# An evolutionary perspective on sedentary behavior

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Ideas and speculations

**Abstract**

Most people are aware of the health benefits of physical activity. Why then do people so easily fall into sedentary habits? The idea developed here is that sedentary behavior reduces acute mortality risk from physical activity, and was strongly selected in our evolutionary past. However, hunter gatherer populations could not reduce activity indefinitely because of the need to hunt for and gather food. Hence they never experienced low levels of activity that are damaging to health, and no corresponding mechanism avoiding low activity evolved. Modern society has facilitated reduced activity by providing many options to become less active, and divorcing food intake from the need to be active. Choosing less active options is in our genes: this explains why being sedentary is so common, and why reversing it is so difficult. Enforcing and incentivizing activity may be enabled using modern technology, but ultimately we may only replace one set of health issues with others.

152 words

**Keywords**

Physical inactivity, sedentary behavior, genetics, evolution, internet of things, smart technology

## Introduction – the problem of physical inactivity

Hippocrates was so enamored by the benefits of being active that he stated "*Walking is man's best medicine*" [1]. Being physically active lowers the rates of cardiovascular disease, hypertension, stroke, type 2 diabetes, depression and frailty [2-4]. Conversely, sedentary behavior (sitting and lying) increases the risk of coronary heart disease, type 2 diabetes and both breast and colon cancer, and hence leads to shortening of lifespan [5]. Estimates of the fraction of the population levels of these non-communicable diseases attributable to being inactive suggests that physical inactivity (defined as not attaining government guidelines for activity) is responsible for 6.8% of cardiovascular disease, 7% of type 2 diabetes, and 10% of breast and colon cancer [6]. Overall physical inactivity was judged to be responsible for 5.3 million of the 57 million deaths that occurred worldwide in 2008 [6]. In comparison smoking was estimated to have caused 5 million deaths in 2000 [7], although there is likely some overlap in these mortality sets because heavy smokers are unlikely to have high levels of activity Reducing the population levels of inactivity by 10% would save around half a million lives annually [6]. The lifespan gains for a person who changes from being inactive to active are estimated at 1.3 to 3.7 years in the USA [8,9], and 2.6 to 4.2 years among East Asians [10]. There is considerable evidence that the epidemiologically identified links are causal [11].

Although these benefits of being physically active are well known, large segments of the world population are physically inactive - not meeting the widely adopted government guidelines to engage in 150 mins of moderate to vigorous activity per week. The WHO estimated that in 2008 31% of the population of individuals aged >15 were insufficiently active. Such data led to the WHO global strategy for physical activity [4]. Despite such strategies physical inactivity has continued to rise and a recent estimate is that 96% of Americans in 2016 did not meet the recommended target levels [12].

## If physical activity is so beneficial why is sedentary behavior so alluring?

Outside my apartment block there is a small paved path that runs across an area of grass. At the end of the grass it meets another path at an angle of about $90^o$. People have the choice at the end of the first path to turn either left or right. At each side of the junction the grass is worn away where people take a shortcut across the corner. You can see evidence of the same shortcuts being used everywhere across the whole world. I walk past this particular example twice every day and have often wondered why people do that. Walking across the corner, instead of staying on the paved section, reduces the path of travel by at most 1m. The time saving is about 1 second. However, corner cutting is so common a behavior that it must be hard wired into our biology. Individually cutting corners results in trivial savings of time and energy. But by doing it repeatedly the savings can start to add up. Imagine I am a hunter gatherer walking 13 to 21000 steps per day [12]. There may be 200 or more occasions on my path where I can optimize the route I take to make it a little shorter. So now I am walking 200m less and saving 200 seconds every day. Over a whole year that means I have saved walking 73km and about 20 hours and 15 mins of walking time.

