Organic Fitness: Physical Activity Consistent with Our Hunter-Gatherer Heritage

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Abstract: Many of the pervasive health concerns in modern society are the result of diet and lifestyle choices that are at odds with the evolutionary milieu for which we remain genetically adapted. This systematic displacement from a very physically active lifestyle in a natural outdoor environment to a sedentary indoor lifestyle may be at the root of many chronic diseases that are endemic in our culture. A proposed solution is to simulate indigenous human activity patterns in such a way that is possible and practical for individuals to achieve. Suggestions for exercise mode, duration, intensity, and frequency are outlined, with a focus on realigning our daily physical activities with the archetype that is encoded within our genome. In a sedentary individual, this type of daily physical activity should help confer the robust vigorous health that enabled our ancestors to survive and thrive as hunter-gatherers in the wild.

Keywords: hunter-gatherer; exercise; cross-training; evolution; fitness; cardiovascular health; prevention; obesity

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Introduction

Physical activity is decreasing in our modern society, particularly in children.[1] Exercise has many beneficial physiologic effects, which result in demonstrable reductions in cardiovascular (CV) and other disease endpoints. Daily exercise favorably alters gene expression[2,3] and improves other parameters, including: CV, musculoskeletal, pulmonary, and general fitness, glucose and lipid metabolism, blood pressure, autonomic balance, mood, sleep quality, and immunity.[4] These profound changes may explain why CV fitness and daily energy expenditure on physical activity are among the strongest correlates of long-term health and survival (Figures 1, 2).[2–7] In fact, increasing daily physical activity in previously sedentary middle-aged individuals has been found to reduce mortality rates and increase smoking cessation.[7]

From the inception of the human genus, *Homo*, approximately 2.4 million years ago,[8] our ancestors lived as hunter-gatherers for approximately 84 000 generations.[9] Survival within the hunter-gatherer niche required a large amount of daily energy expenditure in activities such as food and water procurement, social interaction, escape from predators, and maintenance of shelter and clothing. This lifestyle represents the exercise patterns for which we remain genetically adapted. Accordingly, humans are very capable of performing the wide array of physical activities and behaviors required of the hunter-gatherer. Quantum improvements in technology, such as those that led to the Agricultural Revolution (350 generations ago), Industrial Revolution (7 generations ago), and Digital Age (2 generations ago) have resulted in large systematic reductions in the amount of physical work required by humans.[10,11] In many cases, technological advancements have completely eliminated the need for physical activity in our daily routines; this has been especially true in the past few generations. Nonetheless, our innate exercise capabilities and requirements that evolved via natural selection over thousands of millennia remain essentially the same as for our Stone Age ancestors. Marked deviation from those indigenous exercise patterns is a likely factor for the genesis of many common degenerative diseases, such as obesity and type 2 diabetes. Accordingly, an understanding of the typical hunter-gatherer physical activity pattern appears to be an ideal template from which to design a modern exercise program.[12]

Fitness for Life in the Wild

About 10 000 years ago, a small band of Middle Eastern people transitioned away from a hunter-gatherer lifestyle, and instead cultivated plant crops and domesticated animals. These innovators sowed the

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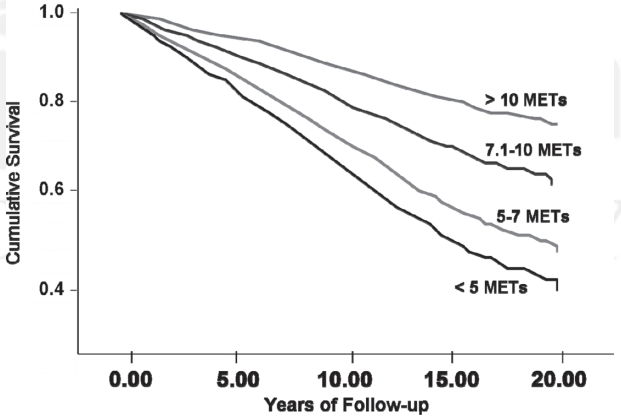
Figure 1. Long-term mortality in middle-aged males is closely associated with fitness as assessed by peak exercise level achieved on a maximal treadmill exercise test.



