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

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**Short Title:** Accelerometers comparisons

## ABSTRACT

The purpose of this study is 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 is 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 one-day test period. There were no significant differences in physical activity when comparing the dominant-vs 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.

**Keywords:** Health, Accelerometry, Methodology, Physical patterns

## Introduction

Moderate to vigorous physical activity is associated with decreased risk factors for obesity, cardiovascular and pulmonary diseases, cancer, depression and increasing bone health in children and adolescents (Pedersen & Saltin, 2006). Accurate measurement of physical activity, therefore, is essential in developing intervention strategies. Physical activity questionnaires, diaries, observations, indirect calorimetry, double-labeled 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 (Vanhelst *et al.*, 2012).

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 center 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; Rowlands *et al.*, 2014; Mannini *et al.*, 2013; Rowlands *et al.*, 2014; Vanhelst *et al.*, 2012).

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 d to assess habitual physical activity). Wrist-worn accelerometers have been studied in a variety of applications (Vanhelst *et al.*, 2012; Rowlands *et al.*, 2014; Mannini *et al.*, 2013; Ellis *et al.*, 2014; Tudor-Locke *et al.*, 2015; Hildebrand *et al.*, 2014). In these studies, differing methodologies have been applied,

including the use of both dominant or 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.

The purpose of this study is 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 is 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: (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; (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, GA 101, 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 one min and output was expressed as mean counts per minute. All participants wore the three accelerometers simultaneously, one at the level of the waist, one on the non-dominant- and one on the dominant wrist (left wrist N = 3, right wrist N = 37). Accelerometers were worn for 24 consecutive hours of free-living conditions. Subjects were instructed to remove accelerometers during swimming, showering, bathing and the night. Data were uploaded each day following testing from the monitor to a computer.

## Materials

### *GT3X ActiGraph accelerometer*

The ActiGraph<sup>®</sup> Monitor (ActiGraph GT3X<sup>®</sup>; 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 × 33 × 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<sup>®</sup> 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 is 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  $7.5 \text{ counts}\cdot\text{min}^{-1} \pm 2.3$  (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 ( $7.5 \text{ counts}\cdot\text{min}^{-1} \pm 2.3$ ). 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.

Statistical analyses were performed with the Statistical Package for the Social Science, Version 22.0 for Windows (SPSS, Inc., Chicago, IL). Data are presented as mean ( $\pm$  standard deviation (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 *vs* non-dominant wrist) were made using a Paired Student *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 vs non dominant wrist are presented in Table 1. No significant differences in physical activity were found between the accelerometer worn on the dominant wrist versus the 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 (Figures 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; Rowlands *et al.*, 2014; Mannini *et al.*, 2013; Ellis *et al.*, 2014; Tudor-Locke *et al.*, 2015; Hildebrand *et al.*, 2014), it is important to determine whether data obtained from these studies is comparable. The purpose of the present study is 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 if there is a difference in results between the two sites (Vanhelst *et al.*, 2012; Rowlands *et al.*, 2014; Mannini *et al.*, 2013; Ellis *et al.*, 2014; Tudor-Locke *et al.*, 2015; Hildebrand *et al.*, 2014). 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 two previous studies performed with another device (GENEA accelerometer) in children and adult populations (Zhang *et al.*, 2012; Rowlands *et al.*, 2014). Even though movements during activities of free living conditions, such as carrying bags, putting hands in pockets while walking, etc. (Rowlands *et al.*, 2014) may not be recorded with a wrist-worn accelerometer, Zhang *et al.* (2012) demonstrated that the ability to detect physical activity with a wrist-worn accelerometer is comparable to waist-worn accelerometers, i.e.  $r = 0.96$  and  $0.97$  for left and right wrist, respectively, during semi-structured activities in the laboratory and outdoor environment. 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 ActiGraph 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 NHANES, HELENA or IDEFICS studies. The wrist-worn accelerometer is usually a waterproof device that does not require removal during the day. As a consequence subject compliance is improved and physical activity levels 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, e.g. bathing, showering, and swimming. 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” (Rey-Lopez *et al.*, 2012; Ruiz *et al.*, 2011; Choi *et al.*, 2011). If these periods are removed from the total of activity it may lead to misclassification of physical activity patterns, i.e. 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<sup>-1</sup>) 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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## Legends

