes, including lacerations (n=226, X^2=21.68, df=1, p<.000), infections (n=157, X^2=6.94, df=1, p=.008), bites/stings (n=148, X^2=13.08, df=1, p<.000), puncture wounds (n=40, X^2=6.4, df=1, p=.011), and abrasions (n= 30, X^2=6.53, df=1, p=.011). Males also suffered more burns than females, though the difference was not quite statistically significant by conventional standards (n=13, X^2=3.77, df=1, p=.052). Males and females did not differ in number of broken bones (n=17, X^2=.059, df=1, p>.8), contusions (n=5, X^2=.2, df=1, p=.655), scars of unknown cause (n=13, X^2=.077, df=1, p=.782), or incidence of severe chronic or acute pain (n=22, X^2=1.64, df=1, p=.2), although sample size for each was relatively small (Figure 2).

Figure 2: Frequency of Health Insult by Type and Sex of Victim



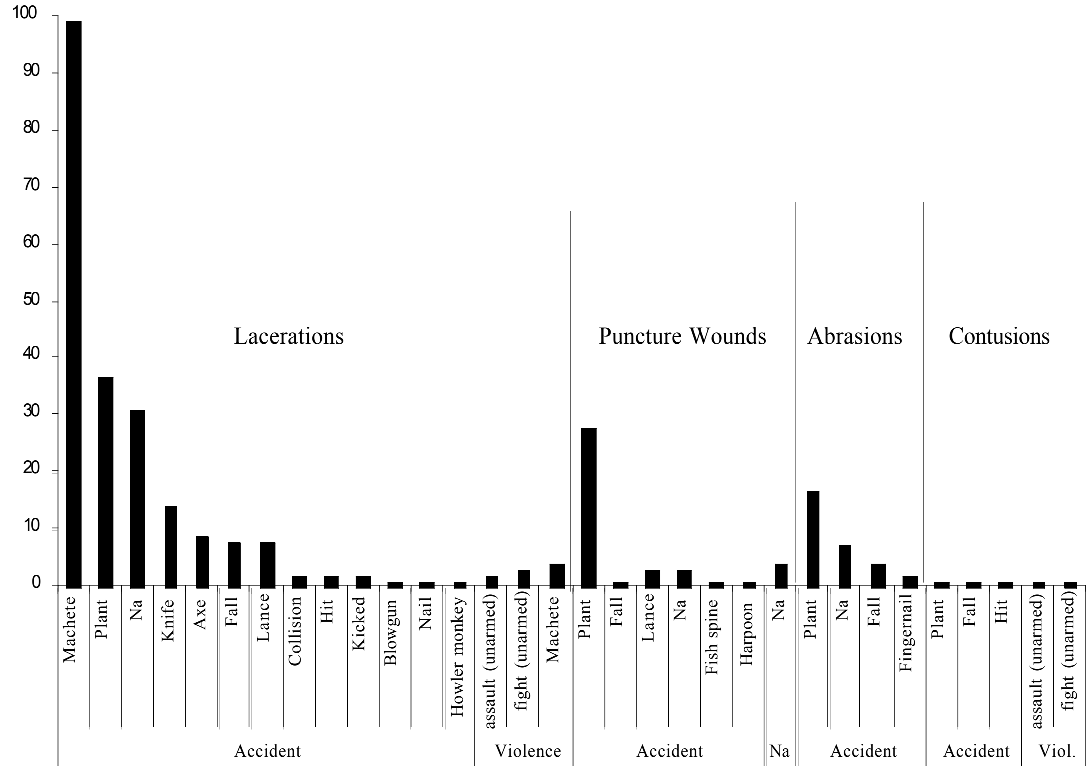
Soft-tissue wounds:

As a class, soft-tissue wounds not caused by animal bites or stings or resulting in significant subsequent infection (i.e., lacerations, punctures, contusions, and abrasions) accounted for 301 (46%) of the 678 health insults observed. Significantly more soft-tissue wounds were observed than infections, the next most frequently observed type of pathology (Figure 2, X^2=45.275, df=1, p<.000). Soft-tissue wounds ranged from small abrasions or cuts to serious wounds (e.g., accidental finger amputation, heel slashed to bone, 5-inch-long gash in thigh). If serious infection was reported, pathology was coded as infection because this was usually the more serious condition. Fourteen incidences of soft-tissue wound resulted in serious bacterial infection, or 4.44% of the 315 primary soft-tissue rupture wounds recorded.

Significantly more lacerations were observed than other types of soft-tissue wound, followed by puncture wounds, abrasion and contusion (X^2=411.31, df=3, p=.000). Sampling bias may account for some of this difference: contusions can only be seen if the injury is current, and abrasions may be less likely to leave scars than lacerations. Nevertheless, the two most prevalent causes of soft-tissue wound--machete cuts and injury from branches, sticks, and logs--are also the most frequently cited causes of soft-tissue trauma overall, and these sources of injury appear more likely to cause laceration than contusion or abrasion. Most lacerations were attributable to accidental causes: machete (46%), running into, being hit by, falling or stepping on branches, sticks, or logs [coded as caused by “plant” (16%)], knife (6.5%), axe (4.2%), and lance (3.7%). In addition, nine (4%) were sustained during interpersonal violent encounters (Figure 4).

All observed puncture wounds stemmed from accidental causes. These included punctures from spines (38.9%), branches or sticks (36%), lance (8.3%), fish spines (2.78%), and harpoon (2.78%). 8.3% of puncture wounds were from unidentifiable causes. Similarly, all abrasions were due to accidental causes: branches, sticks, logs, spines (i.e., “plants”), falls, and a fingernail. Finally, of the 5 contusions observed, 3 were due to accidents and 2 to interpersonal violence.

Figure 3: Frequency of Soft Tissue Wounds by Cause



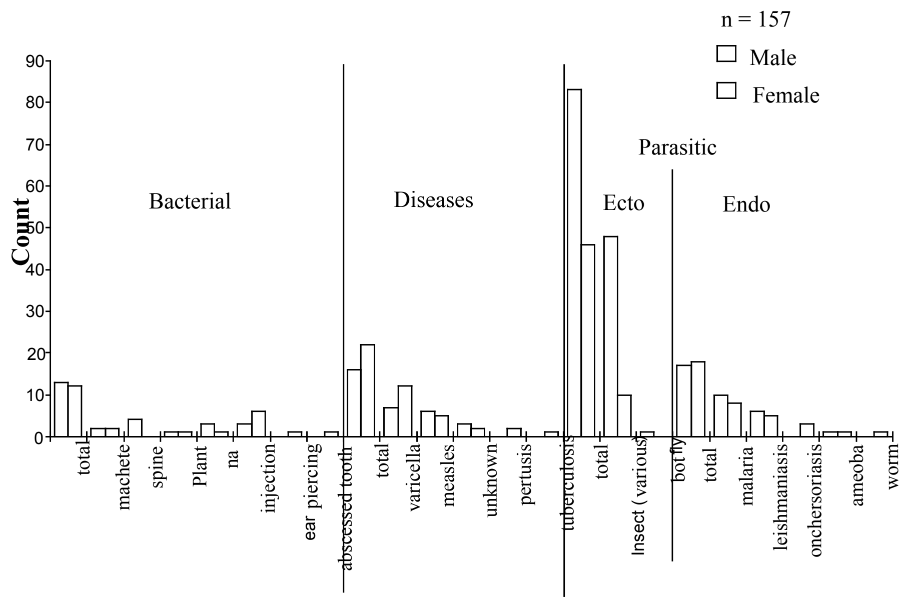
Infections:

Infections -- from disease, parasitic infection, and bacterial infection of wounds -- were the second most frequently observed class of health insults observed, accounting for 157 of the 678 cases in the sample (23.2%). While number of infections observed did not differ significantly from number of bites and stings, the next most frequently observed class of health insults (X^2=.859, df=1, p=.354), bites and stings infections were more frequently observed than all the remaining types of pathology combined (i.e., all pathology excluding soft-tissue wounds and bites/stings [X^2=31.55, df=1, p=.000]). Nevertheless, infectious disease is certainly underreported in this sample. Few infectious diseases leave visible traces, and only the most recent or severe instances are likely to have been recalled or recorded. For example, I made no attempt to ask subjects about common colds or flu, because while actual frequency was expected to be high, reported frequency was not expected to be accurate. Conversely, informants were asked if they had suffered from the following infectious diseases or parasitic infections known to occur in Shiwiar territory: measles, pertusis, tuberculosis, varicella, leishmaniasis, and malaria.

