The Running Man

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ANT 575
Human Adaptability

February 18, 2004
Revised: March 24, 2004

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Text: 19 pages
References: 5 pages

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Introduction

Is the human body designed for running; are humans even adapted to being bipedal? As strange as it may seem to scientists of the 21st Century, these questions have been argued for decades. Out of these arguments have come two main hypotheses. Most scientists agree that early hominids, at some point, began to stand and walk in an upright posture. One hypothesis, however, says that humans are ill suited to being bipedal and that they are, at the least, awkward and inefficient. In this hypothesis, man's natural position is similar to a knuckle-walking quadrupedal or, at the least, walking in a slow strident gait (e.g., Bartholomew and Birdsell, 1953; Birdsell, 1972; Lovejoy, 1981; Arnold, 2003). The other hypothesis is that early hominids began to walk upright and run as a way to escape predators and to cover long distances in their need to find water, food, and other resources. Those adhering to this hypothesis have argued that humans are well suited to both being bipedal and to endurance running. In this hypothesis, man does not have a fixed natural position, but has adapted different postures for different activities. These varied postures include: a recumbent position during rest, a crawling, quadrupedal position during activities such as hunting, and a bipedal position when walking and running (e.g., Balke and Snow, 1965; Groom, 1971; Carrier, 1984; Devine, 1985).

In this paper, I intend to look at these arguments as they relate to running, and especially endurance running. I will look at the recorded physiological observations of endurance runners, the effects of acculturation to a modern sedentary lifestyle, and the impact of such studies on the modern view of physical fitness and cardiovascular health. As examples of endurance running, I will be looking at the early observations and studies of the Tarahumara of the Sierra Madre.

The Efficiency of Bipedalism

The issue of cause or causes of bipedalism has generated a number of conflicting hypotheses (e.g., Preuschoft, 1978; Lovejoy, 1981; Allen, 1982; McHenry, 1982; Richmond et al., 2001). Out of the controversy over human origins and the issue of causality of bipedalism has come one majority opinion, it is that bipedalism was fully developed in the earliest hominids. Contemporary fossil evidence appears to confirm the belief that human ancestors were walking upright by around 3.5 to 4 million years ago (Zihlman, 1981:75; Lovejoy, 1981:341; McHenry, 1982:153). Accepting these conclusions, we then turn to the issue of whether or not humans were better adapted to the upright position.

A general assumption in paleoanthropology has been that modern humans are inferior in both speed and agility to modern quadrupeds. The rarity of bipedalism among mammals has led some scientists to argue that, as a form of locomotion, it was too inefficient and must have developed for some other reason (Bartholomew and Birdsell, 1953; Birdsell, 1972). The most widely suggested reason for the development of bipedalism has been to manipulate tools with free forelimbs (Bartholomew and

Birdsell, 1953; Birdsell, 1972). Birdsell (1972:232) compared the world records for the 200-yard dash to the speed of such animals as the cheetah, antelope, and various monkeys, and concluded that the slowness of the human compared to the speed of animals meant that "man could not escape from any likely predator by running away." Lovejoy (1981:343) came to the same conclusion and stated that "bipedality is useless for avoidance escape from predators" (Lovejoy, 1981:343). Those who postulate the idea that human bipedalism is inefficient have also espoused the idea that modern running records, such as those recorded at the Olympic Games in recent history, represent the pinnacle of achievement in human history (Devine, 1985:559).

In reference to these arguments, Devine (1985:551) comments that the "so-called 'striding gait' of modern humans, one isolated phase of the breadth of human motor skills, has taken on a kind of 'misplaced concreteness' through our biases as sedentary products of industrialization . It was the bipedal striding gait that Napier (1967:125) claimed represented the quintessential human locomotor achievement. Challenges to the arguments that bipedal humans are awkward and inefficient have come from a number of scientists, including those researching in anatomy, anthropology, biomechanics, kinesiology, physiology, and sports medicine.