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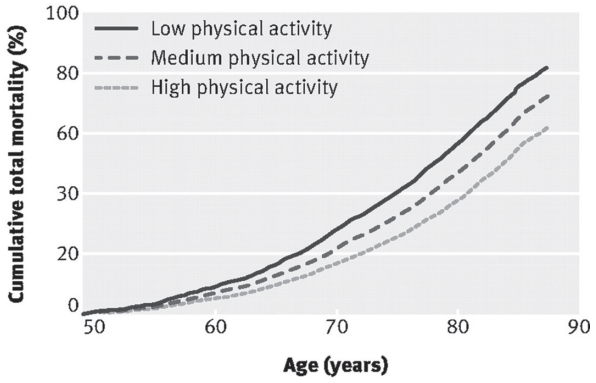
first seeds of agriculture, and in so doing, rejected a mode of life that had sustained humans before them. What began as a renegade way of life in the Levant spread around the world and ultimately drove the hunter-gatherer lifestyle into extinction. Except for a few remote tribes in the Amazon rain forests and on the Andaman Islands in the Bay of Bengal, pure hunter-gatherer cultures no longer exist.[4] Ironically, as the last vestiges of the hunter-gatherer lifestyle are being eclipsed by modern civilization, science is recognizing that some features of this ancient way of life may be helpful for restoring optimal fitness for individuals in the 21st century.[13,14] Compared with the slow pace of genetic evolution, human, technological, and social evolution has occurred rapidly. This discordance has left us genetically adapted for the rigors of life as a hunter-gatherer, despite the fact that we are inhabitants of a high-technology, sedentary, overfed, and emotionally stressed-out 21st century environment. A potential solution to this conundrum is to simulate the activity patterns of our Pleistocene ancestors.

Figure 2. Reduction in long-term mortality in proportion to the amount daily physical activity performed.



Age	50	60	70	77	82	End of study
Men at risk	2205	1904	1406	1123	933	876

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Our Genetic Adaptation to Physical Labor

Natural selection has provided us with the genetic makeup that allowed our ancestors to not only survive the physical work and daily rigors required of the hunter-gatherer, but to thrive in response to these demands.[15] Indeed, just as bone and muscle becomes weak and atrophied when relieved from the work of resisting gravity, the human organism becomes burdened with disease and debility when freed from the highly varied daily physical demands that were required of the hunter-gatherer lifestyle. The rationale underpinning the importance and effectiveness of daily cross-training can be found within our hunter-gatherer genetic legacy.

For hunter-gatherers, exercise was not optional—their harsh world mandated daily physical labor for nearly their entire life.[4] An adult hunter-gatherer would not consider setting off on a run for recreation or repeatedly lifting a heavy stone simply to enhance fitness level. Instead, natural selection provided them with an instinct compelling them to "Move when you have to, and rest when you can." Many of their waking hours were necessarily spent with the physical activities required of everyday life (Table 2). Except for the very young or very old, everyone participated in a wide range of manual labors on a daily basis. Retirement was not an option for hunter-gatherers. Their activities of daily life were all the "exercise" that Stone Age people would have ever needed to maintain superb general fitness.[16] Instincts to preserve energy and strength for these requisite physical chores conferred survival advantages to hunter-gatherers. These instincts, which are still apparent in modern humans, are now maladaptive in the 21st century setting. Our habit of taking the path of least resistance, while living and working in an ultra-convenient, highly mechanized environment, certainly plays a major role in the many of the chronic health concerns endemic to modern cultures.

Ideal Exercise Patterns

Prospective clinical trials assessing the health effects of various exercise regimens as well as observational data are

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generally supportive of the health benefits conferred by a hunter-gatherer–style fitness regimen. A large amount of data indicate that many exercise benefits are gained at relatively low-to-moderate levels of exercise.[17,18] A daily regimen of ≥ 45 minutes and possibly ≤ 90 minutes per day of cumulative physical activity is necessary for most overweight or obese individuals to achieve and maintain ideal body weight.[19] The 10 000 steps-per-day concept emphasizes the importance of total daily energy expenditure. This fitness strategy generally involves walking at a moderate pace intermittently throughout the day.[20] However, intermittent high-intensity activity results in more weight loss and better glucose metabolism than an equivalent amount of continuous low-intensity activity.[21] Additionally, in individuals with type 2 diabetes, combined aerobic and resistive activity has been shown to be superior to high- or low-intensity activity alone for improving glycemic control.[22]