Parasites accounted for 94 of 157 infections recorded (60%). Ectoparasites were the most common form of infectious condition, accounting for 63% of parasitic infections and 37.6% of infectious conditions overall. Ectoparasites were identified based on their having left visible scars. These scars usually resulted from informants having scratched the skin off the affected area, causing minor secondary bacterial infection or delaying the healing process. None of these secondary infections were reported to be serious, consistent with the visible evidence. Common ectoparasites endemic to the study area include mosquitoes, no-see-ums, chiggers, ticks, and bot flies. Although some types of ectoparasites can cause disabling bacterial infection if left untreated (e.g., major infestation of sand flea larvae reportedly caused death among some Yanomamo orphans [Chagnon 1997; Hagen et al. 2000]), none of those reported here caused significant infection. Endoparasitic infection accounted for the remaining 37% of parasitic conditions, and 22.3% of infectious conditions overall. Again, endoparasitic infection is clearly underestimated in this sample. Gastrointestinal amoebas, giardia, and worms are endemic in this population, but these were not usually recorded because it was impossible to get accurate or verifiable reports of periodic bouts of symptomatic diarrhea. The exception to this was a current case of amoebic dysentery observed at the time of the study.

Malaria (*plasmodium vivax, plasmodium falciperum)* occurs in periodic outbreaks in the study area. Informants readily recall bouts of malaria, including when they occurred and whether they resulted in disability. These bouts were easily corroborated by other informants. Eighteen of the 39 individuals surveyed (46%) had suffered from malaria, often in recurring bouts. Eleven individuals showed evidence of and/or reported leishmaniasis (28%); 8 of whom were eventually treated with a course of medication, although some did not complete the full course of treatment. Evidence of onchersoriasis (river blindness) was seen in 3 individuals. Finally, one individual had an infestation of a large unidentified "worm" in the chest area requiring surgical removal at a mission hospital.

Figure 4: Frequency of Infections by Cause



Infectious disease was the second largest class of infectious condition, accounting for 24% of instances recorded. Of the 39 individuals for whom data on disease was recorded, 49% had suffered varicella (chickenpox), 28% sarampion (measles), 5% pertusis, and 2% clear symptoms of later-stage tuberculosis. 23% of the subjects were vaccinated against measles. In addition, 13% reported cases of severe febrile or other illnesses whose specific medical cause could not be identified based on informants' descriptions (informants referred to these, along with most other serious conditions, as the product of shamanistic attacks).

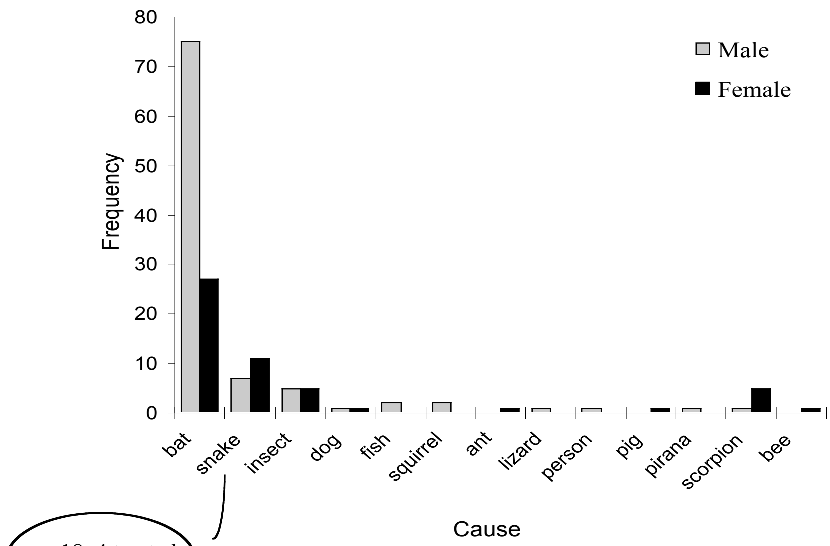
Twenty-five cases of bacterial infection significant enough to result in either drainage of puss or other clear evidence of infection (e.g., tissue inflammation or stench) were recorded: 14 of these were subsequent to accidental laceration (6% of lacerations observed), and 11 were from non-accidental causes. One of the latter, an abscessed tooth severe enough to be draining puss caused extreme pain for months until it could be treated by a dentist. This condition was extant at the time of the study (Walker et. al 1998 for systematic data on dental health in a closely related population).

Bites and stings:

Bites and stings are a fact of life in the study area. Most come from ectoparasitic insects (see above). Numerous stings from bees and wasps, the latter present in swarms during the dry season, are also common. During the height of the dry season one can hardly sit down or lean against a house post without being stung by a wasp. As with most insect bites, most bee and wasp stings are too prevalent to accurately record, and most only cause minor pain and localized swelling. An exception is the *conga*, a species of ground living wasp that causes severe pain lasting several hours. Another exception are Africanized bees, reported to have entered the study area in 1998 and to have inflicted serious injury on a few individuals; to date no deaths have been reported.

The majority of animal bites come from vampire bats, and the majority of victims were young children--predominantly boys--who, according to informants, slept either without mosquito nets or fitfully, thus exposing their bodies to the bats (Figure 5). At the time of the study, rabies was not widespread in the study area, although in 1997 a rabies outbreak among cattle was reported just north of the study area.

