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ARTICLE

The validity of the Tractivity motion sensor during walking.

Darren E. R. Warburton[1,2], Andrew Jeklin[1,2], and Shannon Bredin[2,3]

Abstract

Background: Accelerometers have a distinct advantage over pedometers in the capacity to assess accurately and comprehensively physical activity and sedentary behaviours. However, the widespread use of accelerometers has been limited owing to the marked cost difference between sensors. Recent technological advancements have allowed for the development of accelerometers that are more affordable, increasing the potential usage of accelerometers on a population level. The Tractivity motion sensor has recently been developed to monitor distance, steps, and time spent during physical activities. *Purpose*: To examine the validity of the Tractivity sensor to measure step counts in comparison to direct observation across a range of walking speeds. Methods: Ten participants (5 M; 5 F) were evaluated during four incremental stages of treadmill walking at 2.4, 3.1, 3.5, and 4.1 mph (in randomized order). Each exercise stage lasted 6 min in duration. Step counts were evaluated (in a blinded fashion) via direct observation (video analysis) and the Tractivity sensor. *Results*: The Tractivity device explained 99.2% of the variance in the actual counts with no evidence of systematic bias across exercise intensity. The average difference between Tractivity device and the criterion method was -3.05 steps (0.44%) across the range of walking speeds, with the majority of step counts being within ±10 steps. There was no significant difference between step counts derived by the Tractivity sensor and direct observation. *Conclusion*: The Tractivity sensor is a valid measure of step counts in comparison to direct observation with less than 0.5% error across a range of walking speeds. **Health & Fitness Journal of Canada 2013;6(3):114-122.**

Keywords: Accelerometry; Direct Observation; Validation

From the [1]Cardiovascular Physiology and Rehabilitation Laboratory, University of British Columbia, Vancouver, BC, [3]Physical Activity Promotion and Chronic Disease Prevention Unit, and [3]Cognitive and Functional Learning Laboratory, University of British Columbia, Vancouver, BC. Email: darren.warburton@ubc.ca

Introduction

The health benefits of routine physical activity are clear (Warburton et al., 2006a). Recent evidence also indicates that reducing sedentary behaviours is an important step in decreasing the risk for premature mortality and chronic disease (Matthews et al., 2012; Proper et al., 2011). Motion sensors are effective tools for monitoring physical activity and sedentary behaviours (Shephard, 2013). Moreover, there is compelling evidence that the routine wearing of motion sensors facilitates increased physical activity and likely reduced sedentary behaviours (Shephard, 2013).

There are several types (and numerous brands) of motion detectors including simple pedometers, more sophisticated accelerometers, and even more technologically advanced multi-sensor systems integrating several technologies (such as accelerometry, global position monitoring, and physiological parameters) (Warburton et al., 2006a, 2006b; Warburton, 2012). These devices have been used to monitor physical activity and often sedentary behaviours objectively in free-living conditions (Warburton, 2012).

Accelerometry has increasingly been used to monitor physical activity and sedentary behaviour (Warburton et al., 2006a). Accelerometers measure the acceleration of the human body (uniaxial in one plane and triaxial in three planes)

(Freedson and Miller, 2000). Accelerometers have been used extensively in research studies owing to the ability to provide an accurate and comprehensive assessment of physical activity and sedentary behaviours (Warburton, 2012).

The accuracy and reliability of accelerometry has been consistently demonstrated (Shephard, 2013). However, this research was often completed with accelerometers that cost hundreds of dollars limiting the incorporation of this technology at a population level (Warburton et al., 2006b). As such, pedometers continue to be used more frequently on a population basis owing to the lower cost ($15-30), acceptable accuracy, and ease of usage (Le Masurier and Tudor-Locke, 2003; Mammen et al., 2012; Warburton et al., 2006b). Pedometers have represented a significant breakthrough in physical activity promotion (Le Masurier and Tudor-Locke, 2003; Shephard, 2013; Warburton et al., 2006b). However, the recent incorporation of accelerometry in consumer electronics (particularly in smart phone technology) has allowed for the development of much more affordable accelerometers that can be used by the general population (Warburton, 2012). For instance, a Vancouver based high-tech company (Kineteks Corporation) has developed a low cost, commercially available, triaxial accelerometer for use on the foot/ankle (approximately $30 USD) (www.tractivityonline.com). This system allows for the self-monitoring of distance, steps, time, and estimated calories expended during physical activities. Moreover, the Tractivity motion sensor is supplemented by a comprehensive physical activity monitoring and motivation web-based application. However, the accuracy of the Tractivity motion sensor has not been evaluated systematically. As such, the primary purpose of this investigation was to evaluate independently the accuracy of the new generation Tractivity motion sensor in comparison to directly assessed (via video observation) step counts. We hypothesized that the Tractivity motion sensor would provide an accurate measure of total physical activity step counts.

