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Harvey, Juliet Ann; Rafferty, Danny; Chastin, Sebastien François Martin

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Short Report: Consequences of short interruptions of bouts walking on estimates of compliance to physical activity guidelines.

Authors: Juliet Ann Harvey¹, Danny Rafferty¹ and Sebastien François Martin Chastin¹,
School of Health and Life Science, Glasgow Caledonian University, Cowcaddens Road, Glasgow,
Scotland, UK, G4 0BA.

E-mail of corresponding author: Sebastien.Chastin@gcu.ac.uk

ABSTRACT

Introduction Current guidelines on physical activity suggest that 30 mins of moderate intensity physical activity can be accumulated in continuous bouts of at least 10 mins. It has been shown by use of activity monitoring that it is difficult to achieve 10 mins of completely uninterrupted walking in the free-living urban environment where we have obstacles such as roads to cross. The aim of this study was to examine the effect of short interruptions in walking on the rate of oxygen uptake ($\text{ml}\cdot\text{kg}\cdot\text{min}^{-1}$) to determine if walking with short interruptions can still be considered continuous. This leads to a more meaningful understanding as to what is a physiological break in activity. This is an important consideration for measurement of physical activity especially when exploring measurement by accelerometry.

Methods In a laboratory setting a repeated measure design was used to replicate interrupted walking in urban setting. Healthy volunteers ($N = 10$) walked on a treadmill with walking interruptions of 10s, 50s and 100s. Oxygen uptake was measured using a gas analysis system.

Results 10s interruptions in walking had no significant effect on the $\text{VO}_2\cdot\text{kg}\cdot\text{min}^{-1}$. However two breaks of 50s or 100s introduced into a 5 min brisk walking bout showed a significant reduction in oxygen uptake requirements and metabolic equivalent of task (MET) ($p < 0.001$) compared to continuous walking for the same amount of effective walking, but only the 100s walking period could not be considered greater than 3MET during the interval.

Conclusion Short periods of brisk walking interrupted by 10s breaks can be considered continuous physical activity, but when walking is interrupted by longer breaks e.g. 50s, there is a significant reduction in oxygen uptake requirement suggesting that it is not continuous anymore and should be considered as fragmented.

Keywords Accelerometry, physical activity, guidelines, walking

1. Introduction

Current guidelines on adult physical activity recommend that to promote and maintain health, 30 mins of moderate to vigorous intensity physical activity (MVPA) should be accumulated in continuous bouts of at least 10 mins (Haskell *et al.*, 2007). To make the guidelines more accessible to the in-active population public health campaigns (for example, ‘Get Going Every Day’ Department of Health, 2016) promote integrating physical activity into our daily routines, such as active transport, walking at lunchtime or taking walking meetings. Studies using time stamped objective measure of free-living physical activity showed that it is difficult to achieve 10 mins of completely uninterrupted brisk walking due to environmental obstacles such as, waiting at a pedestrian crossing when walking in an urban environment (Orendurff *et al.*, 2008; Chastin *et al.*, 2009). Brisk walking is considered an activity of moderate intensity and has been found to reduce aspects of cardiovascular health risk when accumulated in bouts of at least 10 mins (Murphy *et al.*, 2002).

Although individuals may report a period of activity to be continuous, when objectively measured by accelerometry this may not be the case (Chastin *et al.*, 2013). In healthy adults walking in an urban setting, the majority of walking bouts last less than 1 min (Orendurff *et al.*, 2008). These bouts tend to be interspersed with short interruptions mostly shorter than 3 mins (Orendurff *et al.*, 2008). So, a period of walking is often a succession of short bouts of walking frequently interrupted by short breaks. This has important consequences, because walking is often used as a mode of physical activity intervention, but the health benefits of different walking pattern might not be the same depending on the way the activity is cumulated (Chastin *et al.*, 2013; Jefferis *et al.*, 2013). This is particularly important when considering how to define physical activity, objectively or subjectively, in measurement methodology.

Much is known about oxygen kinetics, since the early 1900’s oxygen uptake response to muscle work has been examined (Krogh & Linderhard 1913; Hill & Lupton 1923). The field has particularly focused on longer periods of work with a bias toward high demand exercise and durations longer than 10 mins or breaks in higher intensity activity (Tabata *et al.*, 1996). On the onset of moderate intensity activity at a given constant exercise load there is an exponential uptake of oxygen over a 10 to 20s period followed by a steady state (Hill & Lupton 1923). On the cessation on exercise there is a rapid initial decline in ventilation followed by a slow progression to resting levels depending on the demand of the exercise this

is called oxygen debt or post exercise oxygen consumption (EPOC) (Dejours 1963; Brook *et al.*, 1971). Breaks in a walking period result in drop in metabolic demands (Brehm *et al.*, 1986). However, there is no information about how short the break has to be for this drop to significantly change the physiological response of a given walking period, as part of a longer walking duration. This is an important consideration when designing studies where activity is measured using accelerometry as they detect short breaks in activity. Therefore interpreting what is a continuous bout should be determined by the change in physiological response rather than arbitrary thresholds of what duration these breaks might be (Ayabe, *et al.*, 2013; Orme *et al.*, 2014).