Figure 5: Frequency of Bites and Stings



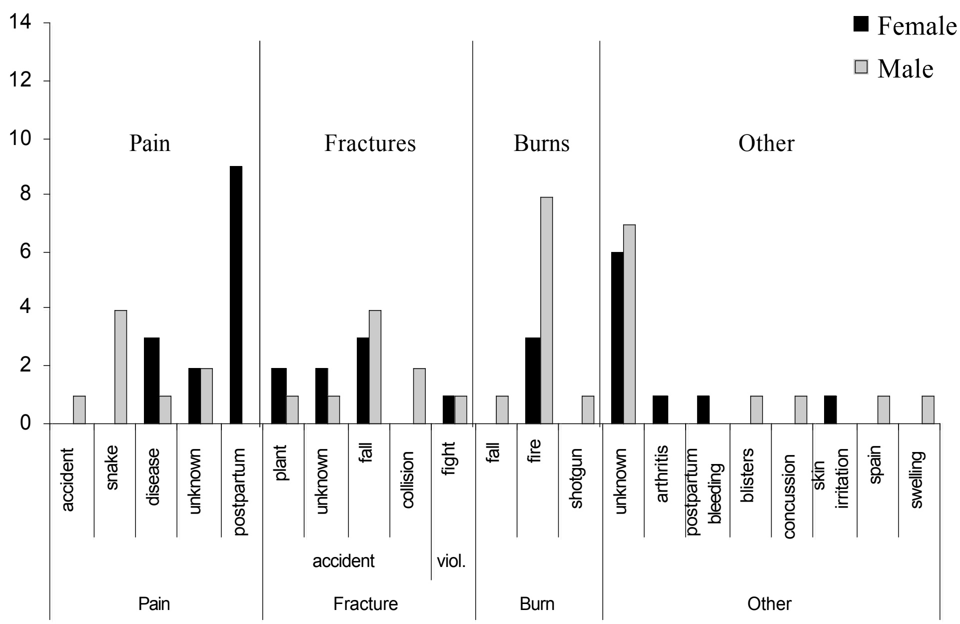
Scorpion stings and caterpillar toxin may cause extreme pain and disability lasting up to two days, but by far the most significant venomous animals in the study area are snakes. Snakebite continues to be a significant cause of death worldwide, and specific precautionary adaptations designed to reduce its occurrence are posited for humans and other primate species (e.g., Cook & Mineka 1988). Ecuadorian Amazon is home to numerous potentially deadly species. 18 cases of snakebite were reported among fourteen of the forty individuals in the study (Figure 5): 4 were treated with antivenin, 2 do not appear to have resulted in significant amounts of envenomation, and 12 were untreated at the time of the bite or were treated by shamans. While shamans are effective in treating certain conditions (e.g., controlling bleeding, setting broken bones, preventing infection of lacerations), and medicinal plants appear to be effective in treating malaria and dysentery among adults (albeit with harsh side effects), there is no evidence of effective shamanic curing of snakebites among the Shiwiar.

Other health insults:

Chronic or prolonged pain (22), fractures (17), burns (13) and a variety of other conditions round out the health insults observed in this sample (Figure 6). Pain often resulted from other health insults, so here recording of pain is limited to conditions extending longer than, or aside from, the primary condition. For instance, the case of pain caused by snakebite recorded here (Figure 6) is not primary pain associated with the bite, but chronic pain suffered as a consequence of walking upon a foot deformed as the result of snakebite.

Of 17 broken bones recorded, 15 (88%) were sustained in accidents and 2 (12%) were sustained during fights. Reports of broken bones were verified by cross-checking with other informants, and by feeling for evidence of a healed fracture. Broken bones are sometimes set by a shaman, some of whom are reportedly skilled at this procedure.

Figure 6: Frequency of Other Health Insults



From what causes, and with what frequency and duration does temporary disability occur?

Seventeen informants from one sample village were asked the duration of disability, if any, associated with each observed health insult, and the information cross-checked with other informants. The Kruskal Wallis test shows that the sex composition of this sub-sample, 8 males and 9 females, does not significantly differ from the larger sample (X^2=.100, df=1, p=.725) although it does contain an older age cohort (comprised mostly of individuals over 15 [X^2=14.31, df=1, p=.000]). Informant's estimates of disability duration were most often reported in even units of days, weeks, months, etc. I converted these to number of days for presentation here. Table 7 shows the frequency with which disabilities of various durations were reported. While most of the 215 health insults recorded in this sub-sample were minor and resulted in no disability, 86 (40%) resulted in disability lasting a day or longer that could be confidently established, 66 (30.7%) resulted in disability lasting a week or longer, 51 (23.7%) lasted 14 days or longer, and 32 (14.9%) lasted a month or longer (Figure 7). In addition, 4 conditions were chronic and resulted in reported periodic disability of varying unspecified duration.

Figure 7: Frequency of Disability by Duration

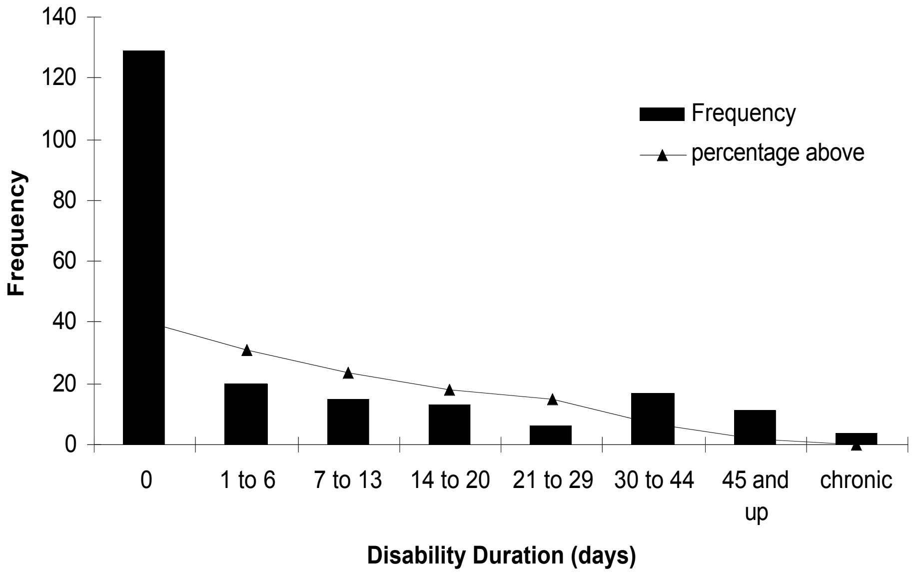


Table 1 summarizes the health insults resulting in disability in the sub-sample. They include 28 infections (13.02% of total cases in sub-sample), 15 bites (6.97%), 13 cases of debilitating pain (6.05%), 11 broken bones (5.12%), 10 lacerations (4.65%), 4 stings (1.86%), and 1 burn, 1 puncture wound, 1 case of postpartum bleeding, and 1 case of multiple simultaneous contusions of unknown origin (attributed to shamanistic attack). Those that caused prolonged injury of two weeks or longer include 10 of the 11 broken bones, 9 bites (8 of 11 of which were snakebites), 6 lacerations, 6 cases of malaria, 5 bacterial infections stemming from lacerations or puncture wounds, 3 infectious diseases of unknown type, 2 cases of post-partum complications (1 near-lethal blood loss, 1 severe pain), 1 multiple contusion, 1 abscessed tooth, 1 acute pain from disease of unknown type, 1 amoebic infestation and 1 puncture wound. Other conditions resulting in disability ranging from 5 days to a year were observed during four study periods

Table 1: Frequency of Disability Duration by Health Insult

Health insult	Duration in days	Total Cases
bite/sting	1	5
	3	1
	7	3
	21	2
	30	2
	45	1
	60	2
	90	1
	180	1
	365	1
bite/sting Total		**19**
bleeding Total	30	**1**
fractures	7	1
	14	3
	15	1
	20	1
	21	1
	30	3
	45	1
fractures Total		**11**
burn Total	7	**1**
concussion	3	**1**

Total		
contusion Total	30	**1**
infection	1	3
	2	1
	6	1
	7	4
	10	1
	12	1
	14	2
	15	3
	21	2
	30	7
	45	2
	60	1
infection Total		**28**
laceration	4	1
	7	3
	11	1
	14	1
	23	1
	30	2
	60	1
laceration Total		**10**
pain	2	7
	17	1
	30	1
	chronic	4
pain Total		**13**
puncture Total	14	**1**
Grand Total		**86**

between 1994 and 1998, but victims were not part of the sample included here. These included knee injury, tooth abscess, snakebite, stroke, malaria, whooping cough, post-partum infection, respiratory ailment and severe foot fungus. In contrast, broken fingers, a severe beating resulting in black eyes and facial contusions, bites from vampire bats, a case in which the tip of a machete was imbedded in the chin, severe laceration of the hand, and a puncture wound from thorn passing through the thumbnail into the thumb were observed over the same period but did not result in observable disability. Victims of these incidents continued working with only minor pause to treat the wound.