Exercise generally has a protective benefit against CV disease,[23] and some evidence suggests physical activity performed outside may be more beneficial in preventing CV disease than physical activity performed indoors.[24] Outdoor exercise provides exposure to sunlight, which stimulates vitamin D synthesis in the epidermis. Vitamin D deficiency is a common and potent risk factor for many health concerns, including CV disease.[25] Vitamin D produced in response to sun exposure maintains serum 25 (OH) vitamin D levels longer than orally ingested vitamin D.[26] Additionally, it has been demonstrated that outdoor exercise decreases emotional stress and improves mood to a greater extent than indoor exercise.[27,28] People who routinely exercise outside, particularly in natural surroundings, may have better long-term persistence with their fitness routine than those who predominantly participate in indoor exercise regimes.[28] Furthermore, a recently published study found that a 60-minute walk in a natural outdoor setting improved memory performance and attention span substantially better compared with a 60-minute outdoor walk through busy urban streets.[27] Weather conditions (warm and sunny vs cold and overcast) had no effects on these findings.

Runners perform most of their walking/running on concrete and asphalt surfaces while wearing highly cushioned running shoes with elevated heels, pronation correction, etc.[29] In contrast, ancient ancestors were barefoot or wore simple leather shoes, boots, or slippers.[30] The highly cushioned running shoes that are currently popular restrict normal range of motion of the foot during propulsion and foot strike while walking and running. This can cause atrophy of musculature and shortening and stiffening of tendons and ligaments in the feet, ankles, and lower legs, which may increase incidence of running-related injuries, such as plantar fasciitis, ankle sprain, and Achilles tendon rupture.[31] Although walking/running while barefoot is generally not practical, simpler shoes that do not excessively restrict normal foot-strike dynamics may be preferable to expensive highly cushioned running shoes.[32] Additionally, natural surfaces, such as dirt, gravel, and grass, or rubberized surfaces provide lower-impact loading during walking and running.

Rest and Cross-Training

From about age 5 to old age, hunter-gatherers would have regularly performed moderate-to-difficult aerobic activity,[33] although they would have likely alternated difficult days with less-demanding days whenever possible.[16] Their routines promoted aerobic endurance, flexibility, and strength, thereby providing them with multifaceted fitness.[33] This varied pattern of movement would have also conferred resiliency and reduced the likelihood of injury, allowing them to hunt and forage without major interruptions because of incapacitation.

Exercise physiologists have reported that the same pattern of alternating a strenuous workout one day with an easier one the next day produces higher levels of fitness and lower rates of injury.[34] In exercise physiology, it has been well documented that an individual's aerobic capacity may increase based on exercise frequency, intensity, and duration.[35] Of these 3 factors, intensity is the most important feature in optimizing aerobic capacity, particularly in individuals who are already trained.[35] However, risks of injury and illness increase as exercise intensity is increased.[36] Thus, to reduce the risk of injury, high-intensity interval workouts should be performed no more than 1 or 2 times per week.

The natural cross-training that was a mandatory aspect of life as a hunter-gatherer has been found to improve performance across many athletic disciplines. For example, when weight training was added to the varsity swimming program at Indiana University in the 1960s, it was considered a revolutionary concept that increased strength, improved performance, and made the athletes more resilient to injury.[37] Currently, most endurance sports coaches incorporate cross training such as strength and flexibility exercises into their prescribed training routines.[38–40]

Fitness Among Forager Women

Although hunter-gatherer women rarely participated in large game animal hunting,[41] they were also very physically fit

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because of their daily physical routines. Ethnographic accounts of hunter-gatherers indicate that women typically foraged to collect food every other day or every third day. They gathered plant foods, including vegetables, fruits, berries, and nuts, dug up tubers, and foraged for animal foods (eg, tortoises and other small reptiles and amphibians, shellfish, insects, bird eggs, and small mammals).[41–43] Women, who usually traveled in groups, spent hours walking to and from sources of food, water, and wood. Sometimes they would help carry butchered game back to camp. These foraging efforts often entailed arduous digging, climbing, bending, and stretching, and frequently involved carrying heavy loads back to camp.[4] Additionally, these forager women often carried their children for extended distances. Anthropologists have estimated that the typical forager mother carried her child until about age 4, covering upwards of 4800 km with the child in her arms over this period.[44] Other common physically strenuous activities females engaged in included construction and repair of tools and shelter, butchering, food preparation, and socialization. Communal dances were typically an important recreational activity for hunter-gatherers and might be held several nights a week, often lasting for hours.[16] Table 1 shows typical hunter-gatherer activities and their modern counterparts along with the associated caloric expenditures.[4]

