Neuroethics
https://doi.org/10.1007/s12152-020-09454-4

ORIGINAL PAPER

Should Couch Potatoes Be Encouraged to Use Transcranial Direct Current Stimulation?

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Received: 17 March 2020 / Accepted: 29 October 2020

Abstract A very high percentage of the world population doesn't exercise enough and, as a consequence, is at high risk of developing serious health conditions. Physical inactivity paired with a poor diet is the second cause of death in high income countries. In this paper, I suggest that transcranial direct stimulation (tDCS) holds promise for "couch potatoes" because it could be used to make them more active, without causing any major side-effect. I also argue that other, less safe, tools could be used to achieve the goal of decreasing physical inactivity, insofar as they have overall fewer side-effects than physical inactivity.

Keywords tDCS · Neurodoping · Doping · Sport

Modern Sedentary Life Style Kills People and Imposes Huge Economic Costs

Over the last century, the lifestyle of people in Western countries has become increasingly sedentary. Most people have a desk job that requires them to spend long hours sitting in front of a computer, allowing very little time to exercise. Even those jobs that were once active, such as in agriculture or farming, have become considerably less physically demanding thanks to the increased use of machines.

Moreover, many people use a car on a daily basis, and therefore don't take the recommended minimum 10,000 steps a day. We also spend more time indoors than we used to, and this is especially true of young people and children who often play indoor with electronic devices rather than playing outdoors [1].

Although the advantages of modern western life are undeniable—we enjoy wealth, healthcare, and comfort that our grandparents couldn't have even dreamt of—sedentary lifestyles poses serious health risks that we need to tackle with urgency.[1] According to the WHO, 26% of men and 35% of women in high-income countries are not active enough.[2] According to a meta-study published in 2018, one in four adults in high-income countries performs less than 150 min of moderate exercise per week [2].

These data are rather alarming when we consider that a sedentary life-style has been linked to increased risk of cardiovascular disease, hypertension, diabetes, dementia and some types of cancers, and that when paired with a poor diet, it is the second leading cause of death in high-income countries [3]. It has been estimated that physical inactivity alone is responsible for 9% of premature deaths worldwide [4], and that 2.8 million people die every year because they are overweight or obese.

Not only does a sedentary life-style cause disability, illness, and premature death (i.e. a conspicuous loss in

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[1] WHO, Global NCD Action Plan 2013–2020 https://www.who.int/nmh/events/action_plan_indicators/en/
[2] WHO, available at: https://www.who.int/news-room/fact-sheets/detail/physical-activity

Published online: 12 November 2020

terms of QALYs), it also imposes huge economic costs on health systems and state budgets. According to the estimate of the WHO, the global cost of physical inactivity was $54 billion per year in direct health care in 2013, with an additional $14 billion attributable to lost productivity. Inactivity accounts for 1–3% of national health care costs, not including the costs associated with mental health and musculoskeletal conditions.[3]

In sum, at the individual level, sedentary life-styles cost many individuals a substantial reduction in life-expectancy, as well a reduced quality of life due to the increase of illness and disability. At a societal level, sedentary life-style results in lost productivity and billions of dollars in medical expenses.

What Makes the Difference between a Couch Potato and an Athlete?

While modern lifestyles may help to explain why we have become collectively less active, they obviously cannot explain why there are huge individual differences in physical activity. One interesting question, therefore, is why some people manage to maintain a very active lifestyle, even when they have to spend long hours at a desk, and other people instead become couch potatoes.

It seems plausible that both the social and physical environment in which a person finds herself play a big role. The fact that a person who may have a preference for being sedentary is forced to walk all day because of her job will make a difference to her overall level of physically activity: a waiter can't sit when she is at work, but a writer can. Similarly, a sedentary person who lives with very active people who invite her to go on hikes and excursions, will probably end up being more active than someone who lives with other sedentary people. Also, living close to parks, pedestrian walkways, sport facilities, and affordable sports equipment may constitute an incentive to be more active, whereas expensive gyms and dangerous neighborhoods provide an excellent alibi for not exercising. In general, we all feel more inclined to go out for a walk when we are immersed in a beautiful environment, whereas even the most active person would find the prospective of going out for a run quite unappealing if they had to do so in the middle of a busy road where the air was full of exhaust gas from motor vehicles. So even among people who enjoy physical exercise, the difference in the frequency with which they practice a sport may have a strong environmental component.

