Physical activity using wrist-worn accelerometers: comparison of dominant and non-dominant wrist

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Summary

The purpose of this study was to determine whether there is a difference in physical activity assessment between a wrist-worn accelerometer at the dominant or non-dominant arm. The secondary purpose was to assess the concurrent validity of measures of physical activity from the wrist-worn accelerometer and the waist-worn accelerometer. Forty adults wore three accelerometers simultaneously, one on the waist and one each on the non-dominant wrist and dominant wrist, respectively, for 24 consecutive hours of free-living conditions. Data were uploaded from the monitor to a computer following a 1-day test period. There were no significant differences in physical activity when comparing the dominant versus the non-dominant wrist, regardless of axis (P>0·05). Mean daily accelerometer output data from both wrists were strongly correlated with average counts per minute from the ActiGraph worn around the waist (r = 0·88, P<0·001). Findings suggest that the choice to wear the accelerometer on the non-dominant or dominant wrist has no impact on results. Data from this study contribute to the knowledge of how to best assess physical activity habits.

Introduction

Moderate to vigorous physical activity is associated with decreased risk factors for obesity, cardiovascular and pulmonary diseases, cancer, depression and increasing bone health (Pedersen & Saltin, 2006). Accurate measurement of physical activity therefore is essential in developing intervention strategies. Physical activity questionnaires, diaries, observations, indirect calorimetry, double-labelled water, heart rate monitors and accelerometry have been used (Luke et al., 2011; Nang et al., 2011; Wilmot et al., 2011). Accelerometry, in particular, is an objective, reliable and valid measurement that is frequently used because of limitations in other tests (Chen & Bassett, 2005).

Accelerometers are used to assess physical activity patterns in intervention, clinical and epidemiological studies (Pedišić & Bauman, 2015). In early studies, most accelerometers were worn around the waist, hip or lower back, close to the centre of gravity (Westerterp, 1999). Subsequent studies demonstrated that accelerometers worn around the waist or at the hip have lower wear-time compliance, especially during sleep and water activities, resulting in selection bias and misclassification of physical activity (Vanhelst et al., 2012; Mannini et al., 2013; Rowlands et al., 2014).

Wrist-worn accelerometers, compared to waist-worn monitors, may be more convenient and comfortable and improve compliance in studies where there is prolonged wear time (usually 7 day to assess habitual physical activity). Wrist-worn accelerometers have been studied in a variety of applications (Vanhelst et al., 2012; Mannini et al., 2013; Ellis et al., 2014; Hildebrand et al., 2014; Rowlands et al., 2014; Tudor-Locke et al., 2015). In these studies, differing methodologies have been applied, including the use of both dominant and non-dominant wrist. Because the dominant arm is stronger and used more often than the non-dominant arm, the wrist selected may affect the outcome in assessing physical activity. It is important to determine whether data obtained from different studies are comparable regardless of the wrist selected. Moreover, like the previous studies on the physical activity was mostly collected from the waist-worn monitors, it is important to determine whether the output already collected from these monitors is comparable to the output from wrist-worn accelerometer.

The purpose of this study was to determine whether there is a difference in physical activity assessment between a wrist-worn accelerometer at the dominant or non-dominant arm. The secondary purpose was to assess the concurrent validity

of measures of physical activity from the wrist-worn accelerometer and the waist-worn accelerometer.

Methods

Participants

Forty healthy sport science students, 24 male and 16 female, from Département STAPS, Université du Littoral Côte d'Opale, Dunkerque, volunteered for the study. The inclusion criteria in the study were as follows: (i) male and female subjects ages 18–35 years; (ii) informed consent form signed by the participant; (iii) no medical contraindication against participation in the study; and (iv) subjects were not participating simultaneously in another biomedical study. Physical characteristics of the subjects are described in Table 1. The purpose and objectives were carefully explained to each subject and written informed consent was obtained prior to the study. The local University Research Ethics Committee approved the study. All procedures were performed in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 2008, and Good Clinical Practice (Béghin et al., 2008).

