Journal of Ergonomics
ISSN: 2165-7556

Ingebrigtsen et al., J Ergonomics 2013, 3:2
DOI: 10.4172/2165-7556.1000119

Research Article Open Access

Validation of a Commercial and Custom Made Accelerometer-Based Software for Step Count and Frequency during Walking and Running

Jörgen Ingebrigtsen[1]*, Ingunn Stemland[2], Caroline Christiansen[2], Jörgen Skotte[2], Christiana Hanisch[3], Peter Krustrup[4] and Andreas Holtermann[2]

[1]*Department of Sport, Centre for Practical Knowledge, University of Nordland, Bodo, Norway*
[2]*National Research Centre for the Working Environment, Copenhagen, Denmark*
[3]*Federal Institute for Occupational Safety and Health Nöldnerstr, 40-42, D-10317 Berlin, Germany*
[4]*Sport and Health Sciences, College of Life and Environmental Sciences, St. Luke's Campus, University of Exeter, Exeter, UK*

Abstract

Background: Walking and running are main human locomotor activities during daily living, and well known to strongly predict health impairment and mortality. Hence, the main aim of this study was to assess the ability of a commercial and a custom made software for determining number of steps and step frequency during walking and running with an accelerometer in a semi-standardized setting.

Methods: 20 subjects (6 males and 14 females) equipped with the Actigraph GT3X+ tri-axial accelerometer at the thigh and the hip carried out a protocol of three walking speeds and three running speeds. The validity of the accelerometer ability to count steps and estimate step frequency was determined by comparing data from ActiLife 5 and custom made software (Acti4) with observations from video recordings from the different activity speeds.

Results: No significant differences in number of steps or step frequencies were found between the video observations and Acti4 measures in any walking and running speeds. The ActiLife 5 software recorded a significantly lower number of steps and step frequencies compared to the video observations in the three walking speeds and in the fastest running speed. Pearson's correlations and Bland-Altman plots indicated large to very large correlations and a high degree of agreement between the video observations and both the custom made Acti4 software and commercially available ActiLife software at all speeds of walking and running.

Conclusion: The custom made Acti4 software showed valid results for estimating steps and step frequency at slow, moderate and fast speeds of walking and running. Combined with the ability to detect activity type, the Acti4 software provides a valid objective method for measurements of number of steps and step frequencies.

Keywords: Human locomotion; Accelerometry; Cadence; Ambulatory measurement

Background

Walking and running are among the most common types of physical activity as they compose the main forms of human transportation [1-3]. Both walking and running have shown to be highly predictive for future cardiovascular and general health [1-6], and the 2008 Physical Activity Guidelines for American States indicates that people should participate in approximately 30 minutes of fast walking five days a week [7].

Support for pedometer-determined physical activity has gained popularity, and a 10,000 steps/day recommendation for general health has been given [8-9]. The advantages of this recommendation are that it is specific, easy to remember and behavior focused [8-9]. There are increasing documentation for 10,000 steps/day or more to be associated with good health (e.g. less body fat and lower blood pressure) [8,10,11]. However, studies have indicated that not only the number of steps per day but also the step frequency are important for the health benefits [3,12]. Moreover, studies indicate that running leads to greater energy expenditure and increased muscular activation, hence more positive health outcomes, compared to walking the same distance [3,13-16].

The existing studies investigating the relation between number of steps and step frequency of walking and health outcomes are primarily based on self-reported information of walking cadence. Self-administered questionnaires are found to be imprecise and biased [17,18]. Therefore, the existing knowledge about the importance of number of steps and step frequency in walking and running with respect to health is uncertain. Objective methods, which are able to identify and differentiate between walking and running, as well as measure the number of steps and step frequency during free-living are important for improving our knowledge about their importance for health.

Accelerometers have become a common way of collecting objective data of physical activity [19]. Recently, we have shown that a single accelerometer placed on the thigh can differentiate between physical activity types like walking and running from other types of activities with a high sensitivity and specificity [20]. In previous research, accelerometers have been applied for measuring step frequency during walking and running [8,21]. However, as outlined by Dinesh et al. [22] and Rowlands et al. [21], it is necessary to investigate if triaxial accelerometers (e.g. Actigraph GT3X+) have the ability to correctly measure the number of steps and step frequency during high walking and running speeds, as this has been a limitation of previous versions of accelerometers (i.e. uniaxial accelerometers). Hence, the main aim

***Corresponding author:** Jorgen Ingebrigtsen, Departement of Sports, Centre for practical Knowledge, University of Nordland, Bodo, Norway, Tel.: +4775517945; Fax +4775517570; E-mail: jorgen.ingebrigtsen@uin.no

Received June 11, 2013; **Accepted** August 31, 2013; **Published** September 03, 2013

Citation: Ingebrigtsen J, Stemland I, Christiansen C, Jorgen S, Hanisch C, et al. (2013) Validation of a Commercial and Custom Made Accelerometer-Based Software for Step Count and Frequency during Walking and Running. J Ergonomics 3: 119. doi:10.4172/2165-7556.1000119

of this study was to assess the ability of commercial software (ActiLife) and custom made software (Acti4) based on data from the Actigraph GT3X+ accelerometer for estimating the number of steps and step frequency during walking and running at three different speeds. For the validation of the two software systems, the estimates during walking and running are compared with video observations (gold standard) in a semi-standardized setting.