When they occur, some types of injury/illness are significantly more likely to cause disability than expected if all health insults are equally likely to cause disability (for those resulting in disability, X^2=20.06, df=9, p=.018 [Table 2]). Fractures are significantly more likely to cause temporary disability than expected (X^2=11.438, df=1, p=.001). Snakebite is highly likely to cause long-term disability. Ten cases for which duration of disability is estimated and was cross-checked were recorded. In four of these instances, antivenin was administered. Eight of the 10 cases accounted for 502 days of disability, with 1 case resulting in permanent disfigurement of the victim's foot. This and another case resulted in major tissue necrosis and gangrene, resulting in disability of a year and 6 months, respectively. The foot disfigurement resulted in a lifelong reduction in mobility due to a pronounced limp, as well as ancillary pain during travel. Interviews and observation indicate that this limp resulted in an impaired gait and curtailment of activities for which quick movement is necessary (e.g., felling large trees, pursuit of game with hunting dogs), as well as limiting the victim's ability to carry heavy loads and to walk long distances at normal speed without pain. Conversely, lacerations appear to be less likely to cause disability than expected (X^2=5.675, df=1, p=.017). Many minor lacerations leave scars, and local knowledge about how to stop bleeding and infection from lacerations through application of plants with coagulant and antibiotic properties appears to be widespread. There was no significant difference between observed and expected frequency with which infections and pain resulted in temporary disability (X^2=1.986, df=1, p=.159; X^2=.693, df=1, p=.405, respectively).

Table 2: Chi-Squared tests: Frequency of Disability by Type of Health Insult

	Observed N	Expected N	Residual	Chi-Square	df	p=
bite/sting	19	18.0	1.0			
bleeding	1	.4	.6			
fracture	12	4.9	7.1	*10.858	1	.001
burn	1	.4	.6			
concussion	1	.4	.6			
contusion	1	.8	.2			
infection	27	30.7	-3.7	.693	1	.405
laceration	10	19.2	-9.2	*5.675	1	.017
pain	13	9.0	4.0	1.986	1	.159
puncture	1	2.0	-1.0			
Total	**86**			***20.060**	**9**	**.018**

Test Statistics
a 6 cells (60.0%) have expected frequencies less than 5. The minimum expected cell frequency is .4.
* indicates statistically significant at the p<.05 level

Is Shiwiar disability primarily due to Western/Industrial impact?

Neither the Shiwiar nor any other group are a perfect model of our evolutionary past--no extant or prehistoric group provides a comprehensive snapshot of the statistical composite of health risks and foraging, social, and demographic conditions that shaped the hypothesized risk-buffering adaptations over the course of their evolution. Nevertheless, the data do provide a window into the range and frequency of disabling conditions suffered by people living in small-scale society with little consistent access to Western medicine who depend on foraging for a significant portion of their subsistence. However, results here would clearly lose relevance in proportion to the degree that Shiwiar disabling conditions were the result of industrial technology, diseases, or a non-foraging lifestyle.

Numerous injuries come from machete wounds and infections stemming from them. As noted however, lacerations from machetes are more likely to leave visible evidence than many other types of health insult (e.g., infectious disease, insect bites, endoparasitic infection), and are therefore likely to be over-represented by the methods used in this study. On the other hand, because machete cuts leave clear physical evidence on the skin, all machete lacerations causing prolonged disability among sample individuals were almost certainly recorded. Because Shiwiar use machetes as general-purpose cutting, scraping, chopping, and digging tools (and occasionally in hand-to-hand combat), frequency of exposure to machete injury may be greater than other single sources. Without comparative data it is difficult to know whether machetes pose a greater or lesser risk of injury/disability than pre-industrial cutting implements (Sugiyama n.d. for discussion).

Nevertheless, long-term disabling incidents reported here are not overwhelmingly due to Western industrial technology or causes. The number of cases of month-long or longer disability attributable to industrial technology (2 machete lacerations and 2 machete cuts leading to subsequent infection [14.28%]), is less than that from all naturally occurring sources (85.72%). Furthermore, industrial technology is less likely to cause disability of a month or more than expected from their prevalence in this sample (20.6% vs. 79.4% respectively). Taken together, encounters with naturally occurring causes of laceration (e.g., branches, logs, spines) produced as many cases of disability lasting a month or longer as Western tools, even though the former represent a smaller proportion of the total cases of health insults observed (13.7% vs. 19.4% respectively). Snakebites, fractures, and infections of endogenous cause are all more frequent causes of prolonged disability than machetes, even in this society where machetes are ubiquitous all-purpose tools. Fractures are more likely to result in long-lasting disability than are lacerations; the primary cause of fractures is collision with logs and branches. Snakes arguably present the greatest threat: snakebite not only appears to be highly likely to result in disability when they occur, but also resulted in the longest lasting disabilities.

How many individuals suffer health insults likely to be lethal without health care provisioning?

As of 1998, there were 410 persons living in 6 villages within the core Shiwiar study area, with an additional 87 siblings or offspring of core Shiwiar individuals living in surrounding villages. 166 persons claim they reside in the 2 villages from which data were collected (63 and 103, respectively), the number of people resident in the villages at any given time varies as people go visiting or on extended foraging trips. The sample of 40 individuals thus represents 24% of the total population in these villages, and 10.25% of the population of the core study area. The 17-person disability sample represents 16.5% of the population of village 2.

Both short- and long-term disability were widely distributed across individuals in the sub-sample; 16 of the 17 individuals reported disability lasting 7 days or longer (94%), 15 reported disability of 14 days or longer (88%), and 11 reported disability of 30 days or longer (64.7%) (Table 3). A specific age of occurrence was reported for 131 of the 215 health insults recorded; 51 were cases in which disability was observed. There is no significant correlation between age at which a pathology occurred and duration of disability (r^2= -.105, p=.465).

Table 3: Disability Duration and Reproductive Success by Individual

ID	**age**	**sex**	**disability duration (days)**				**RS (descending generations)**				**Descendants % population**	
ID	*age*	*sex*	*total*	*7-13*	*14-29*	*30+*	*1st*	*2nd*	*total*	*in village*	*% village*	*% tot. po*
8	16	f	2	1	1	0	0	0	0	0	0	0
5 [c]	18	f	8	2	3	2	0	0	0	0	0	0
10 [a, c]	18	f	3	0	1	1	2	0	2	2	1.94	.40
6 [c]	25	f	1	0	0	1	0	0	0	0	0	0
16 [a, b, c]	27	f	6	0	1	3	2	0	2	2	1.94	.40
12 [a, b, c]	29	f	14	1	1	4	8[e]	0	8	8 [e]	7.78	1.61
11 [a, b]	37	f	4	1	0	3	9[d]	5[f]	14	7[d]	6.80	2.82
2 [a, b, c]	43	f	10	2	3	5	10	8	18	15	14.56	3.6
17	7	m	2	0	2	0	0	0	0	0	0	0
15 [c]	15	m	5	0	3	2	0	0	0	0	0	0
1 [a, c]	22	m	4	2	0	2	2	0	2	2	1.94	.40
7 [a]	24	m	7	1	5	0	3	0	3	3	2.91	6.0
14 [a]	34	m	1	0	0	0	9[e]	0	9	9 [e]	8.74	1.81
3 [a, b]	36	m	1	na	na	1	3	0	3	3	2.91	.60
4 [a]	37	m	3	2	1	0	5	1	6	6	5.83	1.20
9 [a]	43	m	3	2	0	0	9[d]	5[f]	14	7[d]	6.80	2.82
13 [a, c]	50	m	8	1	1	3	11	14	25	24	23.30	5.03
Total			**82**	**15**	**22**	**27**	**54***	**28***	**82***	**73***	**70.87***	**16.49***

[a] individuals who had begun reproduction by time of the study.
[b] individuals who suffered pathology likely to be lethal without provisioning after age of first reproduction (during socially recognized adulthood).
[c] individuals who suffered pathology likely to be lethal without provisioning before age of first reproduction.
[d] represents identical individuals: offspring of a married couple both included in the sample.
[e] 8 of these 9 are identical individuals: offspring of a married couple both included in the sample.
[f] represents identical individuals:
*Totals calculated based on descendants of a couple both of whom are included in the subsample only once.