Methodology

We evaluated 10 participants (5 F; 5 M; Age = 34.4 ± 20 yr (mean ± SD); Range 18-66 yr). All participants completed the evidence-based Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Warburton et al., 2011b) and provide written informed consent.

We tested across a wide range of body types (BMI = 25.2 ± 4.5 kg/m^2; Range = 20-35 kg/m^2); Estimated Body Fat = 20.4 ± 13.8%, Range 1-41%; Waist Circumference = 90.2 ± 13.1 cm; Range = 75-117).

Each participant was required to complete four incremental stages of exercise including treadmill walking at 2.4, 3.1, 3.5, and 4.1 mph (in randomized order). Each exercise stage lasted 6 min in duration. The pace of exercise was based on a the recommendations of a previous investigation (Marshall et al., 2009).

Measures

Anthropometry and Body Composition

Body mass (kg) and standing height (cm) were measured according to standard procedures (Gledhill and Jamnik, 2003), and BMI was calculated. Waist circumference was measured using an anthropometric tape according to the recommendations of the National

Institutes of Health (i.e., at the top border of the iliac crest). Skinfolds were also measured at four sites (triceps, biceps, subscapular, and suprailiac) according to the procedures of Gledhill and Jamnik (2003). Percentage body fat was estimated using these skinfolds (Durnin and Womersely, 1974).

Cardiovascular and Metabolic Monitoring

Expired gas and ventilatory parameters were acquired throughout using a calibrated metabolic cart (Ergocard, Medisoft) allowing for the determination of oxygen consumption during each stage of exercise. Heart rate was measured continuously (via a Polar Heart Rate monitor) and rating of perceived exertion (via the 10-point Borg scale) was assessed every minute (Noble et al., 1983). A qualified exercise professional conducted all tests (Warburton et al., 2013; Warburton and Bredin, 2009; Warburton et al., 2011a).

Steps Counts

Step counts were collected in an independent fashion for the main comparisons of the study. The criterion method involved the direct video recording/observation of the steps taken by the participants during each stage of exercise. All video analyses were conducted by our research team offline and independent of the Kineteks team. During each stage of exercise, concurrent measures of step counts were collected by the latest version of the Tractivity accelerometer. At the end of the recording session, the Tractivity device was returned to the Kineteks team for the retrieval of step count data. The Kineteks team independently recorded the steps from the Tractivity device during the testing and returned these values to our team. As such, the counts from each system were derived independently and blindly such that neither team was aware of the counts from both systems until the data was harmonized. At no time did the Kineteks team have access to our research findings ensuring the unbiased nature of the study.

