THE AMERICAN JOURNAL of MEDICINE®

Achieving Hunter-gatherer Fitness in the 21st Century: Back to the Future

James H. O'Keefe, MD,[a] Robert Vogel, MD,[b] Carl J. Lavie, MD,[c] Loren Cordain, PhD[d]

[a]*Mid America Heart Institute/University of Missouri-Kansas City, Kansas City;* [b]*University of Maryland, College Park;* [c]*Ochsner Clinic, Jefferson, La;* [d]*Colorado State University, Fort Collins.*

ABSTRACT

The systematic displacement from a very physically active lifestyle in our natural outdoor environment to a sedentary, indoor lifestyle is at the root of many of the ubiquitous chronic diseases that are endemic in our culture. The intuitive solution is to simulate the indigenous human activity pattern to the extent that this is possible and practically achievable. 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.

 • *The American Journal of Medicine (2010) 123, 1082-1086*

KEYWORDS: Cardiovascular health; Cross-training; Evolution; Exercise; Fitness; Hunter-gatherer; Obesity; Prevention

Physical activity is decreasing in our society, especially in children as they mature.[1] Clear evidence suggests that physical activity has numerous favorable beneficial physiologic effects that result in demonstrable reductions in cardiovascular and other disease endpoints. Daily exercise substantially alters the expression of a substantial proportion of the genes that comprise the human genome.[2,3] These profound and far-reaching changes in genetic expression may explain why cardiovascular fitness and daily energy expenditure on physical activity are among the strongest correlates of long-term health and survival[2-7] (**Figures 1, 2**).

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 superbly capable of performing the wide array of physical actions and behaviors required of the hunter-gatherer. Quantum improvements in technology such as those that spawned the agricultural revolution (350 generations ago), the industrial revolution (7 generations ago), and the digital age (2 generations ago) have engendered large systematic reductions in the amount of physical work required by humans.[10,11] 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 predictably results in physical disability and disease. An understanding of the typical hunter-gatherer physical activity pattern would seem to be an ideal template from which to design a modern exercise program.

FITNESS FOR LIFE IN THE WILD

Ironically, today, as the last vestiges of the hunter-gatherer lifestyle are being eclipsed by modern civilization, science is coming to realize the importance of this way of life for current-day human health, and its relevance to optimal fitness in the 21st century.[12,13] Compared with the glacial pace of genetic evolution, human technological and social evolution has occurred at light speed. This discordance has left us genetically adapted for the rigors of life as a hunter-

Funding: There was no funding or compensation made in the writing of this article.

Conflict of Interest: None.

Authorship: All authors had access to the information and had a role in the writing of this manuscript.

Requests for reprints should be addressed to James O'Keefe, MD, Cardiovascular Consultants, Mid America Heart Institute, 4330 Wornall Rd., Ste. 2000, Kansas City, MO 64111.

E-mail address: jhokeefe@cc-pc.com

0002-9343/$ -see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.amjmed.2010.04.026

gatherer despite the fact that we are citizens of the high-tech, sedentary, overfed, emotionally stressed 21st-century world. The intuitively obvious solution to this conundrum is to simulate the activity patterns of our Pleistocene ancestors.

Natural selection endowed 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.[14] Our ancient ancestors evolved an instinct compelling them to "Move when you have to, and rest when you can." Many of their waking hours were necessarily consumed with the physical activities required of everyday life (**Table 1**).[15] Except for the very young or the very old, everyone did a wide range of manual labors on a daily basis. 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. However, this inborn proclivity to take the path of least resistance plays a major role in the health woes beleaguering modern Americans.

CLINICAL SIGNIFICANCE

- Humans remain genetically adapted for a very physically active hunter-gatherer lifestyle. Many of the health problems endemic today result from lifestyle that is at odds with this evolutionary milieu.
- The daily physical activity pattern of the hunter-gatherer is an ideal template from which to design a modern exercise regimen.
- Characteristics include: incorporation of physical activity into daily life wherever possible, interval and strength/flexibility training, outdoor exercise on natural surfaces, group exercise, ample time for rest/recovery, and lifelong fitness.