What are the demographic and fitness effects of health care provisioning?

Besides the 51 cases of disability for which an age of occurrence was available, 7 cases were identified either as occurring during "childhood" or before the birth of the victim's firstborn child. Genealogical data is available for all individuals in the sub-sample, making it possible to calculate whether or not an individual had begun reproduction, and if so, the number of offspring who survived prior to the pathology, for 59 cases of disability (Table 4).

Using age of disability occurrence and genealogical data allows calculation of the probable effects of disability on reproduction and mortality. Thirty-three of 59 (55.9%) cases of disability lasting from 1 to 365 days affected individuals before, and 26 of 59 (44%) cases affected individuals after first reproduction. The former includes one unmarried woman with no children who, at 26, was well past the usual age of marriage.13 of the 33 pre-reproduction (22%) and 14 of the 26 post-first-reproduction cases (53.85%) caused disability of a month or longer. The 13 pre-reproduction incidents were distributed among 9 of the 17 individuals (52.94%) in the disability subsample. The 14 post-first-reproduction incidents were distributed among 5 of the 12 individuals in the sub-sample who had begun reproduction at the time of the study (42%). Of these 5 individuals, none were each other's mate. However, two of these five people have offspring with a person in the sample who did not suffer a recorded life-threatening health crisis (Table 4).

Table 4: Disability Duration by Age of Occurrence

Duration/days	***Age***															***Total***
	juvenile	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**30**	**35**	**37**	**39**	**41**	**43**	
1	4							1								5
2	1															1
3			1										1			2
4				1												1
6	1															1
7	6				1		1		1		1			1		11
10															1	1
14	2	2					1			1					1	7
15	3	1														4
17	1															1
20	1															1
21	2			1												3
30	7						1		1			1			1	11
45	2		1													3
60	1			1		1						1				4
90	1															1
180			1													1
365	1															1
Total	**33**	**3**	**3**	**3**	**1**	**1**	**3**	**1**	**2**	**1**	**1**	**2**	**1**	**1**	**3**	**59**

If provisioning is required for individuals to survive disability of 30 days or longer, then 11 of 17 individuals in the sub-sample (64.7%) would have died prior to the study period, 5 of whom had begun reproduction by the time of the study. Without provisioning, even if (1) all other living individuals in the village suffered no significant health insults and therefore no higher rate of mortality, and (2) there was no increase in juvenile mortality associated with increases in adult mortality, then a village population reduction of 6.6% would be associated with mortality from lack of provisioning. This estimate is extremely conservative however.

Shiwiar practice preferential cross-cousin marriage, a period of extended bride-service, and matri-local residence. This effectively means that they live in relatively small groups whose core is descended from a few individuals. In this kind of situation, strategic health-care altruism can have large effects on subsequent generations and the population structure as a whole. Using age of disability occurrence in combination with genealogical data makes it possible to calculate the number of surviving offspring and grand-offspring that would not have been born without health-care provisioning. Fifty-four offspring and twenty-eight grandchildren were born to individuals in the sample, even though only two sample individuals had completed or were approaching probable completed fertility. In addition several reproductive-age individuals in the sample were descendants of other sample individuals. Forty-six of the 54 (82%) members of the first descending generation of sample individuals were born to individuals after the person survived an incident likely to be fatal without health-care provisioning. Twenty-seven of 28 (96.4%) members of the second descending generation were born after a direct ancestor in the sample survived such an incident. In fact, three sample individuals (ID numbers 2, 11, and 13) who survived pathology expected to be lethal without health-care provisioning are either the mother or grandparent of the 27 second-generation descendants. Overall, these three individuals are either the parent or grandparent of 46 or 45% of subsample village residents, and 11.5 % of the Shiwiar population in the study area. One (id # 13), is the parent or grandparent of 23% of the subsample village and 5% of the Shiwiar population block. Another, (id # 2) is the direct ancestor of 14.5% of the village and 3.6% of the population (Table 3).

Strategic health care provided to two of these people had large political as well as fitness effects. Informant 13 suffered a year of disability due to snakebite as a young man. Tissue necrosis left him with a deformed foot. Throughout that disability, the man was moved by allies from house to house across Shiwiar territory to escape enemies of his father, a noted shaman and warrior who was targeted and eventually killed in warfare. Not all individuals are provided with this extreme level of care. Even though disabled, the man later distinguished himself as a warrior, and as a young man was called to live with his mother-in-law as headman of the village in which he now resides. He is now one of the two *juunt*—big men or elders—of this village. The second individual (#2) is his sister-in-law: their kin group forms the basis for one of the two dominant coalitions in the Shiwiar study area.

Discussion

If Shiwiar experience health risk and disability within the normal range of that experienced by foraging humans, then the data presented here is sufficient to have cast doubt upon the hypotheses that long-term disability risk formed a selection pressure for adaptations motivating (1) long-term asymmetrical conferral of benefits to others and (2) social niche specialization. This is not the case: data presented here indicate that, as predicted, health risk is a recurrent feature of Shiwiar life. Disabling conditions were observed in individuals at all stages of the lifespan, suggesting temporal uncertainty about the timing of occurrence and, consequently, the need to consistently engage in behaviors that insure health-care provisioning. Almost all individuals suffer disability lasting 7 days or longer, almost 90% suffer disability of 14 days or longer, and over 60% suffer disability of 30 days or longer. Without provisioning, over 60% of the sub-sample are unlikely to have survived--or, at the very least, the mortality rate of the sub-sample would be much higher. Almost half of the cases of disability that would be lethal without provisioning occurred during the adult lifespan, consistent with the hypothesis that adult strategies functioning to elicit provisioning would have evolved once the dietary basis for such provisioning was in place. Further, these strategies could entail relatively high fitness costs over extended periods, because the fitness costs of not employing them are so high. The effects of provisioning on individual fitness are dramatic. One man who survived after extended health crisis related protection and provisioning subsequently sired or grandfathered 23% of the subsample village and 5% of the Shiwiar population block. One woman who also survived because of protection and provisioning is the ancestress of 14.5% of the village and 3.6% of the population block. Heritable traits conferring these levels of fitness advantage are expected to spread through a population if they arise.

In short, results indicate that among the Shiwiar (a) health insults occur frequently throughout the lifespan, (b) these periods are temporally unpredictable and (c) not primarily attributable to impacts from the Western/Industrial world, (d) most individuals suffer health insults during their lifetimes that are likely to have been lethal without extended provisioning, and (e) the Shiwiar population structure and lifeway is dependent upon infrequent but extended provisioning to temporarily disabled individuals. These findings suggest that selection could favor adaptations motivating individuals to behave in ways that are costly in the short term, if they function to maintaining relationships that yield aid during health care crises.