The human bipedal gait has been subjected to numerous kinematic analyses (Carlsöö, 1972 :80; Inman, 1981:22). Basmajian (1979:177) used electromyography technology (EMG) to demonstrate his hypothesis that humans in the upright position are not more disadvantaged than quadrupeds regarding the antigravity mechanisms. Although the human in a standing rest position may appear to be precariously balanced, with the center mass perched high above a seemingly insignificant two-footed base of

support, it takes a great deal of force to push him off balance (Carlsöö, 1972:30). And, as Basmajian (1979) discovered in his research, the activity of the large muscles of the human gluteal region, thigh, and leg is very slight during relaxed standing. Alexander (1982) also presented evidence that early hominids had the ability to swerve and dodge, which suggests that they could have potentially escaped predators that were not so agile.

It is possible that the striding gait is in reality a biologically based cultural trait that predominates as a locomotor form in western culture, and that to apply it to other groups is a form of ethnocentricism (Devine, 1985:551). Watanabi (1971) and others took the study of human locomotion out of the laboratory and into natural habitats. They attempted to set up classifications for patterns of human locomotion other than the striding gait, and found a variety of gaits in human subpopulations (Watanabi, 1971). The movement patterns of nomadic and semi-nomadic hunting-gathering groups, for instance, provide some interesting examples of varied patterns of human locomotion.

There is a whole spectrum of human societies that exhibit locomotor patterns far more vigorous and strenuous than that of the industrialized westerner. These societies include: herding tribal groups, semi-nomadic forager-herding groups, and subsistent agriculturalists. Although agriculturalists have long been termed "sedentary" they have not always adopted the lifestyle of a sedentary westerner. Instead, many agriculturalists travel long distances on foot to markets, play demanding games such as football, and run exhausting races. In fact, the biomechanical, morphological, and

cultural differences throughout the world have led to the development of numerous variations in gait and style of locomotion.

Long-Distance History

The one thing that everyone seems to agree upon is the fact that people living in small band societies or subsistence economies depend far more on strength, endurance, muscular exertion, long-distance walking, and long-distance running than westernized men and women (e.g., Carrier, 1984; Devine, 1985; Stinson, 1992). Washburn (1960:173) associates the endurance trait with hunting by males, and writes, "The capacity for bipedal walking is primarily an adaptation for covering long distances." On the other hand, Zihlman (1981: 93) stresses the opinion that women were walking long distances in pursuit of gathering well before the advent of hunting. Whichever argument one prefers, the point is that human activity has long been associated with walking and running long distances.

Long-distance running as a method of carrying messages has been well documented. Stories of endurance running to carry messages and ceremonial objects, and to gain prizes and glory in races have been related from ancient times. Greek ceramics and paintings dating to 566 BCE depict scenes of races held during Panathenaic festivals. The Inca used relay runners to send messages throughout the empire. The Fox Indians of North America had a ceremonial system of runners that were sent on errands and carried objects as far away as 400 to 500 miles, running all the

way (Devine, 1985:556). Long pilgrimages and trade routes have been documented from the Middle-Ages. Several tribes of North America have been documented as having played strenuous kick-ball games that involved running long distances. These groups include the Apache, Hopi, Mayo, Navajo (Diné), Opata, Papago, Pima, Plateau, Shoshonean Bannock, Tarahumara, Tepehuan, Yaqui, Yuman, Yurok, and Zuni (Bennett and Zingg, 1935:402).

Underhill (1946) and others have listed numerous references to footraces, not only among men and boys, but also among the women and girls of these groups. Underhill lists several kinds of running songs, including songs for kick-ball races, for betting on races, and to bewilder a rival runner (Underhill 1946:130). Women's races were as common as men's in the Southwest. Some tribal groups, such as the Apache, incorporated running into the puberty ceremonies of young women. Races were not only for those in the warm regions of the Southwest. In the late 1800's, Lapps in Greenland were documented as covering 220-km (137-miles) in 21 hours and 22 minutes on Lapp skis of 2.5 m in length. This is the equivalent of running five marathons at a rate of four hours each in the bitter cold (Bennett and Zingg, 1935; Devine, 1985).