IDEAL EXERCISE PATTERNS

The prospective clinical trials that have been performed assessing the health effects of various exercise regimens and the observational data are generally supportive of the health benefits conferred by a hunter-gatherer style of fitness regimen. A growing body of data indicates that many of the benefits of exercise accrue at relatively low to moderate levels of exercise.[17] Continuous higher-level activity, such as jogging 32 km/week, was not found to be statistically better than walking 19 km/week for reducing features of the metabolic syndrome.[18] On the other hand, a daily regimen of at least 45 minutes and possibly up to 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 modest pace intermittently throughout the day.[20] Combined aerobic and resistive activity has been shown to be superior to either alone for improving glycemic control for individuals with type 2 diabetes.[21] Intermittent intense activity results in more weight loss and better glucose metabolism than equivalent amounts of lower-intensity continuous activity.[22]

Even though exercise in general confers powerful cardiovascular protection,[23] some evidence suggests that physical activity performed outside may be more beneficial than indoor exercise.[24] Outdoor exercise offers the opportunity for sunlight exposure, which stimulates vitamin D synthesis

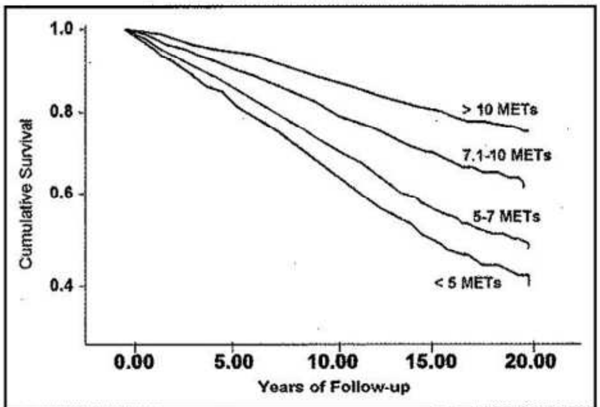

Figure 1 Long-term mortality as a function of fitness is closely associated with fitness as assessed by peak exercise level achieved on a maximal treadmill exercise test.[6] Reproduced with permission.

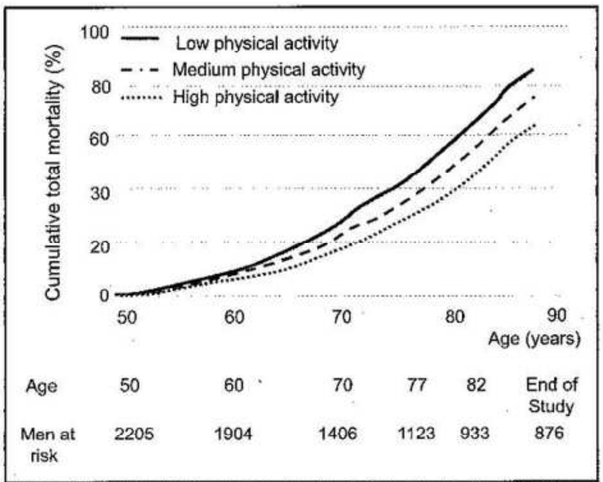

Figure 2 Reduction in long-term mortality in proportion to the amount of daily physical activity performed.[7] Reproduced with permission.

Table 1 Energy Expended: Hunter-Gatherer vs Moderns[15]

Species	Sex	Weight kg	RMR kcal	TEE kcal	Ratio (TEE/RMR)	EE PA kcal	Day Range km
Fossil hominids							
Homo habilis		48.0	1404	2387	1.70	983	
Homo erectus		53.0	1517	2731	1.80	1214	
Homo sapiens (early)		57.0	1605	2880	1.80	1284	
Modern hunter-gatherers							
Kung	M	46.0	1275	2178	1.71	903	10
	F	41.0	1170	1770	1.51	600	8
Ache	M	59.6	1549	3327	2.15	1778	16
Acculturated modern humans							
Homo sapiens	M	70.0	1694	2000	1.18	306	2.4
(office worker)*	F	55.0	1448	1679	1.16	231	2.4
Homo sapiens (runner)†	M	70.0	1694	2888	1.70	1194	11

EEPA = energy expenditure attributed to physical activity; RMR = resting metabolic rate; TEE = total energy expenditure.
*Sedentary office worker (4).
†Runner running 12.1 km/h (4).