The data presented here are therefore consonant with the theory that health risk could have contributed significant selection pressure for adaptations motivating individuals to attempt to generously provide fitness benefits to others because providers of such benefits suffer lower mortality during infrequent, unpredictable bouts of disabling pathology. The design of the proposed adaptations is consistent with ethnographically observed, asymmetrically large benefit transfers between individuals which are not directly reciprocated, such as those seen in some types of food transfers between individuals/households in foraging societies, as well as a range of other benefit transfers which characterize the complex cooperative social networks of human society, and the prestige associated with providing these benefits.

Evidence regarding the frequency, duration, and fitness effects of disabling conditions in forager and forager-horticulturalist societies with little access to Western medicine is sparse. Given this, and the hypothesized importance of health risk for the evolution of human sociality, studies such as this one would be profitably added to the basic data collected on all remaining foraging and forager-horticulturalist societies. Comparative data to estimate disability risk, as well as the relative fitness benefits of health-care altruism within specific populations is needed to estimate the probable strength of selection pressure from health risk. This will begin to delineate how often, consistently, and generously one must signal interest in other's interests to effectively garner aid when disabled, as well as the probable efficacy of this strategy for eliciting long-term disability assistance or health-care altruism.

References

Aiello L, Wheeler P. 1995. The expensive tissue hypothesis: the brain and the digestive system in human and primate evolution. *Current Anthropology* 36(2):199-221.

Alejandro, P. 1996. *Notes on populational significance of paleopathological conditions : health, illness and death in the past*. Alejandro, P. (Ed). Barcelona: Fundaci.

Allen, L.H. 1984. Functional indicators of nutritional status of the whole individual or the community. *Clinical Nutrition* 3:169-75.

Altmann, S.A. 1991. Diets of yearling female primates predict lifetime fitness. *Proceedings of the National Academy of Science USA* 88:420-423.

Alvarez, H. 2000. Grandmother hypothesis and primate life histories. *American Journal of Physical Anthropology* 113:435-450.

Aufderheide, A.C. and Rodriguez-Martin, C. *The Cambridge encyclopedia of human paleopathology*. Cambridge: Cambridge University, 1998.

Bailey, R.C. *The Behavioral Ecology of Efe Pygmy Men in the Ituri Forest, Zaire*. Ann Arbor: Museum of Anthropology, University of Michigan, 1991.

Baksh, M. and A. Johnson. 1990. Insurance policies among the Machiguenga: An ethnographic analysis of risk management in a non-western society. In *Risk and uncertainty in tribal and peasant economies*, E. Cashdan, (Ed.). San Francisco, CA: Westview. pp.193-228.

Berger, T.D. and Trinkaus, E. 1995. Patterns of trauma among the Neanderthals. *Journal of Archaeological Science* 22:841-852.

Blurton Jones, N. 1984. A selfish origin for human food sharing: Tolerated theft. *Ethology and Sociobiology* 5:1-3.

Blurton Jones, N. 1987. Tolerated theft, suggestions about the ecology and evolution of sharing, hoarding and scrounging. *Social Science Information 26*: 31-54.

Blurton Jones N.G., Marlowe F. 2002. Selection for delayed maturity: does it take 20 years to learn to hunt and gather? *Human Nature* 13(2): 199-238.
Bogin B. 1999. *Patterns of human growth*. Cambridge: Cambridge University Press.
Bush, H. & Zvelebil, M. 1991. *Health in past societies : biocultural interpretations of human skeletal remains in archaeological contexts* Oxford: Tempus Reparatum.
Buss, D. 1987. Sex differences in human mate preferences: Evolutionary hypotheses testing in 37 cultures. *Behavioral and Brain Sciences*, 12:1-49.
Buss, D. 1994. *The Evolution of Desire: Strategies of human mating*. New York: Basic Books.
Buzina, R., C. J. Bates, J. van der Beek, G. Brubacher, R. K. Chandra, L. Hallberg, J. Heseker, W. Mertz, K. Pietrzik, E. Pollitt, A. Pradilla, K. Subticanec, H. H. Sandstead, W. Schalch, G. B. Spurr, and J. Westenhofer. 1989. Workshop on functional significance of mild-to-moderate malnutrition. *American Journal of Clinical Nutrition* 50:172-76.
Byrne R.W. 1997. Machiavellian intelligence. *Evolutionary Anthropology* 5:172-180.
Cashdan, E. 1985. Coping with risk: Reciprocity among the Basarwa of Northern Botswana. *Man 20*:454-474
Cashdan, E. 1990. *Risk and Uncertainty in Tribal and Peasant Economies*. San Francisco: Westview.
Chagnon, N.A. 1975. Genealogy, Solidarity and Relatedness: Limits to local group size and patterns of fissioning in an expanding population. *Yearbook of Physical Anthropology* 19:95-110.
Chagnon, N.A. 1979. Mate competition, favoring close kin, and village fissioning among the Yanomamö Indians. In *Evolutionary Biology and Human Social Behavior: An Anthropological Perspective*, N. A. Chagnon & W. Irons, (Eds.). North Scituate, Massachusetts: Duxbury Press. pp. 86-131.
Charnov E.L. 1993. *Life history invariants: some explanations of symmetry in evolutionary ecology*. Oxford: Oxford University.
Cook, M. and Mineka, S. 1991. Selective associations in the origins of phobic fears and their implications for behavior therapy. In Martin PR editor. *Handbook of behavior therapy and psychological science: An integrative approach*. New York: Pergamon. Pp. 413-434.
Nesse, R.M., Williams, G.C. 1994. *Why We Get Sick.* New York: Random House.
Cosmides, L. and Tooby, J. 1992. Cognitive Adaptations for Social Exchange. In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, J. Barkow, L. Cosmides and J. Tooby (Eds.). New York: Oxford University. pp. 161-228.
Descola, P. 1988. *La Selva Culta: Simbolismo y Praxis en la Ecologia de los Achuar,* 1a ed. Quito, Ecuador: Ediciones Abya-Yala.
Dettwyler, K. 1991. Can paleopathology provide evidence for compassion. *American Journal of Physical Anthropology* 84:375-384.
Elerick, D.V. 1997. *Human paleopathology and related subjects : an international bibliography*. Tyson, R. A. (Ed.). San Diego: Museum of Man.
Ewald, P.W. 1994. *Evolution of infectious disease*. Oxford: Oxford University.
Fiddick, L. 1999. *The deal and the danger*. Ph.D. Dissertation, University of California, Santa Barbara.
Fiddick L, Cosmides L, and Tooby J. 2000. No interpretation without representation: the role of domain-specific representations and inferences in the Wason selection task. *Cognition,* 77(1): 1-79.
Fisher R.A. 1958. *The Genetical Theory of Natural Selection*. New York: Dover.
Frisch, R.E. and McArthur, J.W. 1974. Menstrual cycles: fatness as a determinant of minimum weight necessary for their maintenance and onset. *Science* 185:949-951.
Gangestad, S. & Thornhill, R. 1997. Human sexual selection and developmental stability. In J. A. Simpson & D. T. Kenrick (Eds.) *Evolutionary social psychology*. pp 169-195. Mahway NJ: Erlbaum.
Geary, D. and Flinn, M. 2001. Evolution of human parental behavior and the human family. *Parenting: Science and practice* 1(1):5-61.
Grauer, A.L. and Stuart-Macadam, P. 1998. *Sex and gender in paleopathological perspective.* L. Grauer, A.L. and Stuart-Macadam, P. (Eds). Cambridge: Cambridge University.

Green, B.B., J.S. Weiss, and Daling, J.R.. 1986. Risk for ovulatory infertility in relation to body weight. *Fertility and Sterility* 50:721-726.

