Research in Developmental Disabilities 59 (2016) 73–79

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Accuracy of a piezoelectric pedometer in persons with and without Down syndrome

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ARTICLE INFO

Article history:
Received 11 December 2015
Received in revised form 19 July 2016
Accepted 5 August 2016

Keywords:
Physical activity
Disability
Activity monitor
Exercise

ABSTRACT

Background: Piezoelectric pedometers with a tri-axial accelerometer mechanism may effectively monitor physical activity in persons with Down syndrome (DS), but their accuracy has not been determined in this population.
Aim: To examine the accuracy of a pedometer with a tri-axial accelerometer mechanism in measuring steps at different walking speeds in persons with and without DS.
Methods: Eighteen persons with DS (8 women; age 25 ± 7 y) and 22 persons without DS (9 women; 26 ± 5 y) participated in this study. Participants completed six over-ground walking trials at the preferred speed and at 0.5, 0.75, 1.0, 1.25, and 1.5 m s^{-1}, each lasting 6 min. The steps taken were measured with hand-tally and with the Walk4Life MVPa piezoelectric pedometer. Pedometer accuracy was assessed with absolute percent error and Bland-Altman plots.
Results: Absolute percent error did not differ between persons with and without DS across speeds. Error decreased with increased speed ($p < 0.001$), but leveled off at ≥1.0 m s^{-1}. Pedometers underestimated steps at 0.5 and 0.75 m s^{-1}, but were highly accurate at the preferred walking speed and at speeds ≥1.0 m s^{-1}.
Conclusions: A piezoelectric pedometer with a tri-axial accelerometer mechanism measures steps with high accuracy at the preferred walking speed and at speeds ≥1.0 m s^{-1} in persons with and without DS. Accuracy, however, is compromised at slower speeds. Across speeds, pedometer error is similar between persons with and without DS.

What this paper adds

This study is the first to examine the accuracy of a piezoelectric pedometer with a tri-axial accelerometer mechanism (Walk4Life MVPa) during walking in persons with and without Down syndrome (DS). Accuracy of the steps measured by the pedometer was evaluated against the criterion of directly measuring steps with observation during a set of walking trials at a range of speeds. We found that the pedometer was highly accurate at the preferred walking speed and at speeds ≥1.0 m s^{-1},

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http://dx.doi.org/10.1016/j.ridd.2016.08.003
0891-4222/

but underestimated steps at 0.5 and 0.75 m s^{-1}. Error decreased with faster speed, but leveled off at ≥1.0 m s^{-1}. We also found that pedometer error did not differ between persons with and without DS across walking speeds. Rehabilitation and exercise professionals, as well as researchers may use with confidence the Walk4Life MVPa pedometer for monitoring steps at walking speeds ≥1.0 m s^{-1} in persons with and without DS. At speeds below 1.0 m s^{-1}, where the threshold for moderate-to-vigorous activity occurs for most persons with DS, pedometer accuracy is problematic. Pedometers may cost-effectively assess ambulatory activity in persons with and without DS.

1. Introduction

Individuals with Down syndrome (DS) experience health disparities such as shorter lifespans than the general population (Presson et al., 2013), high obesity rates (Stancliffe et al., 2011), low cardiovascular and muscular fitness (Baynard, Pitetti, Guerra, Unnithan, & Fernhall, 2008; Croce, Pitetti, Horvat, & Miller, 1996), functional limitations (Carmeli, Kessel, Bar-Chad, & Merrick, 2004), and a set of other preventable secondary conditions (Pikora et al., 2014). Although physical activity may reduce these health disparities (U.S. Department of Health and Human Services, 2008), most adults with DS do not meet the recommended amount of physical activity (Draheim, Williams, & McCubbin, 2002; Phillips & Holland, 2011; Stancliffe et al., 2012). Therefore, there is a need to promote physical activity in persons with DS.

