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Is there such a thing as sustainable physical activity?

H. B. Bjørnarå, M. K. Torstveit, T. H. Stea, E. Bere

University of Agder, Kristiansand, Norway
Corresponding author: Helga Birgit Bjørnarå, University of Agder, Serviceboks 422, 4604 Kristiansand, Norway. Tel.: 0047 38 14 11 24, Fax: +47 38 14 13 01, E-mail: helga.birgit.bjornara@uia.no

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There is a global need to diminish climate gas emissions, and a simultaneous call for enhanced levels of physical activity. Increased physical activity entails reduced risk for overweight and chronic diseases, as well as a potential to reduce transport's major contribution to global CO_2 emissions. However, increased physical activity level also implies increased energy expenditure. Therefore, we aim to introduce the concept of sustainable physical activity, and to suggest certain physical activity habits due to their potentially sustainable properties. Worldwide, a third of adults and four fifths of adolescents ought to be more physically active in order to comply with current physical activity recommendations. Yet, considering upcoming resource challenges, types of physical activity should be taken into account. Active transportation represents carbon-friendly means of transportation as well as an opportunity for enhanced physical activity. Physical activity conducted in the local community is likely to favor sustainability through less use of fossil fuel, as it makes transportation redundant. Moreover, going "back to basic", using less equipment and appliances for everyday tasks could contribute toward energy balance through increased physical activity, and could decrease resource use. Finally, balancing food intake and energy expenditure would require less food production with accompanying energy savings.

At present there is a global need to reduce climate gas emissions, and at the same time there is a global call for increased physical activity. Increased physical activity level implies reduced risk for overweight and chronic diseases (WHO, 2010), and a potential to reduce transport's major contribution to global CO_2 emissions (Woodcock et al., 2009). However, increased physical activity means increased energy expenditure, and most likely enhanced food consumption (Blundell et al., 2015). Although a considerable amount of research has focused on sustainable diets, including aspects like local foods, few studies have focused on aspects of sustainability related to physical activity. The ambitious goal of the Paris Agreement adopted by 195 countries in December 2015, entailing carbon neutrality before the end of the century (COP21, 2015), demands that initiatives need to be generated within all areas of society. In light of the historic Paris agreement, we believe that sustainable physical activity holds a potential that should be introduced and addressed. Thus, the aim of this discussion paper was to introduce the concept of sustainable physical activity.

In today's society, food procurement no longer depends upon energy expenditure, thus removing the biological drive for subsistence physical activity (Peters et al., 2002). Physical activity and exertion have largely been separated from daily tasks due to labor-saving devices, motorized transportation, and increasingly sedentary recreational pursuits (Booth et al., 2008). For illustration, prehistoric hunter-gatherers spent the equivalent of 19-km walking, or approximately 24 000 steps daily (Cordain et al., 1998), while in Colorado, one of the "leanest" states in the United States, men and women have reported about 7000 and 6600 steps per day, respectively (Wyatt et al., 2005). In Norway, recent published data show that men and women walk about 8005 and 8307 steps per day, respectively (Helsedirektoratet, 2015). Moreover, acculturation from a traditional hunting/fishing lifestyle to a largely Western way of living, i.e., a sedentary lifestyle, has shown to occur in parallel with increased body mass index (BMI), as well as decreased muscular strength and aerobic fitness (Cordain et al., 1998), and increased rates of chronic diseases (Katzmarzyk & Mason, 2009).

Lifestyle behaviors strain the environment, e.g., through transportation habits (de Nazelle et al., 2011), production and processing of food (FAO,