Statistics

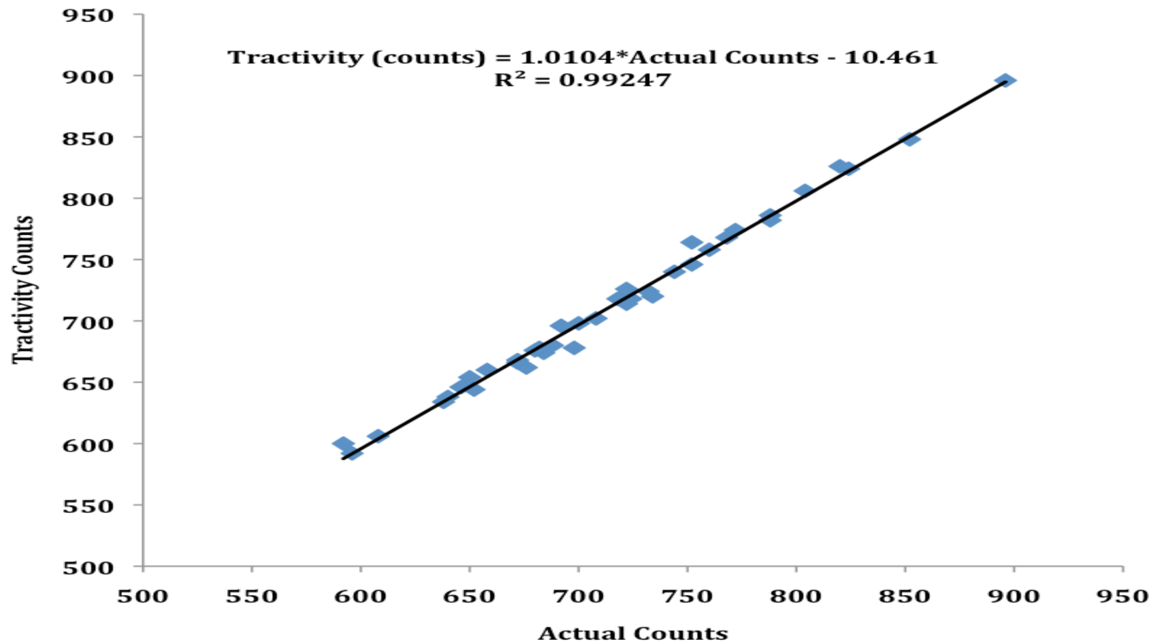
All data is reported as mean ± SD. The relationship between step counts derived from the Tractivity device and the criterion method was determined via linear regression. The relationship between step counts and heart rate, Rating of Perceived Exertion, oxygen consumption, and metabolic equivalents (METs) was also calculated. A Bland-Altman analysis was conducted to determine if any systematic bias existed (Bland and Altman, 1986) and differences (relative and absolute) between devices were calculated. The level of significance was set *a priori* at $p < 0.05$.

Results

There was a significant and strong relationship between the Tractivity sensor and the criterion method (Figure 1). The Tractivity device explained 99.2% of the variance in the actual counts derived from direct observation. As illustrated in Figure 1, the relationship was consistent across exercise intensities.

A Bland-Altman analysis also revealed a strong relationship between step counts derived from the Tractivity device and the criterion (video) method. Figure 2 illustrates the Bland-Altman analyses comparing the two methods. As illustrated in this diagram there was no systematic bias, with the majority of the step counts being within ±10 steps. This strong relationship was demonstrated across the range of walking speeds.

Figure 1: Tractivity counts as a function of actual counts (determined via direct observation).



The average difference between Tractivity device and the criterion method was -3.05 steps (0.44%) across the range of walking speeds.

Table 1 contains the physiological and RPE data in response to the incremental walking stages. Across all conditions, there was a significant relationship between the Tractivity counts and various exercise responses reflecting the convergent validity of the device. The Tractivity counts explained 58, 53, 65, and 65%, respectively, of the variance in heart rate, Rating of Perceived Exertion,

Figure 2: Bland-Altman comparisons relating the step count difference (Tractivity-Video) to the average step counts ((Tractivity + Video)/2).