Another plausible explanation is that genes play a role in individual differences in the level of physical activity. At the present time, as Rod Dishman has pointed out, we don't know much "about how genes, the environment, and their interactions influence the brain's regulation of physical activity behaviour" [5]. However, there seems to be good evidence in support of the claim that genes play a significant role in regulating the amount of time each of us spends being active or sitting on the couch [6].

We don't know how, and to what extent, genes influence one's level of physical activity, but researchers seem to agree that the dopaminergic system is involved in regulating the response to physical exercise. To put it very simply, the more dopamine one produces during physical exercise (or any other activity, for that matter), the more rewarding the physical exercise is perceived to be, and therefore the more the individual will want to exercise again. It is likely that the individuals who produce more dopamine while exercising are also the ones who enjoy exercise more and therefore exercise more often and for longer. Studying the link between dopamine and physical activity, Knab and Lightfoot concluded, "It is clear that the dopaminergic system is affected by physical activity (dopaminergic function=dependent variable), and it is plausible that the amount of voluntary physical activity is regulated at least in part by the dopamine system (dopaminergic function = independent variable). The mechanisms behind this correlation are yet to be fully understood" [7].

Recent research also suggests that the genes regulating the dopamine response to physical exercise also influence exercise reinforcement and tolerance for exercise intensity [8]. The researchers noticed that people with a certain genotype have a stronger dopamine response to exercise, and that such a response is associated with 1) engaging in physical activity at a higher frequency, duration and intensity than people with no strong dopamine response to sport; 2) more frequently choosing to be active as a child [9]; 3) habitual vigorous physical activity as an adult. The researchers concluded that those who have stronger dopamine responses to exercising also have higher tolerance to the unpleasant parts of exercising and are more likely to continue to be

[3] WHO Global Action Plan On Physical Activity 2018–2030, available at https://apps.who.int/iris/bitstream/handle/10665/272722/9789241514187-eng.pdf

active even when they struggle. So, dopamine levels during exercise make a quite substantial difference to whether someone will decide to engage in physical activity, to power on when one she is tired, and to her perception of fatigue itself. Although we still have a poor understanding of which genes influence an individual's level of activity, "it is clear that there is genetic influence on physical activity in both humans and animals strongly suggesting that one can be born with a predisposition toward inactivity or activity" [10].

Regardless of how promising research in genetics appears to be, at the moment there is no genetic intervention that can turn a couch potato into an athlete or even just a moderately active person. Nothing can magically instill the desire to get up from the sofa and run a marathon. Ultimately, people need to find in themselves the motivation to be active (for instance in the form of concerns about their health or their appearance) or in the physical and social environment they live in (a friend who convinces them to go out for a walk, or the promise of a monetary reward for exercising). However, the motivation to stay active is as important as the motivation to start getting active. Every couch potato went to the gym at least once in their life, but probably didn't go back again because they didn't enjoy it, or perhaps because they found it too painful. It is possible that people who struggle with continuing exercise after taking it up for the first time would become more active if they didn't perceive exercising as very painful or, even better, if they perceived it as enjoyable.

In sum, both a change in environmental and social circumstances, as well as genetic engineering interventions, could be game changers for tackling the health issues associated with a sedentary life-style. Another tool that could be tested to achieve these goals is transcranial direct current stimulation (tdCS).

tDCS and Physical Exercise

In its basic form, tDCS involves the stimulation of some areas of the brain through two electrodes connected to a device that provides current. The two electrodes, one positively charged, and the other negatively charged, create a circuit. The low strength in this circuit stimulates neuronal activity without actually triggering any specific action, so as to have a mild stimulating effect on the synaptic transmission between neurons and therefore on synaptic plasticity. Some of the pros of tDCS devices are that they are easy to use, relatively cheap, and don't require a medical prescription or supervision. One of the most popular commercial devices of this sort is the Halo Sport 2. This device looks like a normal wireless headset (one can also listen to music with it), and costs about $400. It is advertised as a tool that can temporarily increase neuroplasticity in order to improve skills like playing music, learning a language, or practicing a wide range of sports.