The fact that we still cut corners suggests that there was a strong selective pressure for this type of behavior to evolve. This implies that there is something negative about physical activity that is selected against. I will develop the argument here that this natural selection pressure *against* physical activity is a major driving factor that causes adoption of sedentary behavior in modern society. This view contrasts previous considerations of the evolution of physical activity which have generally suggested increasing levels of activity to be advantageous and hence endurance was strongly selected for [13-17]. The argument is similar to that by Lieberman (18), Cheval et al [19] and Lee et al [20] but based on a different mechanism. These previous authors have suggested that there is a selection pressure to reduce the total energy that we expend on physical activity [18-20], and thus favor behaviors that minimize energy expenditure. It is suggested this minimization was important during our evolutionary history because energy supplies are limited. In other words, because walking (or running) costs more energy than being sedentary, by cutting corners our activity overall becomes more energy efficient. We visit the same places over the course of a year on our walking travels, but it costs us less energy to do so. This would add to the numerous other adaptations we have when walking, such as modulating step length [21], and co-ordinating our arm movements [22] to minimize energy costs. Modern corner cutting is evidence that our ancestors experienced strong selective pressures to reduce activity time, potentially to save energy. Taking opportunities to be sedentary as opposed to being active is an extension of this phenomenon, and a suggested selective pressure for us to be inactive whenever the opportunities arise [18-20].

**Is the benefit really energy saving?**

How much actual energy would corner cutting save? Sitting costs about 1.7 kcal/min [23]. In contrast the cost of walking is about 3 kcal/min [24], so each minute walking expends an additional 1.3 kcals. Over the hypothetical year of corner cutting the energy saving would amount to 1580 kcals. Given that most vegetables have energy densities in the range from 30-50 kcal/100g, saving this amount of energy would reduce the annual amount of vegetables needed to be eaten by over 3kgs. For a diet consisting mostly of meat, with an energy density around 200 kcal/100g, the weight of saved intake would be lower, but still about 0.8 kgs. Although these seem large amounts of energy and food, energy demands of hunter-gatherers and forager-horticulturalists are around 2500 to 4000 kcal/day [25,26], hence a saving of 1500 kcals by cutting corners over the course of a year is actually only 0.1 to 0.2% of the total annual energy budget. It seems unlikely that this would be a sufficient selective advantage to positively select for the behavior, particularly since this difference in the level of available energy is only indirectly linked to the true drivers of selection, which are reproduction and survival.

Nevertheless, taking opportunities to be sedentary would potentially provide much greater benefits in terms of saved energy than cutting corners would, and so may be selected. However, I suggest based on recent evidence that this is unlikely to be the case. It seems that there is little relationship between the levels of physical activity (and hence also inactivity) and total expenditure of energy. For example, levels of total energy expenditure have remained virtually constant since the 1980s despite evidence that over the same interval direct measures of physical activity levels indicate it has decreased [27]. These observations have been extended more recently to hunter-gatherer populations, showing that while HG populations may be more than twice as active as their western counterparts, their total daily energy demands, when corrected for body size, are not different [26]. It has been suggested that this may be because total energy expenditure is constrained [28]. The fact there is a limit on total energy expenditure is well established [29-31]. Animals working at this limit cannot increase expenditure on a component of their energy budget without cutting back on some other aspect of their energy expenditure. When animals working at this limit become more physically active the expended energy on activity may increase, but this must be compensated by savings in the budget elsewhere. This would explain why levels of activity and total expenditure are not closely linked. However, the levels of expenditure in hunter-gatherer and other populations are well below the levels at which such limits are suggested to apply [29-32] so the constraint explanation is unlikely to be correct. However, the fact that compensation is observed is indisputable, even if we do not fully understand the mechanism. The argument that we are driven to be inactive to save energy [18-20] therefore seems improbable.