Procedures

Testing was conducted at the exercise physiology laboratory, University of Littoral Côte d'Opale, at 08:00 h or 14:00 h, Monday to Friday. Body mass was measured without shoes and heavy outer garments to the nearest 0·1 kg using an electronic scale (Oregon Scientific, Portland, GA, USA). Height was measured without shoes to the nearest 0·1 cm using a standard physician's scale. Physical activity was assessed by accelerometry. Accelerometers were calibrated according to manufacturer specification. The epoch interval used was set at 1 min and output was expressed as mean counts per minute. All participants wore the three accelerometers simultaneously, one on the lower back with an elastic belt and adjustable buckle, one on the non-dominant and one on the dominant wrist (left wrist N = 3, right wrist N = 37) (Oldfield, 1971). They were instructed to remove all accelerometers during swimming, showering and bathing. Accelerometers recorded activity for 1 day (24 h) of free-living conditions and was taken off at night. Data were uploaded each day following testing from the monitor to a computer. Participants who did

not record at least 10 h of recording of activity on the day test were excluded from the analyses. Zero activity periods of 20 min or longer were interpreted as 'not worn time', and these periods were removed from the summation of activity.

Materials

GT3X ActiGraph accelerometer

The ActiGraph® Monitor (ActiGraph GT3X®; ActiGraph, Pensacola, FL, USA) was used to assess physical activity in free-living conditions (Gomez-Marcos et al., 2014). The ActiGraph Monitor is a triaxial accelerometer that measures $46 \times 33 \times 15$ mm and weighs 19 g. Accelerometry assesses physical activity through measurement of mechanical movement in three dimensions, vertical vector (x), anteroposterior vector (y) and mediolateral vector (z). The ActiGraph® accelerometer is based on the piezoelectric sensor principle. The effect of acceleration during a displacement modifies the natural voltage of the crystal elements of the piezoelectric ceramic, giving rise to a potential difference. This electrical impulse is proportional to the intensity of movement and is recorded numerically. The recorded accelerations give a description of the frequency, time and intensity of physical activity produced by body movement. The signal is summarized over a user-defined time, called an epoch, into what are called 'counts'.

Statistical analysis

The purpose of the study was to determine whether there is a difference in physical activity assessment between a wrist-worn accelerometer at the dominant or non-dominant arm. According to the literature, the average amount of physical activity per day measured by an accelerometer worn on the non-dominant wrist is 7·5 counts $\min^{-1} \pm 2·3$ (Rowlands et al., 2014). Our hypothesis is that physical activity assessment measured at the dominant wrist would be superior to 15% than the value measured at the non-dominant wrist (7·5 counts $\min^{-1} \pm 2·3$). To detect an explained variance of 15% (r = 0·4), with a power of 0·80 and an alpha of 0·05, requires a sample size of 34.

Table 1 Physical characteristics of subjects (n = 40).

	Males	Females
N	24	16
Age (year)	22·9 ± 3·1	21·3 ± 2·1
Weight (Kg)	73·7 ± 8·5	59·5 ± 7·6
Height (cm)	178·4 ± 7·1	167·0 ± 4·7
BMI (Kg m^{-2})	23·0 ± 2·1	21·3 ± 2·3

Table 2 Mean ± SD of physical activity (counts $\min^{-1}$) measured by the wrist-worn accelerometers (dominant wrist versus non-dominant wrist; n = 40).
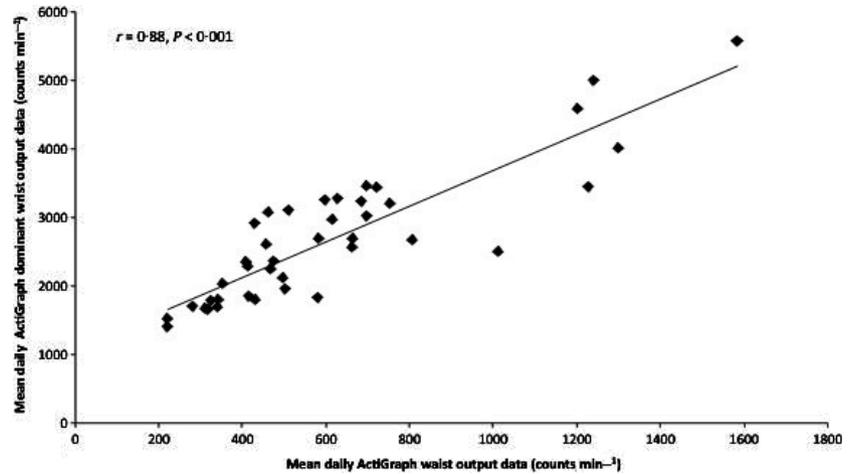
	Dominant wrist	Non-dominant wrist	P^a
X-axis	1462·1 ± 627·7	1369·6 ± 577·3	0·4945
Y-axis	1443·7 ± 499·6	1379·1 ± 517·6	0·5718
Z-axis	1576·1 ± 503·6	1487·9 ± 490·9	0·4302
Vector magnitude	2676·3 ± 952·3	2530·4 ± 922·4	0·4883