This study reports laboratory investigations on the effect of short interruptions in walking on the oxygen consumption and metabolic equivalent of task (MET) requirements during a walking period. In public health guidelines, we define a 10 mins periods of MVPA to have significant and positive health benefits. EPOC is longer with more vigorous activities, therefore a break in vigorous activity is unlikely to affect compliance with guidelines, but with lighter intensity activities we may drop out of the beneficial window when breaking moderate intensity activity. Therefore this study examines short breaks in walking as the demand is at the lower end of MVPA and is one of the most accessible modes of exercise that allows the general population to meet the current physical activity guidelines. Our aim was to explore what duration of a break in physical activity at or above 3 MET constitutes a physiological change.

2. Material and Methods

2.1 Participants

Ten volunteers were recruited from a convenience sample of the Glasgow Caledonian University staff and student population. The participants were healthy volunteers with no history of medical conditions/medications affecting exercise ability or affecting metabolic processes, musculoskeletal complaints affecting their gait and had a body mass index (BMI) within the normal range.

2.2 Procedure

The study was approved by Glasgow Caledonian University School of Health and Life Sciences Ethics Committee. The study followed a repeated measure design. All volunteer received an information pack and gave informed consent to take part in the study. On arrival

at the laboratory, measurements of height and weight were taken and participants' were asked questions regarding health and fitness. The participants confirmed that they had not consumed any stimulants, such as caffeine on the morning of testing. A brisk walk is defined as being between 1.34 and 1.78m/s (Haskell *et al.*, 2007). To allow for scope for individual's stature and stride length, the participants defined their own personal brisk walking pace on a treadmill (Woodway, Germany) within this range (Dal *et al.*, 2010). Each subject was then acquainted with walking on the treadmill for a period of five mins. The Cosmed K4b² (Cosmed, Italy) was then fitted to each individual so they could familiarize themselves with the weight and feel of the device. Participants were then asked to rest seated for a minimum period of 2 mins before walking on a treadmill at their previously selected brisk pace.

To simulate interruptions in walking that occur in free-living condition walking was interrupted on six occasions with periods of quiet standing; two periods of 10s (B-10), two of 50s (B-50), two of 100s (B-100) as illustrated on Figure 1. The time spent walking (totalling 17.5 mins) was segmented in seven bouts carefully controlled to last 2.5 mins each. The six interruptions were paired i.e. a 10s interruption was followed by the second 10s interruption, a 50s interruption was followed by the next 50s interruption and similarly for the 100s interruption. The order in which the pair of interruptions were introduced was randomized to avoid bias. A 2 mins seated rest period followed the treadmill testing period and resting values calculated for the final 30s of this period. There was less than a 10% excursion between values during this 30s period ensuring a steady state was achieved.

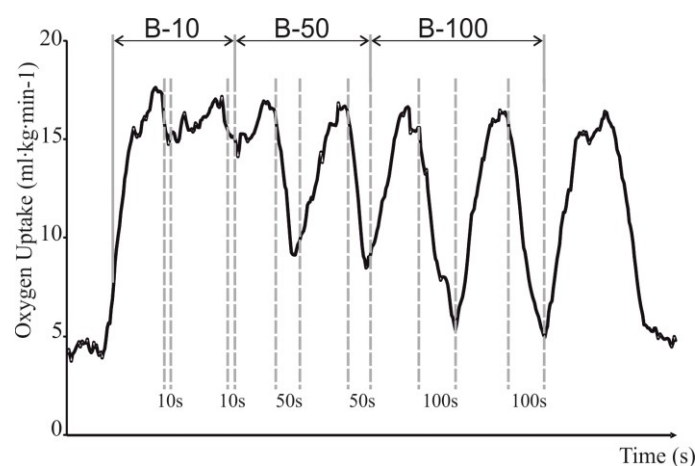


Figure 1: This is an illustration of the walking protocol showing periods of walking and the interruptions. The actual values averaged over all participants may not conform to this illustration as breaks in walking bouts were randomised. The start of each walking periods are marked by solid lines and the interruption by dashed lines.