Sexual activity has always been an integral aspect of human existence and qualifies as a prototypical component of an organic fitness program. Large, long-term, epidemiological studies consistently indicate that engaging in regular sexual activities confers a multitude of quantifiable benefits to health, well-being, and improved longevity for both men and women (assuming that safe sex practices are followed so as to minimize the risk of contracting sexually transmitted infections).[45,46] After adjusting for baseline characteristics, such as age and CV risk factors, men and women who report the highest frequency of sexual relations have lower mortality rates, improved immune system function, lower risk of prostate cancer, and reduced risks for CV disease.[45,46] Sex, at the very least, requires physical exertion. A vigorous 30-minute session of sexual activity will burn up to 200 calories—about the same as walking 2 miles, or running 15 minutes on a treadmill. At orgasm, the peak heart rate is typically 120 to150 bpm, and systolic blood pressure can reach 200 mm Hg, resulting in a cardiac workload similar to that produced by moderate physical exertion. Intercourse exercises the pelvis, thighs, buttocks, arms, neck, and thorax muscles. Sexual activity and orgasm also boost production of testosterone, which promotes improved bone and muscle strength. Sexual intercourse stimulates the production of prolactin, which has been linked to improvements in mood, psychological bonding, and sense of smell.[45,46]

Excessive Exercise and Inadequate Rest

Although it is well established that physical exercise has many protective health benefits, accumulating data indicate that extreme physical activity may be detrimental to CV health. Prolonged and excessive aerobic exercise efforts such as marathons, ultra-marathons, full-distance triathlons, and very long-distance bicycle rides are inconsistent with our genetic heritage. The pattern of exercise for which we are genetically adapted involves a diversity of activities performed intermittently, at moderate intensities, and moderate durations. Even in highly trained individuals, high-intensity, multi-hour endurance exercises are associated with elevated troponin levels (which are

Table 1. Hunter-Gatherer or Forager Activities and Recommended Activities with Comparable Caloric Expenditure[4]

Hunter-Gatherer Activity	Modern Equivalent Activity	Calories Expended er Hour (176 lb-Male)	Calories Expended per Hour (132-lb Female)
Carrying logs	Carrying groceries, luggage	893	670
Running (cross-country)	Running (cross-country)	782	587
Carrying meat (20 kg) back to camp	Wearing backpack while walking	706	529
Carrying young child	Carrying young child	672	504
Hunting, stalking animals	Interval training	619	464
Digging (tubers in field)	Gardening	605	454
Dancing (ceremonial)	Dancing (aerobic)	494	371
Carrying, stacking rock	Lifting weights	422	317
Butchering large animal	Splitting wood with axe	408	306
Walking—normal pace (Fields and hills)	Walking—normal pace (Outside on trails, grass, etc.)	394	295
Gathering plant foods	Weeding garden	346	259
Shelter construction	Carpentry, general	250	187
Tool construction	Vigorous housework	216	162

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Table 2. Daily Caloric Expenditure of Hunter-Gatherers Versus Modern Sedentary Humans[66]

Species	Gender	Total Daily Caloric Expenditure	Calories for Physical Activity	Daily Distances Covered (km)
Fossil hominids				
Homo habilis		2387	983	
Homo erectus		2731	1214	
Homo sapiens (early)		2880	1284	
Modern hunter-gatherers				
Kung	M	2178	903	10
	F	1770	600	8
Ache	M	3327	1778	16
Modern humans				
Sedentary Individual	M	2000	306	2.4
	F	1679	231	2.4

of uncertain clinical significance in this setting) and evidence for connective tissue trauma.[47–50]

Recent data suggest that repetitive, prolonged, and intense aerobic activity might be associated with increased CV risk in some individuals, most likely because of excessive mechanical and physiological demands and high levels of oxidative stress.[51] Serological markers of cardiac damage have been documented during marathon running.[52] One study found increased coronary calcium in 108 middle-aged marathon runners compared with non-runners who had matched risk factors, and CV event rates in the marathoners were equivalent to a coronary disease population.[53] In a case report, Goel et al[52] observed a 49-year-old marathoner who had significant obstructions in all 3 major epicardial coronary arteries with no associated risk factors, and who demonstrated generated protracted oxidative stress with prolonged running. Increases in left ventricular mass and chamber dimensions typically develop in response to high-level, intense, long-term training, particularly in cyclists, cross-country skiers, and rowers.[54] Although the normal adaptations to long-term, high-level exercise do not predispose individuals to fatal arrhythmias, heart failure, or myocardial infarction, some athletes can develop abnormal electrocardiograms and ventricular ectopy, including ventricular tachycardia.[55,56] Additionally, long-term, high-intensity, long-distance bicycle training/racing has been associated with osteopenia in cyclists, particularly in the spine.[55,56]