The Tarahumara

It is possible that no tribe has been more prized and more studied for its endurance abilities than the Tarahumara of the rugged Sierra Madre Mountains in Mexico. Their name, Tarahumara, is probably a Spanish corruption of the name they use to refer to themselves. This name, *Rarámuri*, means roughly "fleet foot" or "foot

runner" (Groom, 1971:304). They have lived for an estimated 2,000 years in and around the great Barranca Del Cobre of Mexico's Sierra Madre Occidentale. They are a Uto-Aztecan people who were first written about by Jesuit priests in the early 1600s. For centuries, due to the ruggedness of the region, they managed to remain fairly well hidden and isolated from the effects of the processes of Christianization and acculturation. It has been only since the mid-twentieth century that they have had to interact with outsiders to any great extent or for extended lengths of time, and this has been mostly in the form of boarding school education and laboring for mining and lumbering interests (e.g., Pennington, 1963; Balke and Snow, 1965; Groom, 1971; Jenkinson, 1972; Raat and Janeček, 1996).

Many Tarahumara are still semi-nomadic agriculturalists who follow a lifestyle of seasonal mobility. Their diet consists primarily of various preparations of corn, beans, and squash. They supplement this diet with wild plant and animal resources of the region when available. Although they have cattle, sheep, and goats, those animals are kept principally as sources of wool, fertilizer, and occasional cash income (Balke and Snow, 1965; Raat and Janeček, 1996). A domestic animal will occasionally be slaughtered for an important festival or a *tesgüinada* (a cooperative work event), otherwise meat usually comes from hunting and may include small mammals, fish, birds, and reptiles. Several varieties of corn are cultivated in the region and, in one form or other, constitute as much as 70-80% of their total caloric intake. The most common corn dish is *pinole*, a kind of parched corn gruel that makes up about 50% of the diet. Tortillas, tamales, *esquiate*, and various *atoles* are also common foods made of corn. Beans

are the chief source of protein, with the kidney bean (*Phaseolus vulgaris*) being the most common (Balke and Snow, 1965; Raat and Janeček, 1996).

Lumholtz (1902) was one of the earliest scientists to report on the endurance running of the Tarahumara. He reported that the Tarahumara could easily run 170 miles without stopping. He also reported that men had carried letters a distance of 600 miles in 5 days. These runners were described as running at a slow steady trot and living only on *pinole* and water (Lumholtz, 1902). Empirical studies were performed more recently by Balke and Snow (1965), Groom (1971), and Kennedy (1978). These studies and others focused on the seemingly unusual stamina of the Tarahumara endurance runners, a stamina that persists despite widespread undernutrition and malnutrition.

Bennett and Zingg (1935) provide several examples of Tarahumara physical stamina. Tarahumara hunters, for instance, were witnessed to hunt by literally running their prey into the ground. Once on the track of a deer or other game, a hunter would continue to jog after it for hours, sometimes running relentlessly for two days, until the animal dropped from exhaustion. By the second day, even the most fleet of game animals usually dropped, exhausted, and was then killed by the hunter with a knife or rock. Of course, the running down method of hunting is not limited to the Tarahumara. Uses of this method have been recorded among other groups in the Americas, and groups in Africa (Marshall, 1958; Washburn, 1960; Watanabe, 1971).