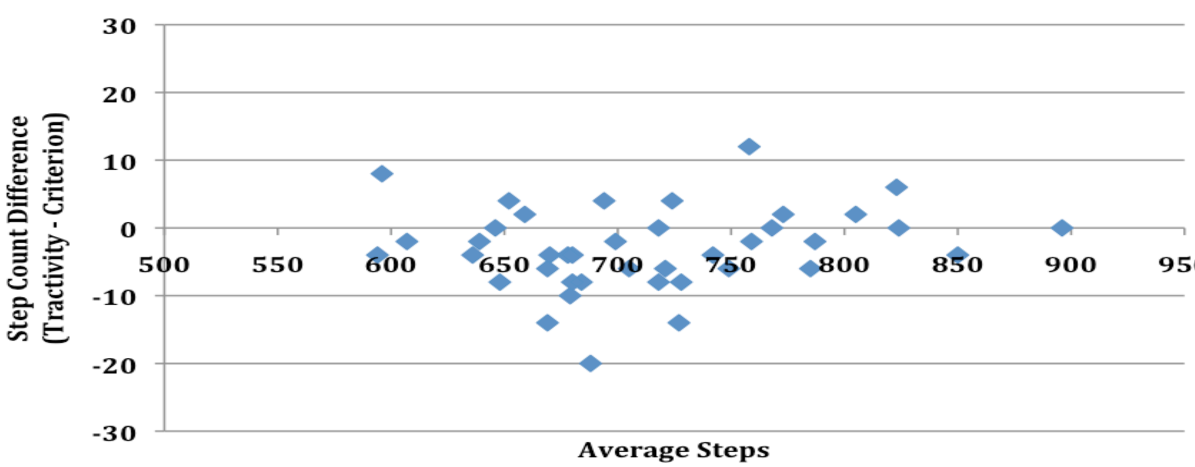


Table 1: Physiological and RPE data in response to incremental walking stages.

Variable	Walking Stage			
	2.4 mph	3.0 mph	3.5 mph	4.1 mph
Heart Rate (bpm)	94.7 ± 8.2	100.0 ± 10.0	109.0 ± 11.1	124.4 ± 11.6*
RPE	1.3 ± 0.6	1.9 ± 0.7	2.8 ± 0.9	4.0 ± 1.8*
Oxygen Consumption ($mL \cdot kg^{-1} \cdot min^{-1}$)	13.6 ± 2.2	15.0 ± 3.2	16.8 ± 3.1	22.3 ± 4.2*
METs	3.9 ± 0.6	4.3 ± 0.6	4.8 ± 0.9	6.4 ± 1.2*

RPE, rating of perceived exertion (0-10); mph, miles per hour. METs, metabolic equivalents.
* significant increase with incremental walking stages ($p < 0.05$).
Average data provided for the last two minutes of each exercise stage.

oxygen consumption, and METs.

Discussion

In this investigation we were able to demonstrate for the first time the accuracy of the new generation Tractivity motion sensor (accelerometer) for assessing step counts during walking in participants with a range of body types. Importantly, the Tractivity sensor was able to explain over 99% of the variance in actual step counts with no systematic bias across a wide range of walking speeds. Step counts derived by the Tractivity device were within 0.4% of actual steps accounts (as assessed by video monitoring). Convergent validity was also found with the step counts being significantly related to exercise-related changes in heart rate, Rating of Perceived Exertion, oxygen consumption, and METs.

Our findings demonstrate the remarkable ability of the Tractivity accelerometer to measure step counts during walking conditions. It should be highlighted that we have also used effectively the Tractivity device in various other clinical and general population studies (*unpublished observations*). We have observed the ease of usage of this device and the ability for this device to lead to positive behaviour change via self-monitoring of physical activity levels. We now have convincing evidence regarding its ability to monitor accurately step counts. The level of accuracy displayed in our study was extremely high and similar (if not higher) to that observed with other more expensive accelerometers (Le Masurier and Tudor-Locke, 2003; Ott et al., 2000).

The findings of this study have important implications for the widespread usage of this technology in physical activity initiatives. For instance, pedometers have previously been advocated over accelerometers owing to the cost, ease of use, and relative accuracy of pedometers (Le Masurier and Tudor-Locke, 2003; Warburton et al., 2006b). The cost and ease of usage are particularly seen as barriers to using accelerometers on a population basis for physical activity monitoring, program evaluation, and intervention via personal feedback (Le Masurier and Tudor-Locke, 2003). For instance, in 2006 we stated that "Currently, the use of accelerometers is generally confined to research applications. With further advancements in the technology and reductions in cost this equipment will likely be utilized increasingly for health promotion." (Warburton et al., 2006a). Our prediction has been supported with a proliferation of accelerometers in the high tech industry. In the past seven years there has been a marked improvement in the affordability of accelerometry technology. With the inclusion of accelerometers in smart phones and other new technologies accelerometers are more readily to the general public. For example, the iPhone® and iPod Touch® (Apple Inc.) have an imbedded accelerometer and gyroscope that can be used for the assessment of physical activity patterns (Nolan et al., 2013; Wu et al., 2012). Of interest is the ability of integrated accelerometry and gyroscope technology to measure motion in six axes. Numerous applications (often free) are also available through Apple's App Store to make further use of this technology and facilitate the self-monitoring of physical activity behaviour. Other companies have also created accelerometers that can be easily integrated into free living conditions. This includes accelerometers that can be incorporated into footwear and/or worn on other locations on the body (such as the arm, chest, waist, or ankle).