The potential impact of tDCS on sport performance is far from clear, but there is growing evidence supporting the hypothesis that such devices could be useful to people practicing sport (and, possibly, those trying to become more active). For instance, recent studies found that tDCS can improve muscle performance and decrease muscle fatigue in both healthy patients and in those affected by pathologies such as stroke, chronic fatigue syndrome, and in rehabilitation [11] (suggesting that tDCS can also be effective on people who are not athletic). Researchers also investigated the potential benefits of tDCS with respect to a number of key skills used by athletes in a wide range of sports, and concluded that that tDCS can improve attention and memory [12], as well as reaction time, motor skill acquisition [13], and reduction of fatigue. People who are less active struggle more with the level of fatigue induced by exercise, so tackling the fatigue could be particularly helpful when tackling lack of exercise. According to the manufacturer of Halo Sport 2, peer reviewed studies show that using the device can: 1) Improve sprint cycling performance by 17%; 2) Increase running endurance by 14.8%. And studies conducted by Halo Sport suggest that their device: 3) accelerates strength development by 20%; and 4) accelerates fine motor skill learning by up to 60%. Other tests performed in partnership with Halo Sport report that 5) Athletes at the Michael Jonhson Performance Centre in Texas improved leg strength by 12% combining training and tDCS, whereas the control group not using tDCS only improved their leg strength by 2%. Similarly, 6) ski jumpers of the US Olympic ski team who used Sport Halo 2 for 4 weeks increased jump smoothness by 11% and increased propulsive force by 13% over the control group.

In sum, there is some preliminary evidence that devices like Halo Sport 2 can be effective at improving sport performance by increasing both endurance[4] and

[4] See the Halo Sport website: https://www.haloneuro.com/blogs/halo/athlete-guide-brain-endurance

[5] See the Halo Sport website: https://www.haloneuro.com/blogs/halo/athlete-guide-brain-strength

strength,[5] not only among professional athletes but also among people with disabilities and, possibly, among people who are not very active. So, could tDCS be an aid for people who have a low dopamine response to sport, and therefore have a less (not at all) pleasant experience when they engage in physical activity?

Some researchers have recently tested the hypothesis that transcranial stimulation can induce dopamine release [14]: they concluded that their study "provides first direct evidence that bifrontal tDCS induces neurotransmitter release in polysynaptic connected subcortical areas." The state that their "findings offer new insights for innovative use of tDCS as a therapeutic solution in neuropsychiatric conditions involving dopamine transmission impairments in the reward–motivation network" though they acknowledge that their study "did not allow for an evaluation of the tDCS effects on dopamine release in the prefrontal cortex". Another study found that "DCS caused a significant release of a dopamine in the right ventral striatum in healthy human male participants" [15].

So, although studies on the effect of tDCS on the release of dopamine are not conclusive and no study yet has addressed the question of whether tDCS could help to increase physical exercise, it is possible that, when used before, while or after exercising, tDCS could promote the release of dopamine and, in turn, help people who are sedentary to become more active. Moreover, it is possible that people using tDCS would be able to obtain better and faster results from their workouts, and this positive feedback, in turn, would make them keen on training more intensely, or for longer intervals, or more consistently, instead of giving up after a few workouts that don't show visible results (as is often the case, given that it takes numerous repetitions to train muscles to perform a certain movement correctly). Given that tDCS also seems to help in reducing fatigue and optimizing the way energy is spent during a workout, there are various ways in which this technology could help tackle the problem of sedentary life-styles by making exercise both more rewarding and less physically demanding.

Arguments against the Use of tDCS

It has been argued that tDCS should be banned, given that some studies suggest that it could be as effective as Modafinil, Methylphenidate, and Dextro-amphetamine at improving athletic performance [16] hence, it can be considered a form of neurodoping. Given that these substances are banned by WADA because they alter the integrity of sport competition, consistency would require us to ban tDCS devices as well.