It is noted that both of the software systems ActiLife and Acti4 include calculation of steps during walking/running. However, the main feature of the Acti4 software is the ability to detect different activity types (i.e. lying, sitting, standing still, moving, walking, running, walking stairs, and cycling) whereas the main outputs of the ActiLife software are activity counts and energy expenditure. Moreover, Acti4 can handle data by up to 4 Actigraphs yielding information of inclination of trunk and arm. So the Acti4 offers some increased and alternative ways of analyzing Actigraph data.

Methods and Procedures

Procedures

The study subjects were asked to perform a semi-standardized protocol of different locomotor tasks including walking and running at six different self selected speeds varying from low to high intensity over defined time spans. This was performed in a wide-open storage room at the participants' workplace. The subjects wore an ActiGraph GT3X+ accelerometer at standard positions at the right thigh and hip and were filmed with a hand-held digital video camera during the entire protocol.

Participants

The staff of an aircraft cabin cleaning company was, through a workers trade union, invited to participate in this study. Six male and 14 female participants (age 43.0 ± 7.2 (± SD) years, body mass 68.3 ± 13.3 kg, stature 168.6 ± 7.6 cm and body mass index 24.1 ± 4.6 $kg \cdot m^{-2}$) volunteered and were recruited. Prior to testing, a written informed consent was obtained from all participants. Thereafter, an initial screening interview, concerning possible exclusion criteria, was conducted. Exclusion criteria were pregnancy and fever on the day of testing in addition to elevated blood pressure (>160/100 mmHg), angina pectoris, medical treatment of heart and lungs and or trauma/pain in involved body parts. Two of the included subjects refrained from doing the running tasks as they had somewhat elevated blood pressure. The experiment was approved by the local Ethics Committee (H-2-2011-047) and conducted in accordance with the Helsinki declaration.

Instrumentation

Two ActiGraph GT3X+ accelerometers (19×34×45 mm, weight 19 g) sampling accelerations in three directions with a frequency of 30Hz were used. Raw data was stored in a 250 MB memory and the dynamic range of the accelerometer was ± 6G (1G = 9.81 m/s^2). The accelerometers were initialized for recording and data downloaded using the manufacturer's software (ActiLife version 5.5). The accelerometers were fixed by tape (3M, Hair-Set, double sided adhesive tape and Fixomull, BSN medical) at the right medial front thigh midway between the crista iliaca and the upper line of patella and on the right side of the hip, just below crista iliaca. The video recordings (Sony, DCR-PC110E, Japan) were later time synchronized with Actigraph data, digitized and played back for manual counting of steps by observations and for the estimation of step frequency.

Protocol for detection of step frequency

A protocol of three walking speeds and three running speeds were performed by all participants. The protocol aimed at having the participants moving with three different step frequencies during walking and running over 30 to 60 seconds. Due to the higher number of steps during running compared to walking we estimated that 30 seconds of running would result in approximately the same number of steps as with 60 seconds of walking. The exact instructions given to the participants are given in Table 1. To produce a reference point for synchronization of the video recordings and the accelerometer, the exact time of beginning the protocol was recorded, and the participants started the protocol by performing a short period of standing still and rapidly lifting the right thigh.

Data analysis

Using the ActiLife software, the raw data were exported to data files (text) with epoch length of 1 s, and the number of steps summarized for each walking and running interval (The Low frequency extension option of the ActiLife software was not used). By using the Acti4 software, accelerometer data recorded by an accelerometer at the thigh were used for classifying activities in periods of walking, running, cycling, stair walking, sitting and standing still [20]. The standard deviation of the acceleration in the direction of the longitudinal axis of the thigh was used to discriminate walking and running. Values less than 0.72 G classify for walking and values above classify for running. The Acti4 software derives the instantaneous step frequency by frequency analysis of the acceleration recorded by the thigh accelerometer in the direction of the longitudinal axis of the thigh. The frequency analysis based on fast Fourier transform (FFT) is performed for a running window with a size of 128 samples (approx. 4 s) with a 1 s displacement between windows. The instantaneous step frequency is then integrated for each walking and running interval to derive the final number of steps.

All video observers participated in a standardized observer training. Therefore, before observing the observers practiced the observational method using five video sequences of 15 minutes with the participants while doing normal working routines. The video recordings were observed according to a predetermined standardized observational guideline modified from an existing observational guideline [23], and the observer used a custom made computer-based program for registration of different activity types (e.g., lie, sit, stand, walk, jog, run, walk in stairs).

Speeds	Instructions
Slow walking	"Walk for 60 seconds with the speed you would choose if you were walking inside your home."
Moderate speed walking	"Walk for 60 seconds with the speed you would choose if you were walking purposely from A to B".
Fast walking	"Walk as fast as you can for 60 seconds"
Slow running	"Jog for 30 seconds with the speed you would choose if you were to jog for an hour."
Moderate speed running	"Run for 30 seconds with the speed you would choose if you had to run for 10 minutes"
Fast running	"Run as fast as you can for 30 seconds"

Table 1: An overview of the six instructions given in the protocol.