Naturally Re-establishing Caloric Balance

Prior to the Agricultural Revolution, energy input (ie, food intake) and energy expenditure (ie, physical activity) were directly and inextricably linked. When humans of the Pleistocene Age were hungry, they had to hunt, gather, forage, fish, etc.[4] Hunger, or even the threat of inadequate food, instills a powerful motivation to move with intensity and purpose. The modern industrialized world has virtually eliminated the evolutionary connection between energy expenditure and calorie intake. The "search and pursuit" time is minimized, and there are few limits on calorie intake. Today, the acquisition of massive amounts of calorie-dense foods and beverages requires minimal energy expenditure, such as a few steps to the refrigerator, a visit to the supermarket, or a drive through a fast food restaurant lane.

The health ramifications of this permanent decoupling of the primal evolutionary link between energy expenditure and energy intake are profound and far-reaching. When calories ingested regularly exceed calories burned, the excess is stored as adipose tissue. Excess fat tissue, especially when stored intra-abdominally, is causally related to many of the most prevalent and serious chronic illnesses in modern society.[57,58] Seventy percent of all American adults are either overweight or obese.[59,60] Cardiovascular disease remains the leading cause of death; the lifetime risk of hypertension is 90%, and the prevalence rates of both type 2 diabetes and Alzheimer's disease are substantially increasing.[61] This systematic and pervasive disconnect between energy intake and energy expenditure inherent in modern cultures is a fundamental factor in these epidemics. Increasing reliance on pharmaceutical agents to counteract this problem is much less logical than simply realigning our lifestyle to be more physically active, and our diet to include more unprocessed, naturally low-calorie whole foods to correct this energy imbalance.[61]

Characteristics of a Hunter-Gatherer Fitness Program

Natural selection did not design humans specifically to run marathons or 100-meter dashes, or to lift extremely heavy

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weights, but instead to survive and thrive in the wild as generalists.[4] Not coincidentally, the exercise patterns that appear to be ideal for promoting fitness and general health, while minimizing injury risks, are similar to the requisite hunter-gatherer activity pattern. The following list outlines fundamental elements of "organic exercise," which may serve as a template from which to design a fitness strategy for adults living in today's modern industrialized culture.

1. A large amount background daily, light-to-moderate activity such as walking was required. Although the distances covered would have varied widely according to hunting and foraging routines, cultures, weather, seasons, ages, etc., most estimates indicate that the average daily distances covered were in the range of 6 to 16 km.
2. Hard days were typically followed by an easier day, but every day a variety of physical activities had to be accomplished just to provide for the basic human needs. The hunter-gatherers' daily energy expenditures for physical activity typically were at least 800 to 1200 kcal or about 3 to 5 times that of modern sedentary individuals.[33]
3. Individuals walked or ran on natural surfaces, such as grass and dirt, and often on uneven ground; our ancient ancestors almost never walked or ran on solid flat rock. The combination of softer natural walking/running surfaces and less biomechanically restrictive shoes is a more evolutionarily congruent strategy to reduce impact loading of the joints.
4. Life in the wild often called for intermittent bursts of moderate-to-high level intensity exercise with intervening periods of rest and recovery. High-intensity interval training sessions should be performed once or twice per week.
5. Cross-training is important and should include exercises focusing on strength (resistive), endurance (aerobic), and flexibility (stretching). Rotation among multiple different forms of exercise develops resilience and multifaceted fitness and reduces the likelihood of overuse injury, boredom, and emotional burnout.
6. Regular sessions of weight training and other strength-building exercises are essential for optimizing health and fitness. These need to be performed at least 2 or 3 times per week, for at least 20 to 30 minutes per session.
7. In general, hunter-gatherers were lean, and probably almost never obese, which reduced trauma to their joints.[16]
8. Virtually all of the exercise was done outdoors in the natural world. Outdoor activities help maintain ultraviolet-stimulated vitamin D synthesis, improve mood, and facilitate adherence to a regular exercise program.
9. Much of the physical activity was done in context of a social setting (small bands of individuals who were hunting or foraging were working together on various chores). There is substantial evidence that some of the psychological benefits of formal exercise training programs are derived from the social bonding and other unique aspects of the group exercise sessions.[23] The benefits of group exercise can be conferred by structured programs and/or informal exercise sessions involving $\geq$ 2 individuals.
10. Genetic evidence suggests that humans and dogs have been coevolving together for as long as 135 000 years.[62] The mutual advantages conferred by this coevolutionary process have been theorized to be related to cooperative hunting between domesticated wolves and our ancient hominin ancestors. Thus, both the dog and the human genomes may be specifically adapted to outdoor exercise involving cooperation between these 2 species.[63] Indeed, studies indicate that dog ownership can facilitate adherence to an exercise program, improve fitness, and reduce excess weight among individuals.[64]
11. Dancing was often performed as a part of rituals and celebrations, and is an ideal form of exercise that improves fitness and reduces stress.[65]
12. Sexual activity has always been an important aspect of human physical and social interaction. A frequency of sexual activity of $\geq$ 1 or 2 times per week correlates with multiple health benefits.
13. Ample time for rest, relaxation, and sleep was generally available to ensure complete recovery after strenuous exertion.