2.3 Outcome Measures

Oxygen uptake ($\text{ml}\cdot\text{kg}\cdot\text{min}^{-1}$) was measured by the COSMED K4b² (McLaughlin, *et al.*, 2001; Duffield *et al.*, 2004). The average oxygen uptake for each period (6 bouts per test) of walking with no interruption was calculated. The average rate of oxygen uptake was evaluated over the succession of two bouts of walking and two interruptions of the same length. Oxygen uptake was also calculated for the interruptions. MET were calculated by taking the average of the final 30s of oxygen uptake for the seated period prior to commencing walking and then dividing the oxygen uptake values for the bouts of walking and the interruptions by this value.

2.4 Statistical Analysis

All data was tested for normality of distribution. A General Linear Model (GLM) was used to test if there was any difference in oxygen uptake due to the order of the walking bout. A GLM was also employed to test the effect of the length of the interruptions on oxygen uptake and MET or the actual oxygen uptake and MET recorded for the interruption. Where a significant effect was found post hoc analysis was conducted using the Tukey method. A one tailed student t test was conducted on MET values recorded during walking to test if a MET of greater than 3 had been achieved. All analysis was conducted in Minitab 17 and data was considered significant if $p < 0.05$.

3. Results

Ten (6 male) subjects were recruited with an average age of 27.6 (± 4.9) years, with an average BMI of 25.3 (± 3.23) $\text{kg}\cdot\text{m}^{-2}$. Sixty percent of participants met the UK guidelines for Physical Activity in the last week, 10% currently smoked and 40% were over-weight or obese. On average the subjects walked for a distance of 1.8 (± 0.18) km at a speed of 1.7 (± 0.16) ms^{-1} . No significant differences in oxygen uptake requirements between any of the walking bouts were found. Therefore the oxygen uptake for each walking bout was averaged and presented as the oxygen uptake for walking. The MET values recorded during walking bouts ranged from 4.1 to 6.6 MET and was significantly greater than 3 for all values ($p < 0.001$). Table 1 shows the average (SD) oxygen uptake and MET during walking and when brisk walking was interrupted and the oxygen uptake and MET values during the interruptions. Figure 2 shows the oxygen uptake and MET values at each condition and the post hoc Tukey comparisons. Data were normally distributed ($p > 0.05$).

Table 1: Mean (SD) oxygen uptake and MET requirements in the four different walking bouts condition and interruptions to walking; walking continuously, (B-10) walking with two 10s interruptions, (B-50) walking with two 50s interruptions, (B-100) walking with two 100s interruptions.

Walking Conditions				
	Walking	B - 10	B - 50	B - 100
Oxygen Uptake ml·kg·min ⁻¹	16.91 (2.64)	16.06 (2.68)	13.72 (2.14)	12.75 (2.57)
MET	4.43 (1.06)	4.23 (1.14)	3.58 (0.79)	3.34 (0.94)
Interruption				
	Walking	10s	50s	100s
Oxygen Uptake ml·kg·min ⁻¹	16.91 (2.64)	14.98 (3.21)	10.85 (2.3)	9.35 (3.27)
MET	4.43 (1.06)	3.96 (1.26)	2.82 (0.70)	2.46 (1.09)

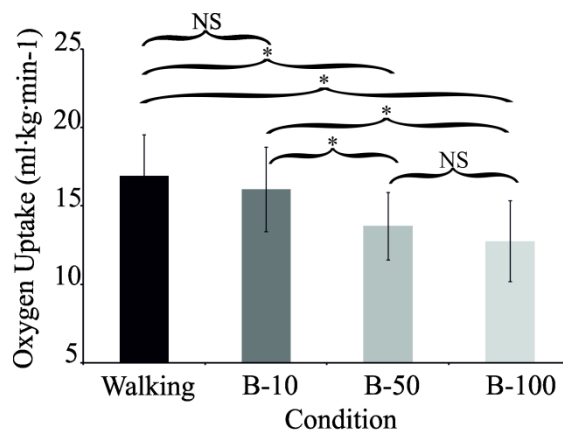


Figure 2: Oxygen uptake (ml·kg·min⁻¹) requirements in the four conditions showing level of significance in ANOVA test (NS = non-significant, *=significant p<0.05).

Introducing two periods of quiet standing of 10s into a 5 min brisk walking bout showed no reduction in oxygen uptake requirements. Introducing two periods of quiet standing of 50s or of 100s into a 5 min brisk walking bout showed a significant reduction in oxygen uptake requirements over the whole period. The results are similar in terms of MET, however if we consider MVPA to be between 3 and 6 MET thus dropping below 3 MET due to an

interruption would indicate a drop away from MVPA. During the interruptions the MET value dropped below 3 MET in 9/20 breaks, during the 100s interval condition, 5/20 breaks in the 50s interval and none of the 10s intervals. Walking, breaks of 10s and 50s had MET values of greater than 3 METs ($p < 0.05$). A break of 100s had a MET values of not greater than 3 MET ($p = 0.143$).