**If it isn't for saving energy then why do we do it?**

Instead I suggest that there may have been other, more direct, advantages of reducing activity time. The first is the risk of predation. I have already discussed elsewhere how risk of being predated may have been extremely high in small early Hominins like Australopithecus, because African populations of predatory cats were much higher and more diverse than presently [33-35]. Australopithecine fossil bones often carry features indicative of predation. Once our ancestors discovered fire and started to use weapons the risk of predation probably declined enormously. But by this time there had been at least three million years of high predation risk and the die had been cast. This risk would select for behaviors minimizing the time spent active because it is active individuals that are more likely to be predated [36]. Twenty hours less activity per year from cutting corners is about 1% less total activity, but this would translate directly to a 1% reduction in mortality risk when foraging, much more important in terms of selection than a 0.1 to 0.2% energy saving, that might in any case be compensated elsewhere in the energy budget. Increases in sedentary time at the expense of activity would bring directly proportional benefits in survival, even if total energy expenditure was unrelated to such changes. Even if predation risk was dramatically reduced 2 million years ago [33-35] the avoidance of activity whenever possible might be sustained because there was no selective advantage to stop doing it (inertia), but also because there are other negative aspects of activity sustaining selection on the trait. For example, although snakes generally do not predate humans, the risk of fatal snake bite is massively increased among walking and running individuals. Moreover, there is the increased risk of injury. Walking, and especially running, entail increased risks of ankle sprains and, exceptionally, limb fractures, relative to being sedentary. In earlier times, with no health care, such events would also likely be fatal. Hence the direct mortality risks of exercise likely provided a much stronger selection pressure against physical activity than their impacts on energy balance.

Gene variants favoring efficiency of physical activity (like corner cutting) and sedentariness were likely advantageous during our evolutionary history. This is probably why there is a high heritability of physical activity levels [37-39] and inactivity levels [40]. Gene variants are known that cause reduced activity [41]. This explains why there is such a strong drive to reduce our physical activity whenever we can. This genetic imperative to minimize activity is hard wired into our biology.

**Is it just a disadvantage of activity or also an advantage of being sedentary?**

The idea developed above is that there are disadvantages of being active that select for genes pushing us to be sedentary. But is there also a fitness 'pull' of being sedentary as well? One thing that primates and humans do extensively when they are inactive is to socialize with each other. These social behaviours are among the most characteristic features of humans and non-human primates, and in theory they may provide a fitness pull towards being sedentary, that magnifies the fitness push from the mortality risks of activity. I suggest this is unlikely. This is because humans do not stop being social when they are active. Sociality among groups of hunters and foragers were likely extremely important, allowing individuals to co-operatively hunt animals larger than themselves, butcher them in the field and carry the pieces back to camp. This fitness benefits of sociality probably therefore occur independently of whether individuals are active or sedentary, and the difference in fitness due to sociality between the states would be unlikely to provide a sufficient fitness pull towards being sedentary.

How might these ideas be tested? Testing evolutionary arguments is notoriously difficult, because we cannot go back and re-run evolution with a different set of selective pressures to see if the outcome differs. The best we can hope then is to test the underlying assumptions on which any given selection scenario is based. A primary element of the argument I have developed is that there is a fitness push towards being sedentary because of the mortality risks encountered during periods of activity. A critical test of the idea then would be to measure directly such mortality risks. If it was shown that being active did not bring significant risks of mortality above being sedentary that would be enough to disprove the hypothesis.

**How is this relevant to activity in the modern world?**

What implications does the fitness push to inactivity have for modern humans? I suggest that it has a major impact. In the modern world, we still cut corners, and select the least energy-consuming ways of getting around. We choose the moving walkway rather than walking. We order our shopping online rather than going to the supermarket. We order takeaway instead of going to the restaurant or cooking ourselves. The building where I work has 6 stories that are accessed via two elevators and a staircase. Last week for a couple of days I sat by the ground floor elevators and counted people returning from lunch who used the stairs and who used the elevators. One hundred and fifty seven people came by, of which only two used the stairs. We make these choices even though we know the options we don't choose are healthier.

Physical inactivity is bad for our health, so it is reasonable to ask why there was not a counter-selection pressure against being sedentary. The reason for this it seems is that to exist as a hunter gatherer you need to do a fair amount of activity to collect food. There are few true hunger-gatherer populations left, but those that have been studied walk a lot – about 6h and 20km per day [12, 42-44]. It seems this level of activity is necessary to collect enough food [18,45]. So, while there was always a selective pressure to minimize activity, you could not sit around all day socialising. Long durations of physical inactivity were never experienced because of the more dominant urge to collect food to eat. It seems plausible that our ancestral populations were never sufficiently inactive that they started to get the diseases we now associate with inactivity [18-20], which would have selected against this trait. Modern hunter-gatherers have virtually no cardiovascular disease, for example [44]. Consequently there was never a countervailing selection pressure against reducing activity levels whenever possible [18-20].