2012), and our consumer society in general. These pursuits are largely responsible for increased emissions of greenhouse gases. Currently, transportation activities produce about 23% of global climate gas discharges (de Nazelle et al., 2011), highlighting the relevance of active transportation as a potential means to decrease carbon footprint (Woodcock et al., 2009; Abagnale et al., 2015). Regarding foods, about 35% of man-made climate gas discharges are related to food production (Foley et al., 2011), with 18% caused by livestock alone (Steinfeld et al., 2006). The situation is aggravated by the fact that roughly 30% of all foods produced are either discarded, spoiled, lost, or crops are consumed by pests (Foley et al., 2011). In addition to the environmental footprint caused by transportation habits and food choices, the consumer mentality in affluent societies entails major energy consumption. For large parts of the population within Western countries, leisure consumption often entails abundance of clothes and equipment, transport intensive activities, various electronic appliances for the home, and holiday journeys by air, all adding significantly to the carbon emissions (Aall et al., 2011). In light of expected global population figures, i.e., approximately 9 billion people in 2050, it is calculated that food production will need to be doubled by that time (Foley et al., 2011). As a result, the term sustainable diets have gained ground, concerning the fact that what we eat affects not only our health but also our environment, economy, and culture. The complexity of the term is captured in a recent definition introduced by the Food and Agriculture Organization of the United Nations (FAO):

> Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources. (FAO, 2012)

Is there such a thing as sustainable physical activity?

Implications for general health and cardiorespiratory fitness have formed the basis for World Health Organization's physical activity guidelines (WHO, 2010). From a health perspective, frequency, intensity, and duration of the activity are the most important factors, not type of activity. Nevertheless, various types of physical activity might provide equal health benefits, but have very different environmental impact. For instance bicycling from our home instead of driving to a fitness center to attend a spinning class, would favor the environment by reducing vehicle-related carbon emissions. Although the link between physical activity and food procurement has been diminished, our genes are mainly the same as 40 000 years ago. Thus, humans have evolved to engage in physical activity in order to develop and function optimally (Cordain et al., 1998), and to prevent non-communicable diseases (Eaton et al., 2002; Mathers et al., 2009). Inspired by FAO's holistic definition on sustainable diets, and the close interconnection between diet and physical activity as lifestyle behaviors, we introduce the concept of sustainable physical activity defined as:

> Sustainable physical activity includes those activities that are conducted with sufficient duration, intensity and frequency for promoting health, yet without excessive expenditure of energy for food, transportation, training facilities or equipment. Sustainable physical activities have low environmental impact and they are culturally and economically acceptable and accessible.

Based on this definition, we will discuss if there is such a thing as sustainable physical activity, and suggest certain physical activity habits due to their potentially sustainable properties.

Discussion

Active transportation

Trend data for high-income countries indicate that occupational (work-related) physical activity has decreased while leisure physical activity has increased in the past 20–30 years (Hallal et al., 2012; Borodulin et al., 2015). Also, there are major differences in active transportation habits across countries, even where geography, population density, and climate are apparently similar (Hallal et al., 2012). Strong policies and effective urban designs are needed in order to increase the safety, appeal, and acceptability of walking and bicycling through creation of environments facilitating active transportation (Woodcock et al., 2009; Das & Horton, 2012). Assuming that transportation is necessary in everyday life, it is likely that active transportation could represent a time-efficient and thus feasible approach for increasing levels of physical activity (de Nazelle et al., 2011). Active transportation incorporating both walking and bicycling has shown to associate with an overall 11% reduction in cardiovascular risk (Hamer & Chida, 2008). Accordingly, active transportation has been reported to relate inversely with metabolic risk factors for cardiovascular disease, prevalence of diabetes type 2, obesity, and cancer, and positively with physical fitness (de Nazelle et al., 2011). Moreover, prospective studies have found that using a bicycle for transportation

decreases the mortality risk by approximately one third (Andersen et al., 2000; Matthews et al., 2007), and in some countries obesity rates tend to increase in tandem with a decrease in active transportation (Saunders et al., 2013). Yet, the causal pathways of obesity are complex, and current literature provides little robust evidence for the effectiveness of interventions targeting active transportation, on obesity reduction (Saunders et al., 2013). In total, it is proposed that increased active transportation may benefit public health mainly through more physical activity for the commuters themselves, and also for the population in general due to a decrease in air pollution (de Nazelle et al., 2011). Also, a lesser demand for and thus less production of motor vehicles, would result in decreased carbon emissions (Berners-Lee, 2010).