The Kineteks' Tractivity accelerometer was released recently costing approximately $30, which is analogous to the costs associated with available pedometers that are often used in large population-based studies. Currently, the Tractivity accelerometer makes use of a triaxial accelerometer to allow for the self-monitoring of distance, steps, time, and calories expended during physical activities (Warburton, 2012). A real strength of the Tractivity system is the online physical activity monitoring and lifestyle management program. Thus, the Tractivity platform goes well beyond a simple accelerometer.

The usage of accelerometry has markedly changed our understanding of the negative health impact of physical inactivity and sedentary behaviour. With the marked reduction in costs, it is possible that accelerometers will be used increasingly in large scale, population-based applications. The Tractivity device is an affordable and highly accurate tool for monitoring walking activities. As such, it is anticipated that the Tractivity device will increasingly be used in population-based studies. According to a recent (August 2013) report on the Tractivity website, Tractivity users have already covered more than 1.2 million kilometres (reflecting approximately 1.7 billion steps) using the Tractivity motion sensor

It is important to highlight that the Tractivity sensor has focused on accelerometry-based physical activity profiling. However, multi-sensor systems have been increasingly used in research applications providing an unique view of the physiological responses to human movement. Recently various vendors have advocated the inclusion of multi-sensor systems in population-based studies. However, as reviewed by Dr. Roy Shephard (2013) in this issue there is little evidence to suggest that multi-phasic monitors offer a marked improvement in the ability to monitor or change physical activity and sedentary behaviours.

It is important to address some limitations of the current research. For instance, in our current study we evaluated specifically the accuracy of the Tractivity device during walking activities and not running or jogging. We addressed the validity of the Tractivity device during walking owing to the potential widespread usage of this technology for walking related applications, and the importance of routine walking for health (Warburton et al., 2006a). Importantly, the walking stages included moderate-to-vigorous MET levels (see Table 1) consistent with international recommendations for physical activity (Warburton et al., 2006a). Also, our previous work with this device involved running applications (i.e., at 5.6 and 6.8 mph) demonstrating similar accuracy (*unpublished observations*). In the future, we hope to expand this research and compare this technology to other available systems.

Previous research has indicated that accelerometers may have greater error at detecting non-step movements (such as those observed while riding in a vehicle) owing to a lower threshold (force) required to register and record a movement (step) with traditional accelerometers versus pedometers (Le Masurier and Tudor-Locke, 2003). However, the Tractivity device overcomes this limitation (in part) by using an 8-bit micro-controller to run a proprietary signal processing algorithm that extracts step-counts from the system. The signal processing algorithm is designed to look for the pendulum motion of a foot swing, filtering out non-periodic foot motion and motions that are at too high of a frequency for human ambulation (*personal communication, Paul Shore, Kineteks Inc*). In our practice, we have not observed increased step counts via the Tractivity device during transit. In the future it would be of interest to test the accuracy of the Tractivity device during various sedentary and physical activity behaviours.

Conclusions

In summary, our findings supported a significant and strong relationship between step counts derived from the Tractivity device in comparison to the criterion video analysis. Linear regression, Bland and Altman analyses, and percentage differences between methodologies all demonstrated convincingly the ability for the Tractivity device to accurately determine step counts. The Tractivity device had less than 0.5% error across a range of walking speeds in comparison to direct observation.

Authors' Qualifications

The authors' qualifications are as follows: Darren E. R. Warburton PhD, MSc, CEP, Andrew Jeklin BKIN, and Shannon Bredin PhD, MSc, CEP.

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