Physical activity promotion may be improved in persons with DS, if their physical activity levels are objectively monitored in a cost-effective manner. One objective method of physical activity monitoring involves pedometers. These relatively inexpensive devices measure steps and can monitor ambulation—a very common activity type in persons with DS (Draheim et al., 2002; Heller, Hsieh, & Rimmer, 2002). There are two types of pedometers: spring-levered and piezoelectric. Spring-levered pedometers employ a lever-arm that detects vertical displacement during ambulation. Piezoelectric pedometers detect accelerations of the body during movement. Some piezoelectric pedometers detect accelerations in two axes (vertical and anteroposterior) and some in three axes (vertical, anteroposterior, and mediolateral). Manufacturers of piezoelectric pedometers set an acceleration threshold above which accelerations are used in registering steps.

Pedometers have acceptable accuracy in measuring steps for research and clinical practice (Tudor-Locke, Williams, Reis, & Pluto, 2002), but their accuracy is compromised at slow walking speeds (Crouter, Schneider, Karabulut, & Bassett, 2003; Melanson et al., 2004). Persons with DS have slower preferred walking speeds than persons without DS (Agiovlasitis, McCubbin, Yun, Pavol, & Widrick, 2009; Agiovlasitis et al., 2011); thus, the utility of pedometers in monitoring steps in this population warrants consideration. One previous study found that a piezoelectric pedometer with a dual-axis accelerometer mechanism had acceptable accuracy in persons with DS at the preferred walking speed, and at slower and faster than preferred walking speeds (Pitchford & Yun, 2010). Furthermore, that piezoelectric pedometer was more accurate than a spring-levered (Pitchford & Yun, 2010). That study also demonstrated that pedometer error—even for the piezoelectric pedometer—was greater in persons with than without DS (Pitchford & Yun, 2010). This greater error may potentially be associated with the fact that a dual-axis piezoelectric pedometer does not detect mediolateral body motion, thus not registering shorter but wider steps. Notably, persons with DS show greater mediolateral body motion during walking, as well as shorter, faster, and wider steps than persons without DS (Agiovlasitis, McCubbin, Yun, Mpitsos, & Pavol, 2009; Kubo & Ulrich, 2006). Therefore, a pedometer with a tri-axial accelerometer, which can capture mediolateral body motion, may potentially be more accurate in measuring steps in persons with DS. Moreover, pedometer error may partially be due to anthropometric differences between persons with and without DS. Some research has shown that spring-levered pedometers may have higher error for persons with greater body mass index (BMI) (Tyo et al., 2011), although this is not a universal finding (Swartz, Bassett, Moore, Thompson, & Strath, 2003) and does not seem to apply to piezoelectric pedometers (Tyo et al., 2011). Nevertheless, the possibility that pedometer error may be greater in persons with DS due to their higher BMI (Stancliffe et al., 2011) should be considered. Finally, pedometer error may be higher in persons with DS because they have shorter height and leg length than persons without DS. Shorter height and leg length cause smaller vertical body motion (Farley & Ferris, 1998), potentially affecting vertical accelerations.

The purpose of this study was to examine the accuracy of a piezoelectric pedometer with a tri-axial accelerometer mechanism in measuring steps across a range of walking speeds in persons with and without DS. This study also examined whether pedometer error is associated with BMI, height, weight, and leg length. We hypothesized that the pedometer would be relatively accurate, but that accuracy would be dependent on walking speed and, possibly, BMI, height, and leg length.

2. Methods

2.1. Participants

The sample consisted of 18 persons with DS (8 women, 10 men) and 22 healthy persons without DS or any other disability (9 women, 13 men). On average, the two groups had similar age (DS: 25 ± 7; Non-DS: 26 ± 5 years) and weight (DS: 75.7 ± 17.2; Non-DS: 73.0 ± 22.1 kg), but they differed in BMI (DS: 32.3 ± 7.6; Non-DS: 24.9 ± 7.2 kg m^{-2}), height (DS: 153.5 ± 7.9; Non-DS: 170.9 ± 8.1 cm), and leg length (DS: 74.0 ± 3.5; Non-DS: 88.3 ± 4.0 cm). All participants resided within a 90-min drive of our campus. We recruited participants without DS by word of mouth targeting a sample with similar age and sex attributes to the sample of participants with DS. To be included in the study, persons with and without DS