Close to 23% of current global greenhouse gas emissions result from transport activities (de Nazelle et al., 2011). Predictions regarding changes in emissions due to mode shifts are complex and uncertain, and there are currently few real-world examples (de Nazelle et al., 2011). Still, it was estimated in a transport scenario for year 2030 that a combination of active transportation and lower emission motor vehicles could reduce annual CO_2 emissions in London and Delhi with 38% and 48%, respectively, entailing major health benefits (Woodcock et al., 2009). Numerous factors affect calculations of carbon footprint, not the least food choices. For example, if one obtains the energy required for cycling one mile from asparagus transported by aircraft from afar, the carbon emissions would be about the same as if driving a mile with a large sport utility vehicle (SUV) (Berners-Lee, 2010). The carbon impact from driving one mile is suggested to range from 344 g CO_2e to 2240 g CO_2e, depending on what car one drives, where, and how one drives it (Berners-Lee, 2010). Large pick-ups are estimated to cause about five times the global warming costs per mile, as compared with a small hybrid vehicle (Lemp & Kockelman, 2008). Nevertheless, bicycling is generally far more carbon-friendly than driving, independent of car type. Different energy sources would naturally entail different energy impact, yet even if all cars were powered by electricity, it would still demand considerably more energy to move the mass of a car than the mass of a bicycle. Also, electric bicycles are becoming more widely used, and emissions of regulated pollutants may be significantly reduced if electric bikes gradually replace cars and mopeds (Abagnale et al., 2015).

Community-based physical activity

Physical activity conducted in the local community makes motorized transportation redundant, favoring the environment through less use of fossil fuel and decreased emissions of climate gases. Some forms of exercise, like running and walking, may be conducted equally well from where we live, instead of driving to the gym in order to use a treadmill. The opposite of community-based physical activity is the trend that many people travel all over the world to be physically active, e.g., snorkeling the reefs of Belize, or skiing in the Alps, which does clearly not represent a sustainable lifestyle. Results from a Norwegian study has shown that the most energy-intensive forms of leisure consumption, e.g., holiday journeys by air, seem to increase the most (Aall, 2011). Additionally, leisure activities in general have become more transport intensive, and the share of private car use for long-distance transportation to outdoor recreation areas has expanded (Aall et al., 2011).

Children and youth

Regarding youth leisure activities, those conducted locally and in sport clubs in the neighborhood, allowing children and adolescents to walk or bicycle to their activities, would be advantageous. This in turn highlights the importance of the building and spatial planning facilitating physical activity in the local community, as a means to increase daily levels of physical activity. Nevertheless, building environments providing features expected to facilitate children's play and walking have shown to influence younger children's moderate-vigorous activity negatively, whereas small to moderate positive effects for adolescents' activity levels were reported (McGrath et al., 2015).

Adults and elderly

Access to nature within the living environment tend to be associated with more physical activity and active lifestyles, yet individual characteristics and environmental barriers are likely to impact the relationship (Calogiuri & Chroni, 2014). Despite the lack of a consistent pattern, some studies have reported positive associations between objectively measured physical activity and access to parks (Bancroft et al., 2015). Also, living in neighborhoods with higher street connectivity, land use mix and residential density, referred to as neighborhood walkability, has been associated with nearly 800 more steps per day in adults, i.e., nearly 8% of the recommended daily amount of steps (Hajna et al., 2015). Concerning elderly, studies investigating associations between the physical environment and total physical activity, and also specific physical activity domains, reveal inconsistent results (Van Cauwenberg et al., 2011). Although methodological limitations could distort

observed associations, the conflicting results also express the challenge and significance of creating environments promoting physical activity throughout the life course.