This running ability is believed to stem from a combination of biological and cultural factors. From early childhood, Tarahumara men and women spend much of their time scrambling up and down hillsides after their herds, and engaging in running

games. Houses and fields are often distant from each other, and from water sources and neighbors. But probably the most important factor is that running is actively encouraged in Tarahumara society. One of the ways a man gains great prestige in this society is to excel at running, especially in the running required of the kick-ball game (Bennett and Zingg, 1935; Jenkinson, 1972). It has been said that a Tarahumara begins to run almost as soon as he learns to walk (Bennett and Zingg, 1935; Jenkinson, 1972). This can be evidenced by the number of young, barefooted children frequently seen racing along in pursuit of their kick-balls. Both boys and girls participate in this sort of play when not chasing after stray goats or doing some other similarly strenuous chore (Groom, 1971:306; Jenkinson, 1972:64).

Practice races of 50 kilometers or so are common among members of a community, as are solo practice runs. Women have their own type of race, called *rowéari*, in which they toss small hoops in the air with sticks. These races may be somewhat shorter than the men's races, but are no less strenuous, especially since they are run in the modest ankle length skirts favored by the Tarahumara (Pennington, 1963; Shrake, 1967:65; Groom, 1971:306). There are, in fact, a number of strenuous games played by both men and women, some involving goals set three-quarters of a mile apart (Pennington, 1963; Shrake, 1967). However, by far the most popular game is the kick-ball race known as *ŕarajípari* (Pennington, 1963:168).

Documentation of Tarahumara kick-ball races is abundant (e.g., Lumholtz, 1902; Bennett and Zingg, 1935; Pennington, 1963). The sport consists of running continuously, day and night, over rough, mountainous terrain, kicking a ball roughly the size of a tennis ball. This little ball is usually carved from oak with a machete. The

actual kicking of the ball is more of a flicking motion in which the runner slips his toes under the ball and flips it with the dorsum of his foot (runners are usually barefoot or wearing simple, homemade sandals). Community races covering a linear 75 miles or so are common. Major races between pueblos or *ejidos* may last for two days and two nights covering a distance of 150-300 kilometers (Balke and Snow, 1965:294; Groom, 1971:306). The big races between *ejidos* attract crowds of several hundred spectators who bet heavily on the outcome. These are poor communities, so betting is usually made in blankets, clothes, livestock, jewelry, land, or anything else of value (Bennett and Zingg, 1935; Balke and Snow, 1965; Pennington, 1963). The winning prize for all this effort is a small portion of the winnings, prestige in the community, and allegedly great popularity with the women (Shrake, 1967).

It is important to note that Tarahumara race courses are laid out over some of the most rugged terrain in the world. The altitudes of the region range from 1,800-2,500 meters. The climate of the barrancas in summer is torrid, and almost unlivable. During that time of year, the uplands are the only places that are relatively cool and pleasant. In the winter, the climate of the uplands is one of the coldest in all of Mexico, while the barrancas offer the most warmth and shelter. Rainfall in the region is scanty in all areas and tends to be concentrated in late summer and early fall (Balke and Snow, 1965:294). Runners undergo very little special training prior to races, and their normal diet is, by western standards, deficient. The main treatment given to runners before and after races is ceremonial rituals intended to bring luck and strength, and to protect the runner from the evil devices and tricks of other runners (Bennett and Zingg, 1935; Balke and Snow, 1965; Pennington, 1963).

Physical and Physiological Observations of the Tarahumara

Balke and Snow (1965), and Groom (1971) recorded observations on Tarahumara physical performance capacity. According to Balke and Snow (1965: 297), a good runner covers steadily for many hours a distance of 10-15 km per hour, or about 190 meters per minute . The physiological demands of such performance expressed in oxygen requirements amount to approximately 43 ml/min per kilogram of the runner's body weight (Balke and Snow, 1965:297). This is about 12 times his resting metabolic rate. At this rate, the total oxygen consumption of an individual weighing 60 kg would average about 2.5 liters per minute. This would be nearly equal to an energy expenditure of 12 kcal per minute, or 720 kcal per hour. The total energy cost to this individual for a 100-mile race would be well beyond 10,000 kcal. According to Balke and Snow (1965), this far bypassed the recorded energy expenditure of athletes measured in the most strenuous feats of physical endurance in modern western competitions, including mountain climbing, cross-country skiing, and bicycling (Balke and Snow, 1965:297). The records of these competitions, at the time Balke and Snow (1965) published their study, exhibited a limit of 10,000 kcal of energy expenditure within a period of 24 hours.