in the epidermis. Vitamin D deficiency is a common and potent risk factor for many health problems, including cardiovascular disease.[25] Outdoor exercise reduces emotional stress and enhances compliance to a daily fitness regimen better than indoor exercise.[26,27]

Although hunter-gatherer women rarely participated in large-game animal hunting,[28] they too were very physically fit as a result of the demands of their daily physical routines. Ethnographic accounts of hunter-gatherers indicate that women typically went out foraging to collect food every other or every third day. Women, usually in groups, spent hours walking to and from sources of food, water, and wood.[4] Additionally, these forager women were often carrying their children for extended distances as well. Anthropologists have estimated that the typical hunter-gatherer mother carried her child until about age 4 years, covering upwards of 4,800 km with the child in her arms over this period of time.[29]

REST AND CROSS-TRAINING

Hunter-gatherers would have likely alternated difficult days with less demanding days when possible.[16] Their routines called for endeavors that promoted aerobic endurance, flexibility, and strength; thereby bestowing them with multifaceted fitness that would have also conferred resiliency and reduced the likelihood of injury. The same pattern of alternating a strenuous workout one day with an easy one the next day produces higher levels of fitness with lower rates of injury.[30] In exercise physiology, it has been well documented that aerobic capacity within an individual may increase based upon exercise frequency, intensity, and duration.[31] Of these 3 factors, intensity is the most important feature in optimizing the aerobic capacity, especially in an already trained individual.[31] 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. Now, most endurance sport coaches incorporate cross-training such as strength and flexibility exercises into their prescribed training routines.[32-34]

THE DANGERS OF EXCESSIVE EXERCISE AND INADEQUATE REST

Whereas physical exercise is unquestionably protective, there are evolving data from Vogel et al[35] and others that extreme physical activity may be detrimental to cardiovascular 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 exercise effort is associated with damage to the myocardial cells and connective tissue.[36-39]

NATURALLY REESTABLISHING CALORIC BALANCE

For all humans before the dawn of the Agricultural Revolution, energy input (food) and energy expenditure (physical activity) were directly and inextricably linked. When humans of the Pleistocene Age were hungry, they had to hunt, gather, forage, and fish.[4] Hunger, or even the threat of inadequate food, instills a powerful motivation to move with intensity and purpose. The convenient modern world has virtually eliminated the evolutionary connection between energy expenditure and calorie ingestion. The "search and pursuit" time are minimized, while the caloric payoff is almost unlimited. Today, the acquisition of massive amounts of calorie-dense foods and beverages requires minimal energy expenditure.

This systematic and pervasive disconnect between energy intake and energy expenditure inherent in modern

Table 2 Caloric Cost of Various Hunter-gatherer or Forager Activities and Recommended Equivalent Modern Activities[4]

		Caloric Expenditure (Kilocalories/Hour)	
Hunter-Gatherer Activity	Modern Equivalent Activity	176-lb Man	132-lb Woman
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

cultures is a fundamental factor in the obesity epidemic. Increasing reliance on pharmaceutical agents to counteract this problem is much less logical than simply realigning our lifestyle to be more physically active, (**Table 2**) and our diet to include more unprocessed, naturally low-calorie, whole foods in order to correct this energy imbalance.[40]

CHARACTERISTICS OF A HUNTER-GATHERER FITNESS PROGRAM

1. A large amount of background daily light-to-moderate activity such as walking was required. Although the distances covered would have varied widely, most estimates indicate average daily distances covered were in the range of 6 to 16 km. The hunter-gatherers' daily energy expenditures for physical activity typically were at least 800 to 1200 kcal,[41] or about 3 to 5 times more than the average American adult today.
2. Hard days were typically followed by an easier day. Ample time for rest, relaxation, and sleep was generally available to ensure complete recovery after strenuous exertion.
3. Walking and running were done on natural surfaces such as grass and dirt, often over uneven ground. Concrete and asphalt surfaces are largely foreign to our genetic identity.
4. Interval training sessions, involving intermittent bursts of moderate- to high-level intensity exercise with intervening periods of rest and recovery, should be performed once or twice per week.
5. Regular sessions of weight training and other strength and flexibility building exercises are essential for optimizing musculoskeletal and general 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.
6. Virtually all of the exercise was done outdoors in the natural world.
7. Much of the physical activity was done in context of a social setting (small bands of individuals out hunting or foraging). Exercising with one or more partners improves adherence and mood.[23]
8. Except for the very young and the very old, all individuals were, by necessity, physically active almost their entire lives.