The main problem with modern life is that we have come to the point where we are able to indulge our drive to be sedentary, to a low level of physical activity not seen previously in our evolutionary history. Importantly, in addition our food intake has become disconnected from physical activity levels. We can be inactive without starving to death. Our ancestors could not. Our genetic legacy pushes us towards inactivity at every opportunity, and we succumb almost every time that opportunity arises. This explains why large sectors of industrialised society have levels of activity that are damaging to health (reviewed above). Our Australopithecine genetics never prepared us for this eventuality, and worse, they help us to resist any initiative to reverse the trend.

**What can be done to overcome the hardwired desire to be sedentary?**

Because the desire to be sedentary is in our genes, it will be difficult to reverse. Moreover, the history of public health science tells us repeatedly that giving people information that their behavior is damaging does little to motivate behavior change. The simplest way to reverse this trend would be to eliminate the possibilities to avoid activity. Recently both elevators in my office building were simultaneously broken. There was no option but to take the stairs. If nothing else this showed that people can do it if they are forced to. Generally, initiatives to improve physical activity levels will be most successful if they include removing the option to choose a more sedentary alternative. Grass only regrows at the corners of intersecting pathways if the ability to walk across the corner is restricted by a barrier. Lieberman, makes similar suggestions, but additionally suggests exercise might be encouraged if we made it more fun [18]. This may work for sporting activity but I am less sure that fun will be a sufficient motivator to overcome our deep genetic history for more mundane activities. There is only so much fun that can be derived from walking up stairs!

Removing options to be sedentary will be difficult. Removing elevators, thus forcing people to take the stairs, for example, would likely increase physical activity levels, but clearly also have some undesired side effects. Elevators facilitate the movement of people who have mobility issues, reduce the time spent commuting around office space to improve productivity, and they are also used to transport things, other than people. Modern technology, however, may enable solutions to this problem. It would be relatively easy, for example, to issue people with disabilities who need to use elevators with swipe cards permitting them to do so, while blocking out individuals that do not have such needs. Many hotel elevators already have such technology to restrict individual access to guest room levels. This could be further enabled if the population using the elevator was known, by using face recognition technology, thereby eliminating the need for physical swipe cards, and issues if people lost for forgot their cards etc. I recently visited a company in South China where using the elevators was simply not permitted by staff with the stated goal of promoting their physical activity levels because it was good for them. I did not find out what the sanctions were for breaking the rules (apart from bad health).

As technology develops one might envisage all sorts of scenarios where we could be incentivized to engage in activity. For example, many people now carry smart phones that have integral accelerometers that log physical activity. The advent of big data means that conceivably such activity could be centrally accumulated and people reaching certain activity levels could be given tax breaks. One would need to have safeguards, for example, to prevent people attaching their phones to their dogs to reach the tax break threshold, but that could be easily enabled by having a small implanted ID chip linked to the external device.

Sooner or later, however, if we force or incentivize large numbers of individuals to take the stairs, or walk the streets some of them will fall and get injured, or be hit by a car or involved in street violence (predated), and then we will be reminded why we are selected to be inactive. In the USA, for example, there are 2.3 deaths per million residents per annum due to cars hitting cyclists [46]. If we increased the amount of cycling by a factor of 5 that would potentially lead to an extra 3600 activity related deaths per year. The question is, will the frequency of such negative outcomes at the population level negate the benefits of doing the extra physical activity?

**Conclusion**

Reducing activity levels whenever possible has probably been under strong selection during our evolutionary history. However, the drive to eat which required us to collect food and hunt meant we never experienced low levels of activity. Hence there were never the conditions for a countervailing selection pressure to avoid low activity levels that we now know are damaging to health. We consequently take all opportunities that present themselves to reduce our physical activity, and, crucially, there is no lower limit to that imperative. Modern industrialised society has largely facilitated this behavioral change by continuously presenting us with options to reduce our activity, and disconnecting the need to eat from the need to be active. Attempts to encourage us to choose the option requiring more activity are largely futile in the face of our evolutionary history and genetics. Probably the only way to successfully increase activity will be to remove the low activity alternatives, but this will often have other negative consequences. Modern smart technology and may enable solutions to these issues, but in the end forcing people to be active may expose them to a different set of health issues.

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