Heart rate and blood pressure observations on the Tarahumara have been just as interesting. Groom (1971) summarized his findings after a 5 hour race in which he and his crew had taken measurements before, during, and after the race:

> Each contestant in the race lost about five pounds in weight, attributed to dehydration at an ambient temperature of approximately 65° F. More surprising was the marked decrease in diastolic blood pressure which was a universal finding. Whereas all the runners had normal blood pressures at the beginning, two of them (ages 22 and 32) showed diastolic readings of zero during and

> immediately at the end of the race, rising within a few minutes to 60 to 80 mm. Hg. Others had diastolic levels (by the usual cuff method) ranging from 40 down to 8 mm. Hg. All runners, checked at both the three-quarter point and at the end of the race, showed declines of systolic as well as diastolic pressures, the highest levels being 122/80 and the average approximately 110/70 (Groom, 1971:307-308.)

The maximum pulse rate recorded by Groom (1971) was 158 beats per minute in the latter half of the race on a 23 year old. Rates on all the others he measured were in the 120 to 150 range, counted immediately after they crossed the finish line. This is compared to the resting pulse rates recorded on supine individuals of 56 to 60 beats per minute. Balke and Snow recorded the pulse rates of boys 6 to 10 years old after a kick-ball race. The one ten-year-old in the group was recorded as 176 beats per minute immediately after the race, 154 at three minutes after, and 132 at five minutes after. A nine-year-old's pulse rate five minutes after the race was 108 beats per minute (Balke and Snow, 1965:297). Balke and Snow also measured oxygen requirements and recorded measurements similar to those Groom observed in 1971 (Balke and Snow, 1965:298). They compared the rates observed among Tarahumara boys and men to the rates observed among American boys at a YMCA Summer Camp and male medical officers of the U. S. Air Force (after eight weeks conditioning), and found the Tarahumara to far exceed the maximum work capacity of what was considered normal for the American male. According to Balke and Snow (1965:298), the estimated metabolic equivalents for the average velocities were close to 14 times the resting metabolic rate in the Tarahumara men. This is in comparison to the U. S. Air Force men who achieved only a maximum expenditure of about 11 times the resting rate.

Groom (1971) went a step farther and compared height and weight measurements, took chest x-rays, and EKG measurements. Physically, the Tarahumara

were conspicuously thin and relatively short compared with the standard population in the United States. In height they measured from 5 ft. 2 in. to 5 ft. 6 in. with an average weight of 120 lb. None of the race contestants he measured showed any physical evidence of cardiac enlargement, unusual or splitting of the second heart sound, or heart murmurs (Groom, 1971). They also had an impressively firm musculature, but the one thing that truly impressed Groom was the fact that, after running for hours, they could stand around quietly without panting while he examined them (Groom, 1971:309).

Discussion

Although it would be a mistake to assume that the observations and ethnographic descriptions of such groups as the Tarahumara apply to the 4-million-year history of hominid and human bipedalism, it is nonetheless legitimate to use these observations in the attempt to find the roots of such walking, running, and racing traditions. These observations also give some indication of the possibilities, and extremes, of human endurance and physical conditioning. Some of the locomotor traits mentioned may be relatively recent adaptations that represent only a fraction of the history of bipedalism. Acting as selective forces, different environments and subsistence activities may have dictated the types of physical activities early man participated in. This may have predisposed certain groups – through natural selection – to higher levels of endurance, and resulted in the variations in gaits found in human subpopulations.