4. Discussion

4.1 Relevance of Results

In free living condition walking periods usually considered to be continuous MVPA over periods longer than 10 mins might actually be series of much shorter MVPA bouts. This study investigated the oxygen uptake response due to short breaks in walking bouts as encountered in walking pattern characteristic of urban environment. The aim was to discover what length of interruption when introduce in a period of walking significantly change the oxygen uptake requirement so that the period of walking need to be considered as two separate bouts. The results suggest that a period of between 10s and 50s would represent a significant reduction in oxygen uptake requirements of brisk walking.

Guidelines for physical activity advocate continuous bouts of 10 mins of MVPA. However these are constructed on the basis of self-reported data and laboratory studies for example, recall/record using activity logs that we walked from a train terminus to our work place and record this as a 10 mins walk. In fact this walk will probably have been broken by a number of bouts of walking. Self-report do not take into account how fragmented a period of 10 mins might be in free living conditions, as is observed when measured objectively by accelerometer based activity monitors. These data suggest that a 50 or 100s break during 5 minutes of activity can lower our oxygen uptake response by 18% (≈ 0.5 MET) or 25% (≈ 1 MET) respectively in comparison to a continuous bout of activity.

Our results suggest that when short bouts of brisk walking are separated by 10s of quiet standing has no effect on the oxygen uptake or MET requirements and could be considered as a single continuous bout, but when the separation is larger than 50s then these should be considered as separate bouts of activity. However, our data shows that a period of quiet standing of 50s or more introduced into brisk walking results in significant drop in metabolic requirement, but the MET value remained above 3 MET for this period. Only with a break of 100s the MET could not be viewed as greater than 3 MET.

4.2 Consequence for physical activity monitoring

This fragmentation of bouts of walking should be taken into account while monitoring physical activity. It was shown that the results of monitoring compliance to physical activity guidelines changes dramatically whether walking bouts interrupted by short breaks are considered continuous or not (Chastin *et al.*, 2009). Currently the common practice is to consider that a bout of moderate to vigorous activity is interrupted when physical activity intensity drops below MVPA level for 3 mins (Troiano *et al.*, 2008). It is not clear whether this is based on evidence or heuristic decision. However the data presented here would support this in that two breaks of 100s in a five min walking bout produced MET values of not greater than 3. However simply considering a deviation from MVPA obscures the fact that breaks of activity of 50s does significantly reduce the rate of oxygen uptake expended for that interruption in comparison to continuous walking.

4.3 Strength and Limitations

This is a small scale study conducted in young and healthy adults, therefore care should be taken when interpreting and generalising the results. In particular, it is very likely that the effect of the interruption is mediated by an individual level of fitness and age. However, the study appears sufficiently powered to show that interruptions have significant impact on how MVPA is accumulated. The precise length of breaks and nature of the interruption (e.g. quiet standing or seated) that lead to significant interruption requires further investigation in larger and diverse target population. It should also be noted that the testing period of five minutes is of relatively short duration and that were the subjects to have walked for longer bouts this could have potentially led to less of a change in $\text{VO}_2 \cdot \text{kg} \cdot \text{min}^{-1}$ during the break than has been recorded in these data. It has been demonstrated that the measurement of oxygen uptake on a treadmill leads to elevated values resulting in the values presented in this work being higher than would be expected for over-ground free-living gait (Dal *et al.*, 2010). Nonetheless the interruptions and resulting changes in physiological response should still be generalizable to over-ground free living gait. The estimation of resting VO_2 by taking the last 30s of the 2 mins rest potentially leads to an overestimation of RMR resulting in an underestimation of MET values. The manuscript seeks to explore what constitutes a change in physiological response ($\text{VO}_2 \cdot \text{kg} \cdot \text{min}^{-1}$) as a result of breaking activity and the MET values are reported to allow the reader to relate these to commonly published values.

5. Conclusion

In summary, this study shows that short interruptions within a bout of brisk walking significantly affects the metabolic demand, and that a break of more than 50s requires that a bout of walking be considered as physiologically different and considered as two separate bouts, and is not continuous. The equivalence, or possibly lack of, in terms of health benefits from continuous or discontinuous MVPA is out with the scope of this work, but this result suggests that this should be investigated. These findings should also be taken into consideration when exploring accelerometry data in that bouts of activity should only be considered different if separated by a break of greater than 50s.

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