Equipment

Various equipment and labor-saving devices have gradually replaced manual work, both in private homes and at workplaces. Less effort, and to a certain degree less time, is spent to accomplish everyday tasks, and physical disabilities caused by continuous heavy labor have been reduced (Hallal et al., 2012). Yet, there is a price to pay for this drive for productivity and convenience in the shape of a more sedentary lifestyle, and thus enhanced prevalence of non-communicable diseases (Lee et al., 2012). Furthermore, the proliferation of electronics and various household devices in the average home has caused a rapid increment in electricity expenditure, especially in OECD countries (Cabeza et al., 2014). In non-OECD countries experiencing income growth, procurement of household appliances is expected to cause significant carbon footprints due to the carbon intensive electricity production in several of these countries (Cabeza et al., 2014). In addition to the direct emissions related to the use of household equipment, the indirect emissions are remarkable, i.e., energy required for production, distribution, and disposal of goods (Kok et al., 2006). Clearly it would not be realistic or desirable to expect people to refrain from basic appliances like washing machines and refrigerators which represent an improved standard of living from which we have benefitted for decades. Instead we could question our need for devices and gadgets invented mainly for convenience. Although less use of equipment and a higher degree of manual labor might result in a more time-consuming lifestyle, it would entail both decreased carbon emissions and increased physical activity, and may therefore be worth considering. For example, shoveling snow by hand is estimated to require twice as much energy as riding a snow blower (Ainsworth et al., 2000). Moreover, a recent pilot study assessing the physical activity level during bread baking showed that on average the 10 participants obtained 16.2 min of moderate physical activity, out of in total 28 min (Karlsen, 2015). This elucidates the potential to meet the minimum level of physical activity required for health through everyday activities, which in turn could save time otherwise needed for engaging in additional physical activity. Also, facilities like sports halls, indoor ice rinks, ski lifts, etc., entail increased emissions through energy demands for construction and operation. Activities requiring less equipment and amenities would be more carbon-friendly (Schmidt, 2006) and thus preferable. Artificial needs constructed by the market forces and personal attitudes may also play a part, as the amount of equipment considered necessary for conducting sports is probably highly relative. Nevertheless, in Norway, and likely in other rich Western countries as well, a strong materialization of leisure activities has taken place, entailing increased demand for specialized equipment and clothing (Aall et al., 2011).

Energy expenditure

An individual's basal metabolic rate, i.e., the threshold for maintaining bodily functions, generally accounts for 60–70% of total energy expenditure with variation by age, body mass, height, and sex, and represents the fundamental basis for estimating energy requirements in humans (Shetty, 2005). Total energy expenditure is often calculated as multiples of basal metabolic rate, commonly referred to as the physical activity level (PAL) index (Shetty, 2005). A PAL of 1.4 indicates a sedentary lifestyle, while the recommended PAL of 1.75 requires an occupation involving regular physical activity, or conducting regular exercise (Saris et al., 2003). From an evolutionary perspective, the latter energy expenditure is still limited, as it has been calculated that the total energy expenditure of a typical current Westerner is about 65% of that of Paleolithic Stone Agers (Cordain et al., 1998).

Physical activity recommendations

The many health benefits from physical activity are well documented (WHO, 2010), and adults are recommended to do at least 150 min of moderate-intensity aerobic physical activity, or at least 75 min of vigorous-intensity aerobic physical activity, or a combination of these, every week. Also, muscle-strengthening activities involving major muscle groups should be conducted on 2 or more days a week (WHO, 2010, Helsedirektoratet, 2014), and sedentary time should be reduced (Helsedirektoratet, 2014). For further health promotion and maintenance of a healthy body composition, weekly amount of physical activity is suggested to be doubled (WHO, 2010, Helsedirektoratet, 2014). Despite methodological limitations and challenges regarding physical activity monitoring, there are substantial disparities in physical activity levels across regions and populations where surveillance has been conducted. Worldwide, one third of adults and four fifths of adolescents do not reach physical activity guidelines (Hallal et al., 2012), something which is further estimated to cause 6–10% of the major non-communicable diseases of coronary heart disease, type II diabetes, breast- and colon cancer, and 9% of

premature deaths (Lee et al., 2012). Concerning daily energy expenditures for physical activity, calculations have suggested that modern sedentary adults reach about 38% of that of a typical hunter-gatherer (Cordain et al., 1998). In order to approximate these differences, about one additional hour of aerobic physical activity daily would be required (Saris et al., 2003).