Conflict of Interest Statement

James H. O'Keefe MD, Robert Vogel MD, Carl J. Lavie MD, and Loren Cordain, PhD disclose no conflicts of interest.

References

1. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA*. 2008;300(3):295–305.
2. Booth FW, Laye MJ, Lees SJ, Rector RS, Thyfault JP. Reduced physical activity and risk of chronic disease: the biology behind the consequences. *Eur J Appl Physiol*. 2008;102(4):381–390.

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3. Booth FW, Lees SJ. Fundamental questions about genes, inactivity, and chronic diseases. *Physiol Genomics*. 2007;28(2):146–157.
4. Cordain L, Friel J, eds. *The Paleo Diet for Athletes: A Nutritional Formula for Peak Athletic Performance*. New York, NY: Rodale Books; 2005.
5. Sandvik L, Erikssen J, Thaulow E, Erikssen G, Mundal R, Rodahl K. Physical fitness as a predictor of mortality among healthy, middle-aged Norwegian men. *N Engl J Med*. 1993;328(8):533–537.
6. Kokkinos P, Myers J, Kokkinos JP, et al. Exercise capacity and mortality in black and white men. *Circulation*. 2008;117(5):614–622.
7. Byberg L, Melhus H, Gedeborg R, et al. Total mortality after changes in leisure time physical activity in 50 year old men: 35 year follow-up of population based cohort. *BMJ*. 2009;338:b688.
8. Hill A, Ward S, Deino A, Curtis G, Drake R. Earliest Homo. *Nature*. 1992;355(6362):719–722.
9. Fenner JN. Cross-cultural estimation of the human generation interval for use in genetics-based population divergence studies. *Am J Phys Anthropol*. 2005;128(2):415–423.
10. Tremblay MS, Esliger DW, Copeland JL, Barnes JD, Bassett DR. Moving forward by looking back: lessons learned from long-lost lifestyles. *Appl Physiol Nutr Metab*. 2008;33(4):836–842.
11. Bassett DR. Physical activity of Canadian and American children: a focus on youth in Amish, Mennonite, and modern cultures. *Appl Physiol Nutr Metab*. 2008;33(4):831–835.
12. O'Keefe JH, Vogel R, Lavie CJ, Cordain L. Achieving hunter-gatherer fitness in the 21st century: back to the future. *Am J Med*. 2010;123(12):1082–1086.
13. O'Keefe JH Jr, Cordain L. Cardiovascular disease resulting from a diet and lifestyle at odds with our Paleolithic genome: how to become a 21st-century hunter-gatherer. *Mayo Clin Proc*. 2004;79(1):101–108.
14. Frassetto LA, Schloetter M, Mietus-Synder M, Morris RC Jr, Sebastian A. Metabolic and physiologic improvements from consuming a paleolithic, hunter-gatherer type diet. *Eur J Clin Nutr*. 2009;8(63):947–955.
15. Eaton SB, Konner M, Shostak M. Stone agers in the fast lane: chronic degenerative diseases in evolutionary perspective. *Am J Med*. 1988;84(4):739–749.
16. Eaton SB, Shostak M, Konner M. The first fitness formula. In: *The Paleolithic Prescription*. New York, NY: Harper and Row; 1988:168–199.
17. Haskell WL, Lee IM, Pate RR, et al; American College of Sports Medicine; American Heart Association. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116(9):1081–1093.
18. Johnson JL, Slentz CA, Houmard JA, et al. Exercise training amount and intensity effects on metabolic syndrome (from Studies of a Targeted Risk Reduction Intervention through Defined Exercise). *Am J Cardiol*. 2007;100(12):1759–1766.
19. Jakicic JM, Marcus BH, Lang W, Janney C. Effect of exercise on 24-month weight loss maintenance in overweight women. *Arch Intern Med*. 2008;168(14):1550–1559.
20. Tudor-Locke C, Bassett DR Jr. How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med*. 2004;34(1):1–8.
21. Trapp EG, Chisholm DJ, Freund J, Boutcher SH. The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. *Int J Obes (Lond)*. 2008;32(4):684–691.
22. Sigal RJ, Kenny GP, Boulé NG, et al. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: a randomized trial. *Ann Intern Med*. 2007;147(6):357–369.
23. Lavie CJ, Thomas RJ, Squires RW, Allison TG, Milani RV. Exercise training and cardiac rehabilitation in primary and secondary prevention of coronary heart disease. *Mayo Clin Proc*. 2009;84(4):373–383.