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

**Table 2.** Mean  $\pm$  SD of physical activity (counts.min<sup>-1</sup>) measured by the wrist-worn accelerometers (dominant wrist vs non dominant wrist) ( $n = 40$ )

**Figure 1.** Relationship between mean daily output data from the waist-worn ActiGraph (counts.min<sup>-1</sup>) and the dominant wrist-worn ActiGraph (counts.min<sup>-1</sup>)

**Figure 2.** Relationship between mean daily output data from the waist-worn ActiGraph (counts.min<sup>-1</sup>) and the non-dominant wrist-worn ActiGraph (counts.min<sup>-1</sup>)

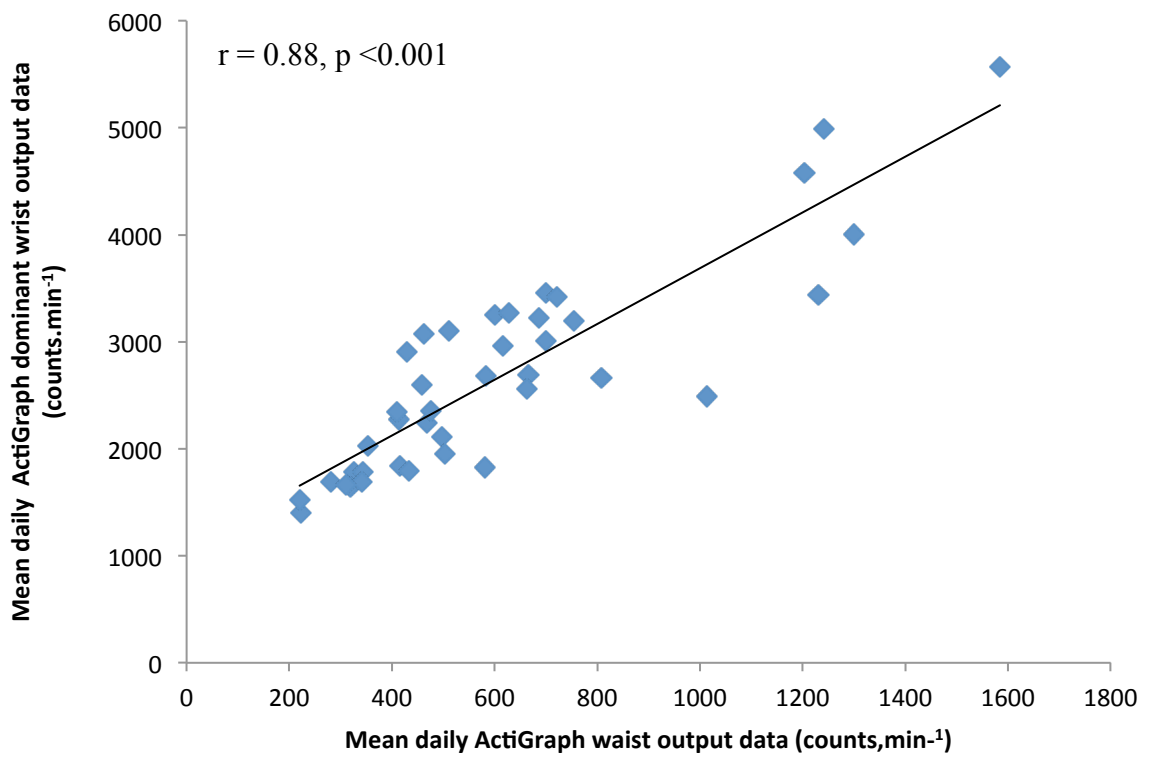
**Table 1.** Physical characteristics of subjects ( $n = 40$ )

	<b>Males</b>	<b>Females</b>
<b>N</b>	24	16
<b>Age (yr)</b>	22.9 $\pm$ 3.1	21.3 $\pm$ 2.
<b>Weight (Kg)</b>	73.7 $\pm$ 8.5	59.5 $\pm$ 7.6
<b>Height (cm)</b>	178.4 $\pm$ 7.1	167.0 $\pm$ 4.7
<b>BMI (Kg/m<sup>2</sup>)</b>	23.0 $\pm$ 2.1	21.3 $\pm$ 2.3