Gurven, M., Allen-Arave, W., Hill, K., and Hurtado, A.M. 2000. "It's a Wonderful Life": Signaling generosity among the Ache of Paraguay. *Evolution & Human Behavior.* 21:4, 263-282.

Hagen E.H, Hames R.B, Craig N.M, Lauer M.T, and Price M.E. 2001. Parental investment and child health in a Yanomamö village suffering short-term food stress. *Journal of Biosocial Science* 33:503-528.

Hames, R.B. 1990. Sharing among the Yanomamö: Part I, The effects of risk. In *Risk and Uncertainty in Tribal and Peasant Economies,* Cashdan, E. (Ed.). San Francisco, CA: Westview, pp. 89-106.

Hamilton, W.D. 1980. Sex versus non-sex versus parasites? *Oikos,* 35:282-290.

Hamilton W.D. 1966. The molding of senescence by natural selection. *Journal of Theoretical Biology* 12:12-45.

Hawkes, K. 1990. Why do men hunt? Benefits for risky choices. In *Risk and Uncertainty in Tribal and Peasant Economies,* Cashdan, E. (Ed.) San Francisco, CA: Westview. pp. 145-166.

Hawkes, K. 1991. Showing off--tests of an hypothesis about mens foraging goals. *Ethology and Sociobiology* 12:29-54.

Hawkes K., Bliege Bird R. 2002. Showing off, handicap signaling, and the evolution of men's work. *Evolutionary Anthropology* 11:58-67.

Hawkes K., O'Connell J.F., and Blurton Jones N.G. 1997. Hardworking Hadza grandmothers. In: Standen V, Foley RA, eitors. *Comparative socioecology of humans and other mammals.* London: Basil Blackwell. P 341-366.

Hawkes K., O'Connell J.F., Blurton Jones N.G., Alvarez H., Charnov E.L. 1998. Grandmothering, menopause, and the evolution of human life histories. *Proceedings of the National Academy of Sciences* 95:1336-1339.

Hawkes K., O'Connell J.F., Blurton Jones N.G., Alvarez H., Charnov E.L. 2000. The grandmother hypothesis and human evolution. In: Cronk L, Chagnon NA, Irons W, editors. *Human Behavior and Adaptation: An Anthropological Perspective.* New York: Aldine. p 371-395.

Hawkes K., O'Connell J.F., Blurton Jones N.G. 2001. Hunting and nuclear families: some lessons from the Hadza about Men's work. *Current Anthropology* 42(5):631-695.

Hewlett B.S. 1992. *Father-child relations: cultural and biosocial contexts*. New York: Aldine.

Hill K. 2002. Altruistic cooperation during foraging by the Ache, and the evolved human predispostion to cooperate. *Human Nature* 13(1):105-128.

Hill, K., and Hurtado, A.M. *Ache Life History: The Ecology and Demography of a Foraging People*. New York: Aldine de Gruyter, 1996.

Hill, K. and Kaplan, H. 1999. Life history traits in humans: theory and empirical studies. *Annual Revuew of Anthropology* 28:397-430.

Hill, K., Boesch C., Goodall J., Pusey A., Williams J., and Wrangham R. 2001. Mortality rates among wild chimpanzees. *Journal of Human Evolution* 40(5):437-450.

Janson, C.H. and Von Shaik, C.P. 1993. Ecological risk aversion in juvenile primates: slow and steady wins the race. In: Pereira M and Fairbanks L, editors. *Juvenile primates: life history, development and behavior.* New York: Oxford University Press. pp 57-76.

Kaplan, H. and Hill, K. 1985. Food sharing among Ache foragers: Tests of explanatory hypotheses. *Current Anthropology 26*:223-245.

Kaplan, H., Hill, K. and Hurtado, A.M. 1990. Risk, foraging and food sharing among the Ache. In *Risk and Uncertainty in Tribal and Peasant Economies*, E. Cashdan, (Ed.). San Francisco, CA: Westview. pp.107-144.

Kaplan, H., Hill, K., Lancaster, J., Hurtado, A.M. 2000. A theory of human life history evolution: Diet, intelligence, and longevity. *Evolutionary Anthropology*. 156-185.

Kohrs, M.B., Harper, A.E. and Kerr G.R. 1976. Effects of a low-protein diet during pregnancy of the rhesus monkey: 1. Reproductive efficiency. *American Journal of Clinical Nutrition* 29:136-145.

Kluger, M.J. 1991. The adaptive value of fever. In P.A. Makowiac (Ed.) *Fever: Basic measurement and management*. New York: Viking. Pp. 105-124.

Lambert, P. 1993. Health in prehistoric populations of the Santa Barbara Channel Islands. *American Antiquity* 58(3):504-522.
Lovell, N. C. 1990. *Patterns of injury and illness in great apes: a skeletal analysis*. Washington : Smithsonian Institution.
Low, B. 1998. Pathogen stress and polygyny in humans. In *Human Reproductive Behavior: A Darwinian Perspective*, L. Betzig, M. Borgerhoff Mulder and P. Turke (Eds.). Cambridge: Cambridge University Press, pp. 115-121.
Lukacs J.R. and Pastor, R.F. 1988. Activity-induced patterns of dental abrasion in prehistoric Pakistan: Evidence from Mehrgarh and Harappa. American Journal of Physical Anthropology 76:377-398.
Mader, E. 1999. *Poder y Metamorphosis*. Quito: Abya Yala.
Manocha, S.L., and Long, J. 1977. Experimental protein malnutrition during gestation and breeding performance of squirrel monkeys. *Primates* 18:923-930.
Marks, I. 1987. *Fears, phobias, and rituals: Panic anxiety, and their disorders*. New York: Oxford University Press.
Marks, I. & Nesse, R. 1994. Fear and fitness: An evolutionary analysis of anxiety disorders. *Ethology and Sociobiology*. 15:247-261.
Marlowe F. 1999. Showoffs or providers? The parenting effort of Hadza men. *Evolution and Human Behavior.* 20(6):391-404.
Marlowe F. 2001. Male contribution to diet and female reproductive success among foragers. *Current Anthropology* 42(5)755-763.
Martin, D.L. and Frayer, D.W. 1997. *Troubled times: Violence and Warfare in the Past. War and Society Volume 3.* Amsterdam: Gordon and Breach.
Medawar, P.B. 1952. *An unsolved problem in biology*. London: Lewis.
Mineka, S. and Cook, M. 1988. Social learning and the acquisition of snake fear in monkeys. In Zentall T.R. and Galef B.G. (Eds.). *Social learning: Psychological and biological perspectives*. Hillsdale NJ: Erlbaum. pp 51-73.
Nesse R.M. and Williams G.C. 1994. *Why We Get Sick*. New York: Random House.
Ortner, D.J. and Aufderheide, A.C. 1991. *Human paleopathology : current syntheses and future options.* Washington: Smithsonian Institution Press.