24. Peplonska B, Lissowska J, Hartman TJ, et al. Adulthood lifetime physical activity and breast cancer. *Epidemiology*. 2008;19(2):226–236.
25. Lee JH, O'Keefe JH, Bell D, Hensrud DD, Holick MF. Vitamin D deficiency an important, common, and easily treatable cardiovascular risk factor? *J Am Coll Cardiol*. 2008;52(24):1949–1956.
26. Holick MF. Vitamin D and sunlight: strategies for cancer prevention and other health benefits. *Clin J Am Soc Nephrol*. 2008;3(5):1548–1554.
27. Berman MG, Jonides J, Kaplan S. The cognitive benefits of interacting with nature. *Psychol Sci*. 2008;19(12):1207–1212.
28. Simonsick EM, Guralnik JM, Volpato S, Balfour J, Fried LP. Just get out the door! Importance of walking outside the home for maintaining mobility: findings from the women's health and aging study. *J Am Geriatr Soc*. 2005;53(2):198–203.
29. Stewart SF. Footgear—its history, uses and abuses. *Clin Orthop Relat Res*. 1972;88:119–139.
30. Reinschmidt C, Nigg BM. Current issues in the design of running and court shoes. *Sportverletz Sportschaden*. 2000;14(3)71–81.
31. Nyyssönen T, Luthje P, Kröger H. The increasing incidence and difference in sex distribution of Achilles tendon rupture in Finland in 1987–1999. *Scand J Surg*. 2008;97(3):272–275.
32. Digby CJ, Lake MJ, Lees A. High-speed non-invasive measurement of tibial rotation during the impact phase of running. *Ergonomics*. 2005;48(11–14):1623–1637.
33. Cordain L, Gotshall RW, Eaton SB, Eaton SB 3rd. Physical activity, energy expenditure and fitness: an evolutionary perspective. *Int J Sports Med*. 1998;19(5):328–335.
34. Bowerman WJ, Harris WE. *Jogging the Original Book a Medically Approved Fitness Program for All Ages*. New York, NY: Grossett and Dunlap; 1967.
35. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Energy, Nutrition and Human Performance*. Philadelphia, PA: Lea and Febiger; 1991: 421–451.
36. Cheung K, Hume P, Maxwell L. Delayed onset muscle soreness: treatment strategies and performance factors. *Sports Med*. 2003;33(2):145–164.
37. Counsilman JE. *The Science of Swimming*. New York, NY: Prentice Hall; 1968.
38. Loy SF, Hoffmann JJ, Holland GJ. Benefits and practical use of cross-training in sports. *Sports Med*. 1995;19(1):1–8.
39. White LJ, Dressendorfer RH, Muller SM, Ferguson MA. Effectiveness of cycle cross-training between competitive seasons in female distance runners. *J Strength Cond Res*. 2003;17(2):319–323.
40. Kraemer WJ, Ratamess NA, French DN. Resistance training for health and performance. *Curr Sports Med Rep*. 2002;1(3):165–171.
41. Hurtado AM, Hawkes K, Hill K, Kaplan H. Female subsistence strategies among Ache hunter-gatherers of Eastern Paraguay. *Human Ecology*. 1985;13(1):1–28.
42. Bird RB, Bird DW. Why women hunt: risk and contemporary foraging in a Western Desert aboriginal community. *Curr Anthropol*. 2008;49(4):655–693.
43. Ember C. Myths about hunter-gatherers. *Ethnology*. 1978;17:4439–4448.
44. Panter-Brick C. Sexual division of labor: energetic and evolutionary scenarios. *Am J Hum Biol*. 2002;14(5):627–640.
45. Hall SA, Shackelton R, Rosen RC, Araujo AB. Sexual activity, erectile dysfunction, and incident cardiovascular events. *Am J Cardiol*. 2010;105(2):192–197.
46. Ebrahim S, May M, Ben Shlomo Y, et al. Sexual intercourse and risk of ischaemic stroke and coronary heart disease: the Caerphilly study. *J Epidemiol Community Health*. 2002;56(2):99–102.
47. Fortescue EB, Shin AY, Greenes DS, et al. Cardiac troponin increases among runners in the Boston Marathon. *Ann Emerg Med*. 2007;49(2):137–143, 143.e131.
48. Hubble KM, Fatovich DM, Grasko JM, Vasikaran SD. Cardiac troponin increases among marathon runners in the Perth Marathon: the Troponin in Marathons (TRIM) study. *Med J Aust*. 2009;190(2):91–93.
49. Jassal DS, Moffat D, Krahn J, et al. Cardiac injury markers in non-elite marathon runners. *Int J Sports Med*. 2009;30(2):75–79.