As to whether the bipedal human is awkward and inefficient, such studies as those done by Carlsöö (1972) and Basmajian (1979), suggest that the bipedal human is far from being awkward and disadvantaged either in walking, running, or escaping from a less-intelligent, no-so-agile predator. These studies, and those of such cultural groups

as the Tarahumara, demonstrate that the human body has the capacity for great endurance. By comparing these studies to the studies of the effects of westernization on groups such as the Pima Papago of the southwestern United States, we find that it is culture, especially the culture of the industrialized western world, that has produced a detrimental pattern of low tolerance and inefficiency of the human body. The Pima at one time participated in running and running games similar to the Tarahumara, but today, the change to a western diet and sedentary pattern has produced in the Pima the highest prevalence of diabetes mellitus in the world (Stinson, 1992: 151; Frisancho, 2002: 432).

Modern studies of diabetes and obesity have concluded that westernization is responsible for the high incidence of disease in a large number of people from a variety of ethnic groups. Among the other westernized populations showing high rates of diabetes, high blood pressure, and obesity in the late 20th and early 21st centuries are the aboriginal populations of Australia, Polynesian groups such as the Samoans, and second-generation Japanese-Americans (Bindon et al., 1991; Stinson, 1992:153).

The advent of agriculture has been hypothesized by many to be the main culprit in the introduction of disease and deterioration in the human population (e.g., Stinson, 1992; Carrier, 1984; Devine, 1985 Frisancho, 2002). I do not dispute this hypothesis but add to it the influences of European cultural values and practices that eventually came into the Americas and have permeated the majority of the industrialized world. Ancient texts and other archeological evidence of long-distance racing and other feats of physical endurance have been found proving that Crete, Greek, Roman, and other

civilizations believed in physical fitness (Devine, 1985). And yet, by the Middle Ages we begin to see evidence of hostility toward recreational practices.

The Medieval Christian Church espoused a doctrine that encouraged the denial of the flesh and a preoccupation with the destination of the spiritual being in the afterlife. Not only was bathing discouraged, lest one fall into the temptations of the flesh, but also any activity that was purely recreational. Class stratification further impacted the cultural value placed on physical activities. Freeman (1970) described how, in Spain, people who kept and herded their animals were placed in a lower social position than those who may have owned animals but did not move around with them. European and American culture has a long history of disdain and derision toward itinerants, wandering peddlers, gypsies, herdsmen, and pastoral communities.

It was not until the early twentieth century that scientists and physicians began to seriously consider the possibility that the human body might actually need to be exercised regularly. Studies of such problems as heart disease, cancer, and diabetes began to point to the fact that the eating habits and physical activity of the human could not only affect, but cause serious health problems (e.g., Baker, 1984; Devine, 1985; Stinson, 1992; Frisancho, 2002). Lumholtz' observations of the Tarahumara endurance runners in the late 19th and early 20th century were especially interesting to the scientific community, evidenced by the numerous studies this fascination produced (e.g., Lumholtz, 1902; Bennett and Zingg, 1935; Balke and Snow, 1965; Groom, 1971).

It had long been accepted by the scientific community that participating in any form of strenuous physical exertion could be hazardous to health (Thompson, 1997). This belief dates back to around 490 BCE when Pheidippides allegedly dropped dead

after running 39 km to Athens to deliver the news of victory over the Persians on the battlefield at Marathon (Martin et al., 1977). The long-range limitation traditionally ascribed to athletic activities was cardiac enlargement. There are numerous references to hypertrophy of the athlete's heart in older medical literature, although little evidence exists (Groom, 1971). The implication was that the premature death of athletes was from, or could be caused by, overwork of their hearts. The observations of the Tarahumara made by Groom and others disclose no cardiac abnormality, either physical or electrocardiographic (Balke and Snow, 1965; Groom, 1971; Carrier, 1984). The only physical factor reported to limit the endurance of the Tarahumara runner was pain in the legs (Groom, 1971: 311). Examinations found these pains to be predominately muscle rather than joint pains, possibly induced by the loss of electrolytes due to dehydration.