^{a}Paired t-test.

Figure 1 Relationship between mean daily output data from the waist-worn ActiGraph (counts min^{-1}) and the dominant wrist-worn ActiGraph (counts min^{-1}).

Figure 2 Relationship between mean daily output data from the waist-worn ActiGraph (counts min^{-1}) and the non-dominant wrist-worn ActiGraph (counts min^{-1}).
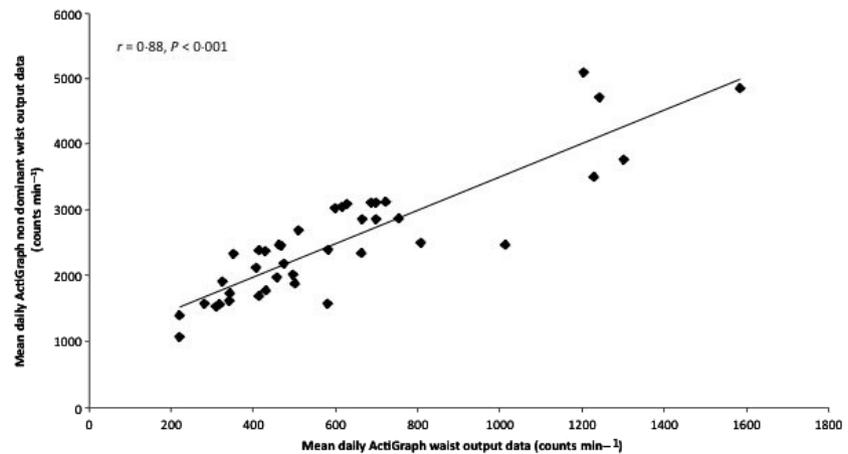
Statistical analyses were performed with the Statistical Package for the Social Science, Version 22.0 for Windows (SPSS Inc., Chicago, IL, USA). Data are presented as mean ± SD for quantitative variables. Normality of distribution was checked graphically and by using the Shapiro–Wilk test. Bivariate comparisons between the two accelerometers (dominant wrist versus non-dominant wrist) were made using a paired Student's t-test. Pearson correlations were used to determine concurrent validity of the ActiGraph accelerometer worn on the wrists relative to the ActiGraph accelerometer on the waist. Statistical significance was set at P<0·05. Preliminary analyses showed that gender had no effect on agreement between monitors and therefore was omitted in presenting results.

Results

Data of physical activity measured by wrist-worn accelerometers, dominant versus non-dominant wrist are presented in Table 2. No significant differences in physical activity were found between the accelerometer worn on the dominant wrist versus the non-dominant wrist, regardless of the axis (Table 1).

Mean daily accelerometer output data obtained from the ActiGraph worn on the wrist, dominant or non-dominant, were positively correlated with average counts per minute from the ActiGraph worn around the waist (Figs 1 and 2).

Discussion

Accelerometry is useful for prescribing exercise and quantifying habitual physical activity. Accelerometers used in epidemiological and clinical studies have been validated for assessing physical activity patterns (Pedišić & Bauman, 2015). Given the increasing number of clinical studies and differing methodologies using a wrist-worn accelerometer (Vanhelst et al., 2012; Mannini et al., 2013; Ellis et al., 2014; Hildebrand et al., 2014; Rowlands et al., 2014; Tudor-Locke et al., 2015), it is important to determine whether data obtained from these studies are comparable. The purpose of the present study was to determine whether there is a difference in physical activity assessment between a wrist-worn accelerometer at the dominant or non-dominant arm.