Energy balance

If physical activity increases to recommended levels for the population as a whole, it will also increase total energy expenditure. Despite variability in biological responsiveness between individuals, long-term increased energy expenditure is related to increased basal hunger (Blundell et al., 2015). Consequently, overall energy intake is likely to increase (Blundell et al., 2015), probably entailing the need for enhanced food production. Therefore, it is reasonable to believe that with increased PA levels, as recommended, more food is needed. Diet and food production represents a major issue regarding global sustainability (FAO, 2012); however, different foods and different food production methods have greatly different impact. For illustration, greenhouse gas (GHG) emissions per gram of protein for ruminant meat are about 250 times those of legumes (Tilman & Clark, 2014). Simultaneously, rising incomes and urbanization drives a dietary transition entailing, among others, increased meat consumption (Tilman & Clark, 2014). Worldwide dietary energy supply for the years 2014–2016 is calculated to be 12 146 kJ per person per day, which should be sufficient for meeting energy requirements for the current world population (FAO, 2013). Still, approximately a billion people live in chronic hunger (FAO, 2012), while about 1.9 billion adults are overweight or obese (WHO, 2011). This clearly expresses the pivotal role of food, yet a comprehensive discussion regarding food issues is beyond the scope of this paper.

Still, overconsumption of energy resulting in accumulation of fat tissue and weight gain may be considered indirect food waste, and the current obesity epidemic illustrates global imbalance in energy distribution. In 2010, high BMI (>25 kg/m^2) represented the sixth leading risk for deaths worldwide, and overweight and obesity were estimated to cause 3.4 million deaths and 3.8% of disability-adjusted life-years (Lim et al., 2013). Between 1980 and 2013, the prevalence of overweight and obesity combined increased by 27.5% for adults and 47.1% for children, yet since 2006, weight gain seem to have attenuated in developed countries (Ng et al., 2014). Obesity is clearly not sustainable, yet to decrease food intake in order to feed more people and prevent excessive weight gain, is not a simple task. The mismatch between biological predispositions and current food environment (Cordain et al., 1998) is illustrated by the fact that no country has achieved a significant decrease in obesity rates during the last 33 years (Ng et al., 2014). More specific, Lobstein calculated that an 8% reduction of current food purchase patterns in the United Kingdom would be required over a period of at least 3 years, in order to reduce population BMI to 1980 levels (Lobstein, 2011). In order to achieve and maintain energy balance, the overall rate of energy movement, referred to as energy flux, has been emphasized by some researchers (Hand & Blair, 2014; Blair et al., 2015). It is proposed that a high energy flux, meaning high levels of both energy intake and expenditure, is likely to reflect the optimal strategy for maintaining a healthy weight, as well as improving metabolic parameters (Hand & Blair, 2014). However, weighting up both resource demands, food production, and human biology, it could be assumed that a level of physical activity meeting the minimum requirements for health would be the most sustainable one, yet may not optimal from an evolutionary point of view (Cordain et al., 1998).

Perspective

Globally, a third of adults and four fifths of adolescents ought to be more physically active in order to promote health and prevent major non-communicable diseases. Nevertheless, in light of upcoming resource challenges and the fact that various types of physical activity could provide equal health benefits yet different environmental impacts, types of physical activity should be taken into account. Therefore, in order to bridge the topical issues of sustainability and physical activity, which is previously undone, the aim of the present paper was to introduce the concept sustainable physical activity, and suggest certain physical activity habits due to their potentially sustainable properties:

- Active transportation represents a carbon-friendly mean of transportation, as well as an opportunity for enhanced physical activity levels.
- Physical activity conducted in the local community is likely to favor sustainability from a broad perspective.
- Going "back to basic" using less equipment and appliances for everyday tasks could contribute toward energy balance through increased physical activity, and could also decrease resource use.
- Balancing food intake and energy expenditure would require less food production with accompanying energy savings.

Key words: Resource challenges, environmental impact, health promotion, active transportation, community-based physical activity, equipment, energy balance.

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