More recent studies of endurance runners found that the majority of fatal cardiac arrests were due to arteriosclerosis (Thompson, 1997). Up to and including 1993, there were two deaths from cardiac arrest in 14 London marathons. This is out of an estimated total of 275,000 runners. Up to 1997, there were three deaths in 24 New York marathons. Although the death of one of the youngest athletes in these marathons was believed to have been from hypertrophic cardiomyopathy, postmortem examinations of all the middle aged runners showed evidence of severe arteriosclerosis (Thompson, 1997). The belief is that the plaque in the arteries is dislodged or ruptured during the kind of extreme physical exertion of these three to four hour races.

Conclusion

Ethnohistorical accounts, such as those of the Tarahumara, present us with images of humans in constant motion. There is no doubt as to the superiority of the physical endurance of the Tarahumara runner. If we add the ability of the human to think his way out of a dangerous situation while on the run to the data on locomotion and endurance, it is reasonable to question the hypothesis that humans were slow, clumsy creatures who "could not escape from any likely predator by running away" (Birdsell, 1972:95). It is possible that humans escaped predators by a combination of dogging and darting, and running. If their hands were not being used for running, they could also have used them to throw or swing objects at their attackers while dodging and darting. But whether or not this evidence of physical endurance and efficiency applies to the early hominid is yet to be proven. The evidence does show, as Groom (1971) observes, "that most of us, brought up in our sedentary, comfortable civilization of today, actually develop and use only a fraction of our potential cardiac reserve." The evidence also demonstrates that those humans still living in relatively non-westernized societies may provide not only an example of human potential, but also clues to answering the question of early human bipedal efficiency. None of the Tarahumara in the studies appeared awkward or inefficient, and physical examination proved that they were in good physical condition (Balke and Snow, 1965; Groom, 1971)

Studies of modern marathon runners provide us with a contrast to the physical capability of both the modern Tarahumara and earlier, non-industrialized humans. It is clear that even westernized humans have the potential capability to perform well in feats of physical endurance. However, the western diet and sedentary lifestyle has had a devastating effect on the cardiovascular system, evidenced by the high rate of

arteriosclerosis, diabetes, and high blood pressure (Bindon et al., 1991; Thompson, 1997; Frisancho, 2002). This does not mean that exercise should be avoided by those with evidence of heart disease – on the contrary. Among the positive effects of regular physical activity are a reduction in blood pressure, enhanced insulin sensitivity, and an improvement in lipid profiles (Pate et al., 1995).

There is also evidence that the angiographically gauged progression of coronary artery disease can be arrested, but it requires an energy expenditure of about 6.27 mj a week. To induce regression of arteriosclerotic plaque, it requires an energy expenditure of 9.20 mj per week which is equivalent to five to six hours of exercise a week (Northcote, 1985; Pate et al., 1995). This information has led the Centers for Disease Control and Prevention, and the American College of Sports Medicine, to recommend that every adult should exercise for 30 minutes or more everyday in moderate intensity activity (Pate et al., 1995). To most Americans this probably appears like a great deal of physical activity, but nothing compared to the prolonged physical activity of the Tarahumara runner.

There are a few more questions that need to be answered before final conclusions can be made about the physical endurance of such groups as the Tarahumara. For instance, none of the physiological assessments looked at the role of diet, work habits, and other factors they may have influenced Tarahumara adaptations to their environment. Also not analyzed in these assessments were comparisons to other similar populations. Certain features of the American Indian physiology and physique may represent pre-adaptations which may have aided in producing the Tarahumara physical capabilities. There is also the problem of how well the individuals studied

represented the population as a whole. It could have been that the most physically fit among the Tarahumara were also the most outgoing, and therefore, the most likely to run races and volunteer for physical examinations (Balke and Snow, 1965). On the other hand, as pointed out by Balke and Snow (1965), most of the subjects they chose "were to some degree acculturated [to a western life-style] and may actually [have] under-represented the potentialities of their more primitive co-tribesmen." This is a good thought to ponder over our next slice of pizza in front of the television.

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