Findings from our study indicated no significant differences when comparing results from an accelerometer worn on the dominant versus the non-dominant wrist, regardless of the axis. Although the dominant arm is used more often and is stronger than the non-dominant arm (Armstrong & Oldham,

1999), our findings show that physical activity measured was the same regardless of the wrist chosen. Our result has important implications when planning methodologies to assess physical activity patterns with the use of wrist-worn accelerometers. Presently, studies using wrist-worn accelerometry to assess physical activity have selected dominant or non-dominant arms without knowing whether there is a difference in results between the two sites (Vanhelst et al., 2012; Mannini et al., 2013; Ellis et al., 2014; Hildebrand et al., 2014; Rowlands et al., 2014; Tudor-Locke et al., 2015). Our findings suggest that the ActiGraph accelerometer worn on the dominant or non-dominant wrist assesses physical activity similarly. Results confirm that data from previous studies are comparable regardless of the wrist used.

Mean daily accelerometer output data from the ActiGraph worn on the wrist, dominant or non-dominant, positively correlated (linear relationship, r = 0·88) with average counts per minute from the ActiGraph worn around the waist. Our results concur with a previous study performed with another device (GENEA accelerometer) in children (Rowlands et al., 2014). Rowlands et al. (2014) showed that the assessment of children's activity level in free-living conditions, time spent sedentary and time in moderate to vigorous physical activity estimated from the hip or wrist-worn GENEA accelerometer was comparable with a uniaxial ActiGraph worn around the waist (r > 0·83). Our study is the first to investigate concurrent validity of measures of physical activity from the Acti-Graph accelerometer worn at the wrist and around the waist in free-living conditions in a young adult population. This finding is important in determining whether assessment with wrist-worn accelerometers is comparable or related to data already obtained from waist-worn accelerometers. Our results suggest that data are comparable, and therefore, the analysis of physical activity patterns of previous studies performed is valid, despite differences in location of the accelerometer.

Further studies are recommended for defining physical activity thresholds in adult populations. Results of our study confirm the use of the ActiGraph wrist-worn accelerometer to assess physical activity patterns. Furthermore, wearing an accelerometer at the waist, back or hip may be more inconvenient and may contribute to low compliance in studies where there is prolonged wear, usually 7 days for assessing habitual physical activity in epidemiological studies such as National Health and Nutrition Examination Survey (NHANES), Healthy Lifestyle in Europe by Nutrition In Adolescence (HELENA) or Identification and prevention of dietary and lifestyle induced health Effects In Children and infantS (IDEFICS) studies. The wrist-worn accelerometer is a device that does not require removal during the day. As a consequence, subject compliance is improved and physical activity level patterns in free-living conditions are assessed more precisely. When the accelerometer is worn around the waist with an elastic belt or on a belt clip, the subject is obliged to remove the device for sleeping, changing clothes, doing contact sports or during activities in water, for example bathing and showering. These constraints may lead to lower compliance. In addition, when using waist-worn accelerometers, zero activity periods of 20 min or longer are analysed as 'not worn time' (Choi et al., 2011; Ruiz et al., 2011; Rey-López et al., 2012). If these periods are removed from the total of activity, it may lead to misclassification of physical activity patterns, that is underestimation of sedentary time.

Results of the study provide important information regarding the use of accelerometers. However, there are limitations to consider. Wearing multiple accelerometers simultaneously is possible but may be difficult for the subject and could influence physical activity in free-living conditions. A second limitation is the time period used to monitor activity. Collecting data over varying lengths of time may have an effect on findings. Finally, our analyses were made only on total physical activity (counts $\min^{-1}$) because there are no thresholds developed and validated for the ActiGraph wrist-worn accelerometer in adults. We cannot exclude the possibility that our results could be different if our analysis was performed according to physical activity intensities.

In summary, our findings suggest that there is no difference in physical activity assessment between an accelerometer worn on the dominant wrist or the non-dominant wrist. Furthermore, a strong correlation was found between output data obtained to the ActiGraph accelerometer worn at the waist or the wrist, either dominant or non-dominant. Data suggest that the use of accelerometers in previous studies is valid regardless of the wrist that was used for data collection. Results from the study contribute to a better understanding of physical activity assessment, an important public health interest.

Conflict of interest

The authors declare that they have no competing interests.

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