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50. Middleton N, Shave R, George K, et al. Altered left ventricular diastolic filling following a marathon is a reproducible phenomenon. *Int J Cardiol*. 2007;122(1):87–89.
51. Schwartz JG, Merkel-Kraus S, Duval S. Does elite athleticism enhance or inhibit coronary artery plaque formation. Presented at: American College of Cardiology Scientific Sessions. Atlanta, GA; March 16, 2010.
52. Neilan TG, Januzzi JL, Lee-Lewandrowski E, et al. Myocardial injury and ventricular dysfunction related to training levels among nonelite participants in the Boston marathon. *Circulation*. 2006;114(22):2325–2333.
53. Möhlenkamp S, Lehmann N, Breuckmann F, et al; Marathon Study Investigators; Heinz Nixdorf Recall Study Investigators. Running: the risk of coronary events: prevalence and prognostic relevance of coronary atherosclerosis in marathon runners. *Eur Heart J*. 2008;29(15):1903–1910.
54. Maron BJ, Pelliccia A. The heart of trained athletes: cardiac remodeling and the risks of sports, including sudden death. *Circulation*. 2006;114(15):1633–1644.
55. Maron BJ. Hypertrophic cardiomyopathy and other causes of sudden cardiac death in young competitive athletes, with considerations for preparticipation screening and criteria for disqualification. *Cardiol Clin*. 2007;25(3):399–414, vi.
56. Rector RS, Rogers R, Ruebel M, Hinton PS. Participation in road cycling vs running is associated with lower bone mineral density in men. *Metabolism*. 2008;57(2):226–232.
57. Bays HE, González-Campoy JM, Henry RR, et al; Adiposopathy Working Group. Is adiposopathy (sick fat) an endocrine disease? *Int J Clin Pract*. 2008;62(10):1474–1483.
58. Després JP, Lemieux I, Bergeron J, et al. Abdominal obesity and the metabolic syndrome: contribution to global cardiometabolic risk. *Arterioscler Thromb Vasc Biol*. 2008;28(6):1039–1049.
59. Hill JO, Wyatt HR. Role of physical activity in preventing and treating obesity. *J Appl Physiol*. 2005;99(2):765–770.
60. Lavie CJ, Milani RV, Ventura HO. Obesity and cardiovascular disease: risk factor, paradox, and impact of weight loss. *J Am Coll Cardiol*. 2009;53(21):1925–1932.
61. O'Keefe JH, Gheewala NM, O'Keefe JO. Dietary strategies for improving post-prandial glucose, lipids, inflammation, and cardiovascular health. *J Am Coll Cardiol*. 2008;51(3):249–255.
62. Reid PJ. Adapting to the human world: dogs' responsiveness to our social cues. *Behav Processes*. 2009;80(3):325–333.
63. Hare B, Brown M, Williamson C, Tomasello M. The domestication of social cognition in dogs. *Science*. 2002;298(5598):1634–1636.
64. Coleman KJ, Rosenberg DE, Conway TL, et al. Physical activity, weight status, and neighborhood characteristics of dog walkers. *Prev Med*. 2008;47(3):309–312.
65. Hui E, Chui BT, Woo J. Effects of dance on physical and psychological well-being in older persons. *Arch Gerontol Geriatr*. 2009;49(1):e45–e50.
66. Cordain L, Gotshall RW, Eaton SB. Evolutionary aspects of exercise. *World Rev Nutr Diet*. 1997;81:49–60.

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