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;300:295-305.
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;102:381-390.
3. Booth FW, Lees SJ. Fundamental questions about genes, inactivity, and chronic diseases. *Physiol Genomics*. 2007;28:146-157.
4. Cordain L, Friel J. *The Paleo Diet for Athletes: A Nutritional Formula for Peak Athletic Performance*. New York: 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;328:533-537.
6. Kokkinos P, Myers J, Kokkinos JP, et al. Exercise capacity and mortality in black and white men. *Circulation*. 2008;117:614-622.
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;128:415-423.

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;33:836-842.
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;33:831-835.
12. 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;79:101-108.
13. 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;63:947-955.
14. Eaton SB, Konner M, Shostak M. Stone agers in the fast lane: chronic degenerative diseases in evolutionary perspective. *Am J Med*. 1988; 84:739-749.
15. Cordain L, Gotshall RW, Eaton SB. Evolutionary aspects of exercise. *World Rev Nutr Diet*. 1997;81:49-60.
16. Eaton SB, Shostak M, Konner M. The first fitness formula. In: *The Paleolithic Prescription*. New York: Harper & Row; 1988:168-199.
17. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116:1081-1093.
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;100:1759-1766.
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;168:1550-1559; discussion 1559-1560.
20. Tudor-Locke C, Bassett DR Jr. How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med*. 2004; 34:1-8.
21. Sigal RJ, Kenny GP, Boule 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;147:357-369.
22. 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;32:684-691.
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;84:373-383.
24. Peplonska B, Lissowska J, Hartman TJ, et al. Adulthood lifetime physical activity and breast cancer. *Epidemiology*. 2008;19:226-236.
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;52:1949-1956.
26. Berman MG, Jonides J, Kaplan S. The cognitive benefits of interacting with nature. *Psychol Sci*. 2008;19:1207-1212.
27. 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;53:198-203.
28. Hurtado AM, Hawkes K, Hill K, Kaplan H. Female subsistence strategies among Ache hunter-gatherers of Eastern Paraguay. *Hum Ecol*. 1985;13:1-28.
29. Panter-Brick C. Sexual division of labor: energetic and evolutionary scenarios. *Am J Hum Biol*. 2002;14:627-640.
30. Bowerman WJ, Harris WE. *Jogging: A Medically Approved Fitness Program for All Ages*. New York: Grossett and Dunlap; 1967.
31. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Energy, Nutrition and Human Performance*. Philadelphia, PA: Lea & Febiger; 1991:421-451.
32. Loy SF, Hoffmann JJ, Holland GJ. Benefits and practical use of cross-training in sports. *Sports Med*. 1995;19:1-8.
33. 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;17:319-323.
34. Kraemer WJ, Ratamess NA, French DN. Resistance training for health and performance. *Curr Sports Med Rep*. 2002;1:165-171.
35. Goel R, Majeed F, Vogel R, et al. Exercise-induced hypertension, endothelial dysfunction, and coronary artery disease in a marathon runner. *Am J Cardiol*. 2007;99:743-744.
36. Fortescue EB, Shin AY, Greenes DS, et al. Cardiac troponin increases among runners in the Boston Marathon. *Ann Emerg Med*. 2007;49: 137-143, 143.e1.
37. 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;190:91-93.
38. Jassal DS, Moffat D, Krahn J, et al. Cardiac injury markers in non-elite marathon runners. *Int J Sports Med*. 2009;30:75-79.
39. Middleton N, Shave R, George K, et al. Altered left ventricular diastolic filling following a marathon is a reproducible phenomenon. *Int J Cardiol*. 2007;122:87-89.
40. 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;51:249-255.
41. Cordain L, Gotshall RW, Eaton SB, Eaton SB 3rd. Physical activity, energy expenditure and fitness: an evolutionary perspective. *Int J Sports Med*. 1998;19:328-335.