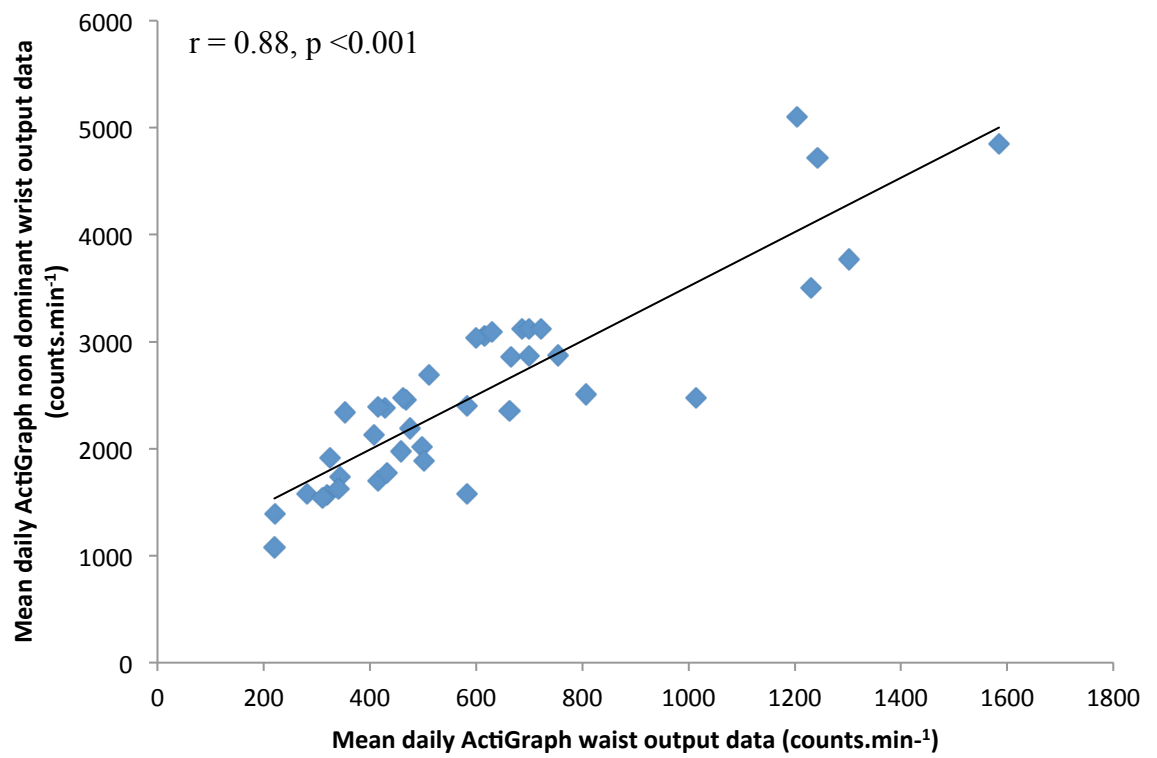
**Table 2.** Mean  $\pm$  SD of physical activity (counts.min<sup>-1</sup>) measured by the wrist-worn accelerometers (dominant wrist vs non dominant wrist) (n = 40)

	<b>Dominant wrist</b>	<b>Non-dominant wrist</b>	<b>P*</b>
<i>X axis</i>	1462.1 $\pm$ 627.7	1369.6 $\pm$ 577.3	0.4945
<i>Y axis</i>	1443.7 $\pm$ 499.6	1379.1 $\pm$ 517.6	0.5718
<i>Z axis</i>	1576.1 $\pm$ 503.6	1487.9 $\pm$ 490.9	0.4302
<i>Vector Magnitude</i>	2676.3 $\pm$ 952.3	2530.4 $\pm$ 922.4	0.4883

\* Paired *t* test



**Figure 1.** Relationship between mean daily output data from the waist-worn ActiGraph (counts.min<sup>-1</sup>) and the dominant wrist-worn ActiGraph (counts.min<sup>-1</sup>)



**Figure 2.** Relationship between mean daily output data from the waist-worn ActiGraph (counts.min<sup>-1</sup>) and the non-dominant wrist-worn ActiGraph (counts.min<sup>-1</sup>)