Although this is an interesting issue, the present paper is not concerned with doping by athletes. Hence the question about whether tDCS should be considered a form of neurodoping or whether athletes should be allowed to use doping in some or all forms will not be discussed here. Instead, I am here concerned with the use of tDCS for people who are not athletes, and whose physical inactivity represents a health risk. But even if we leave aside objections to tDCS based on sport essentialism,[6] (i.e. that doping is against the spirit and the telos of sport), we need to deal with objections based on the potential negative impact of tDCS on individuals who use it, or on society as a whole. So, the relevant question to address here is whether tDCS could have a negative impact on individuals or on society, either directly (for instance by causing long-term side effects) or indirectly (by promoting an unhealthy life-style).

tDCS devices differ from some of the drugs used to enhance sport performance, such as Modafinil, Methylphenidate and Dextroamphetamine in at least one relevant aspect, i.e. tDCS appears to be safe for both athletes and couch potatoes in the short and in the long term. By contrast, Modafinil can have unpleasant side-effects, including headache, dizziness, nausea, lack of appetite, and nervousness. More importantly, the long-term effects of Modafinil are still unknown. Methylphenidate can cause anxiety, loss of appetite, and nervousness in the short term and, in the long term, can cause episodes of mania and depression, signs of psychotic disorder and suicidal thoughts. Similarly, Cextroamphetamine can cause headache, spasms, constipation or diarrhea, restlessness and, in the long term, memory problems, mood and behavioural changes, as well as circulatory and cardiovascular issues. tDCS devices cause very minor side effects in the short term (such as itchiness on the scalp), and there is no reason to believe that it will cause serious side effects in the long run (although, of course we can't be certain). So, objections to common form of sport enhancing substances (such as Modafinil, Methylphenidate and Dextroamphetamine) based on short term and long term side effects do not apply to tDCS.

[6] For an analysis of these objections see for instance [17].

Another objection to the use of relatively safe sport-enhancing (or perhaps neurodoping) tools such as tDCS is that their use could normalize and even promote the use of sport enhancers, something that could act as a gateway to the use of unsafe drugs. So, the argument goes, once people develop an interest in enhancing their sport performance through safe tools such as tDCS, they will be tempted to use other sport enhancing tools, which may be more effective but are less safe. Given that Modafinil, Methylphenidate and Dextroamphetamine are not as safe as tDCS, it is understandable that prospective of such slippery slope prompts some serious concerns. But are these concerns strong enough to ban the use of tDCS on couch potatoes? The answer to this question depends on a cost-benefit analysis and the outcome of such analysis largely depends on individual differences.

Some of the relevant factors to take into account relate to the personality of people who use sport enhancers. For instance, risk-averse people are less likely to go down the path of experimenting with less safe and more effective drugs. To them, the goals achieved through tDCS would probably be good enough, and they would rather be less fit than take the risk of using unsafe drugs. So the use of tDCS would appear to be safer for risk-averse individuals than for people who enjoy taking risks.

However, it's possible that some people, especially those who have high risk tolerance, might feel encouraged by the positive results obtained with tDCS to test increasingly effective but decreasingly safe enhancers, ending up worse off than if they had not used any performance enhancer at all.

Even if we agree that this is a bad scenario, reducing to the chance that it materializes to the absolute minimum could be very costly. For instance, we would have to ban all forms of enhancement (including the safe ones such as tDCS) because they might pave the way to more dangerous ones. Similar concerns have been raised in the context of the legalization of soft drugs: even though it is unlikely that the majority of people using soft drugs would end up using hard drugs, we can't be absolutely certain that at least some people wouldn't develop an interest in hard drugs after having a taste of soft ones. Hence, the argument goes, we shouldn't legalize soft drugs even though they are quite innocuous in themselves. Like in the case of recreational drugs, it is possible that a genetic predisposition to substance abuse plus some environmental factors could make some people more likely to develop an addiction to dangerous sport enhancing drugs (or hard drugs, for that matter). But even after giving due consideration to this argument and to the possible negative consequences from the use tDCS, it seems that banning soft dtDCS altogether on the basis of this possible slippery slope argument wouldn't be in the best interest of people whose health is at risk because of their sedentary life-style, especially those (most likely the majority) who would not end up taking unsafe drugs if they had access to tDCS. The health risks posed by a sedentary life-style are so numerous, so severe, proved by so many studies, and so expensive in terms of QALYs lost and costs incurred by individuals and by national healthcare systems that it would be unreasonable to ban the use of tDCS just to make sure that some people don't end up using harmful forms of doping.