Owsley D. W. & Jantz, R. L. 1994. *Skeletal biology in the Great Plains: migration, warfare, health, and subsistence*. Washington: Smithsonian Institution.
Pagel, M.D. and Harvey P.H. 1993. Evolution of the juvenile period in primates. In Pereira ME, Fairbanks L.A., (Eds.). *Juvenile primates: Life history, development, and behavior.* New York: Oxford University Press. pp 28-37
Pereira, M. E. 1993. Juvenility in Animals. In Pereira ME, Fairbanks LA, editors. *Juvenile primates: Life history, development, and behavior.* New York: Oxford University Press. pp 17-27.
Pereira M.E. and Fairbanks L.A. 1993. Why be juvenile? In Pereira ME, Fairbanks LA, editors. *Juvenile primates: Life history, development, and behavior.* New York: Oxford University Press. p 13-15.
Prentice, A.M., Cole, T.J. Foord, F.A. Lamb, W.H. and Whitehead, R.G. 1987. Increased birthweight after prenatal dietary supplementation of rural African women. *American Journal of Clinical Nutrition* 46(6):912-925.
Profit, M. 1991. The function of allergy: Immunological defense against toxins. *Quarterly Review of Biology*, 66:23-62.
Profet, M. 1992. Pregnancy sickness as adaptation: A deterrent to maternal ingestion of teratogens. In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, J. Barkow, Cosmides, L. and Tooby, J. (Eds.). Pp. 327-366. New York: Oxford University. pp. 327-366.
Riley, A.P., Samuelson, J.L. and Huffman S.L. 1993. The relationship of age at menarche and fertility in undernourished adolescents. In *Biomedical and Demographic Determinants of Reproduction*, R. H. Gray, H. Leridon, and A. Spira, (Eds.). pp. 50-64. Oxford: Clarendon. pp 50-64.

Rothschild, B.M. and Martin, L.D. 1993. *Paleopathology : disease in the fossil record*. Boca Raton: CRC Press.

Rozin, P. 1976. The selection of food by rats and other animals. In *Advances in the study of behavior: Vol 6*, J. Rosenblatt, R. A. Hinde, and E. Shaw (Eds.). New York: Academic. pp. 21-76.

Rozin, P. 1996. Towards a psychology of food and eating: From motivation to module to model to marker, morality, meaning and metaphor. *Current Directions in Psychological Science* 5: 18-24.

Rozin, P. & Fallon, A. E. 1987. A perspective on disgust. *Psychological Review*. 94(1): 23-41.

Rozin, P., Haidt, J. and McCauley, C.R. 1999. Disgust: The body and soul emotion. In *Handbook of cognition and emotion*. Dalgleish, T. & Power, M. J. (Eds.). pp. 429-445.

Haidt, J., Rozin, P., McCauley, C. and Imada, S. 1997. Body, psyche, and culture: The relationship between disgust and morality. *Psychology & Developing Societies* 9(1) 107-131.

Rutherford, M., Cosmides, L. and Tooby, J. 1996. Adaptive sex differences in reasoning about self defense. Paper presented at the Human Behavior and Evolution Society, Evanston Il

Schwartz, S.M., Wilson, M.E. Walker, M.L. and Collins, D.C. 1988. Dietary influences on growth and sexual maturation in premenarcheal rhesus monkeys. *Hormones and Behavior* 22:231-251.

Singh, D. 1993. Adaptive significance of waist-to-hip ratio and female physical attractiveness. *Journal of Personality and Social Psychology*. 65:51-65.

Singh, D. and Young, R. K. 1995. Body weight, waist-to-hip ratio, breasts, and hips: Role in judgments of female attractiveness and desirability for relationships. *Ethology and Sociobiology*. 16:483-507.

Stearns, S. *Evolution in health and disease*. 1998. Oxford: Oxford University.

Steckel, R.H., J.C. Rose, C.S. Larsen, and P.L. Walker. 2002. Skeletal health in the Western Hemisphere from 4000 BC to the present. Evolutionary Anthropology 11(4):142-155.

Stone VE, Cosmides L, Tooby J, Kroll N, and Knight R. 2002. Selective impairment of reasoning about social exchange in a patient with bilateral limbic system damage. *Proceedings of the National Academy of Sciences, USA* 99 (17): 11531-11536.

Sugiyama, L.S. 1996. *In search of the adapted mind: A study of human cognitive adaptations among the Shiwiar of Ecuador and the Yora of Peru.* Ph.D. Dissertation, University of Santa Barbara. Michigan: UMI.

Sugiyama, L.S. 1998. Evolutionary Ecology of Native Amazonians. Paper presented at the Institute for Latin American Studies, Post-graduate lecture series on Biological Studies in Latin America, University of Austria, Vienna.

Sugiyama, L.S. 2003. Illness, Injury, and Disability among Shiwiar Forager-Horticulturalists: Implications of Health Risk Buffering for the Evolution of Human Life History. *American Journal of Physical Anthropology* (forthcoming).

Sugiyama, L.S. & Chacon, R. 2000. "Effects of Illness and Injury on Foraging Among the Yora and Shiwiar: Pathology Risk as Adaptive Problem." In *Human Behavior and Adaptation: An Anthropological Perspective.* Cronk, L., Chagnon, N.A. and Irons, W. (Eds.). New York: Aldine, pp. 371-395.

Sugiyama, L.S. & Scalise Sugiyama, M. Social Roles, Prestige, and Health Risk: Social Niche Specialization as a Risk-buffering Strategy. *Human Nature*. (forthcoming).

Symons, D. 1979. *The Evolution of Human Sexuality*. New York: Oxford

Symons, D. 1989. The psychology of human mate preferences. *Behavioral and Brain Sciences*, 12: 34-45.

Symons, D. 1995. Beauty is in the adaptations of the beholder: The evolutionary psychology of human female sexual attractiveness. In P. R. Abramson & S. D. Pinkerton (Eds.). *Sexual nature, sexual culture*. Pp 80-118. Chicago: University of Chicago Press

Tomarken, A.J., Mineka, S., & Cook, M. 1989. Fear-relevant selective associations and covariation bias. *Journal of Abnormal Psychology*. 98: 381-394.

Tooby, J. 1982. Pathogens, polymorphism, and the evolution of sex. *Journal of Theoretical Biology*, 97:557-576.

Tooby, J. and Cosmides. L. 1996. Friendship and the Banker's Paradox: Other Pathways to the Evolution of Adaptations for Altruism. *Proceedings of the British Academy*, 88:119-143.

Tooby, J. & DeVore, I. 1987. The reconstruction of hominid behavioral evolution through strategic modeling. In, *The evolution of human behavior: Primate models*. Kinzey, W. G. (Ed). Albany: State University of New York Press, pp. 183-237.

Trevathan, W.R. & Smith, E.O. 1999. *Evolutionary medicine*. Oxford University.

Trinkaus, E. 1983. *The Shanidar Neandertals*. New York: Academic Press.

Truswell, A.S. and Hansen, J.D.L. 1976. Medical Research among the !Kung. *In Kalahari Hunter-Gatherers: Studies of the !Kung San and Their Neighbors*. R. B. Lee and I. DeVore eds. Cambridge: Harvard University.

Walker, P.L. 1989. Cranial injuries as evidence of violence in prehistoric Southern California. American Journal of Physical Anthropology 80:313-323.

Walker, P.L., Sugiyama, L.S., and Chacon, R. 1998. Diet, Dental Health, and Cultural Change among Recently Contacted South American Indian Hunter-Horticulturalists. In *Human Dental Development, Morphology and Pathology: Essays in Honor of Albert Dahlberg.* John Lukacs and B. E. Hemphill eds. University of Oregon Anthropological Papers, 1998.

Webb, S. 1995. *Palaeopathology of aboriginal Australians: health and disease across a hunter-gatherer continent*. Cambridge: Cambridge University.

Weinberg, E.D. 1984. Iron withholding: A defense against infection and neoplasia. *Physiological Review* 64:65-102,

Winterhalder, B. 1996. Social foraging and the behavioral ecology of intragroup resource transfers. *Evolutionary Anthropology* 5:46-57.

Williams GC. 1957. Pleiotropy, natural selection, and the evolution of senescence. *Evolution* 11:298-411.