Given the costs that individuals and society incur because of lack of exercise, there are good reasons to allow (if not actively encourage) the use of harmless or low risk forms of doping or enhancement aimed at improving the health and overall wellbeing of people. So, in cases where a sedentary life-style is associated with the development of pathological conditions causing severe disability or death, one should be allowed and even encouraged to use reasonably safe sport performance enhancers such as tDCS. More controversially, I argue that taking drugs such as Modafinil, Methylphenidate or Dextroamphetamine might also be permissible for people that don't respond to safer enhancers and are at high risk of developing serious conditions because of their lack of exercise. Unless the use of a tool aimed at making people active is likely to cause worse health outcomes than a sedentary life-style, there are good reasons for allowing people to choose between the risks posed by a couch-potato life-style and forms of neurodoping with increasingly severe side-effects. Neither option is ideal, of course, and hopefully devices such as tDCS (and in the future, genetic engineering) will make people more active and fitter, hence providing a good alternative to the use of more dangerous drugs.

Another objection to the use of tDCS is that it might exacerbate the disadvantages of the poor, who already find it difficult to afford healthy foods. The price of tDCS devices ranges between $300 and $500, which is similar to the cost of a home exercise bike. It's true that some people can't be active because they cannot afford a gym subscription or even a pair of trainers. But it would be unreasonable to claim that, since some people are so poor that they cannot afford training shoes, then it is morally impermissible for others to practice sport and buy training shoes (or tDCS devices, for that matter) [18]. Moreover, if such devices proved effective and public health system started using them to tackle the consequences of sedentariness and obesity, the cost could be at least partly offset through public subsidization. And given that one only needs to wear the device for a short amount of time before exercising, gyms could buy a number of sets and allow clients to take turns using them just like they do with regular gym equipment. In sum, tDCS could be accessible to anyone who can afford a gym subscription, which includes the largest majority of people in the Western world.

Conclusions

The overwhelming evidence that sedentary life-style is detrimental to health, and even lethal, has evidently not been sufficient to motivate every unfit or overweight person to be active. Society needs to work out strategies that can actually succeed at increasing activity levels and making people less sedentary.

Strategies aimed at increasing the level of physical activity are rather difficult to implement, and not much success has so far been achieved at the global or local level [19]. The effectiveness of tools such as behavioural incentive programmes with cash rewards, or changes in the urban planning that favour and encourage physical activity [20, 21] have produced mixed results [22]. For instance, there is some evidence that monetary incentives can be effective at increasing physical activity. However, such increases in activity are largely explained by the monetary incentive itself, and may not be sufficient to create a habit that is maintained once the incentive is removed [23].

Research on the genes influencing levels of activity and inactivity looks quite promising, and perhaps in the future we will be able to edit the "couch potato genes" inside an individual's genome. However, until such advances in genetic engineering are achieved, we need to find other ways to make sure people are active even when they have a genetic predisposition to be inactive. Rather than providing an excuse for people who don't enjoy being active, genetic differences can help us to develop better programmes for tackling lack of exercise, which take into account both environmental factors and human genetic variability.

As a society, we need to implement the most cost-effective measures, i.e. those that succeed in making people active for the longest time and at the lowest cost, and ideally without any side effects. The chance that there will be long-term side effects associated with the use of tDCS appear to be extremely low, whereas the potential benefits are quite large (though, admittedly, unexplored). Moreover, tDCS has the great advantage of being a cheap option, something that could make a huge difference in terms of feasibility when we are looking for health interventions on a very large scale. In sum, considering the cost of lack of exercise and the overall safety of tDCs, it is reasonable to argue that the use of tDCS should be encouraged and even subsidized by public health authorities, at least for patients who struggle to maintain an active lifestyle. The hypothesis that tDCS could help physically inactive people has not yet been tested, but given the evidence that it can stimulate the production of dopamine, reduce fatigue, increase strength and endurance, and improve motor skill acquisition, there is ample reason to begin doing so.

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