Statistical analysis

Statistical analyses were conducted in IBM SPSS statistics version 19 (SPSS Inc., Chicago). Statistical significance was set at $p \leq 0.05$. Pair wise missing data (n = 3, all of them missing "Slow running", "Moderate speed running" and "Fast running") are excluded in the conducted comparisons. To examine correspondence in number of steps and step frequency of the Acti4 and ActiLife software with the video observations, Pearson's product moment correlation was used. Further, Student's paired t-tests were used to investigate differences in number of steps and step frequencies between the two measurement software systems (Acti4 and ActiLife) and the video observations in each of the respective walking and running tasks. Further, Bland-Altman plots were used to test the agreement between the number of steps and step frequencies measured by the video observations and the Acti4 and ActiLife software for all walking and running speeds. Plots with bias (mean difference between video observations and Acti4 and ActiLife) and limits of agreements (mean difference ± 1.96 SD) are presented.

In order to establish the inter rater reliability (IRR), three persons observed video recordings from 10 participants. The inter rater reliability was calculated using intra-class correlation coefficient (ICC; 3.1) [24]. An ICC value of ≥ 0.75 was considered good and ≥ 0.9 was considered excellent [25].

Results

Very low absolute differences in step count (-0.4 to 0.6) were revealed between the Acti4 estimations and the video observations (Table 2). This corresponds to an overestimation of 0.3 to 0.7%. Assessed by the paired t-tests, no significant differences in walking and running speeds were found. Furthermore, high correlations between the Acti4 estimations and the video observations within all walking and running speeds (r = 0.857 to 0.979) (Table 2) were observed. Also, the Bland-Altman plots indicate good agreement between the video observations and the Acti4 estimations (Figure 1).

A significant difference was found between the number of steps observed with video and the estimates from the ActiLife software in slow walking (4.2 ± 3.6 steps, $p \leq 0.001$), moderate speed walking (2.6 ± 2.7 steps, $p \leq 0.001$), fast walking (3.0 ± 4.2 steps, $p \leq 0.01$) and fast running (3.6 ± 5.0 steps, $p \leq 0.05$) (Table 3). This corresponds to an underestimation of steps of 3.7%, 2.1%, 2.2% and 4.0% during slow walking, moderate speed walking, fast walking and fast running, respectively. Furthermore, high correlations (r = 0.585 to 0.937) between the two measurement methods for all three walking and running tasks were found (Table 3). Also, the Bland-Altman plots indicate good agreement between the video observations and the ActiLife estimations (Figure 2).

Reliability of video observations

The inter-rater reliability (ICC; 3.1) was 0.97-0.98 in settings comparable to the one used in this study, which is generally considered to be excellent [23].

Discussion

The purpose of this study was to assess the ActiLife 5 and custom made Acti4 software systems ability to estimate the number of steps and step frequency during walking and running at different speeds with accelerometers. The main findings were that a low numerical difference, no statistical differences and high degree of agreement were found between the custom made Acti4 software algorithm and the video observations for step count and step frequency in the three walking and three running speeds. When assessed by the commercially available ActiLife 5 software, statistical significant lower numbers of steps were found compared to the video observations within the three walking speeds. This corresponds to an underestimation of steps of 3.7%, 2.1%, 2.2% and 4.0% during slow walking, moderate speed walking, fast walking and fast running, respectively. The latter strengthens previous findings of limited accelerometer abilities to correctly estimate movements with high speed/frequency. Assessed by the Pearson's correlation coefficient, large to very large relationships between the video observations and the ActiLife 5 estimations were found.

The very high correlations between the video observations and the custom made Acti4 software in step count and frequency within all three walking and running speeds indicate that the Acti4 software is very well able to estimate step count and frequency. We interpret the Bland Altman plots to strengthen these findings, as they show good agreement between the two measurement methods.

Also, the correlations between the commercial ActiLife 5 software estimations and the video observations were very large, and we interpret the Bland Altman plots to indicate good agreement between the ActiLife estimations and the video observations as well. Previous research have shown that measurements of fast running when using the Actigraph accelerometer or other motion sensors is complicated and can fail [21-22]. Problems stemming from amplitude and band pass filtering of raw signals has been shown to reduce response to high speed and frequency of movements [22]. Hence, it could be problematic to distinguish between moderate and fast speed running, as experienced and expressed by significant difference between video observations and ActiLife 5 estimates in the present study. However, Rowlands et al. [21] previously found very large and significant correlations between visual counted steps (i.e. step frequency) and estimations from the commercial ActiLife 5 software when wearing the Actigraph accelerometer. This is in line with the present findings,

Speed/Activity	Video observations		Acti4 estimations		Mean Difference ± SD		95 % Confidence Interval		Pearson's correlation
	Step count	Steps/s	Step count	Steps/s	Step count	Steps/s	Step count	Steps/s	*r*-value
Slow/Walking	114.7 ± 7.5	1.91 ± 0.12	114.3 ± 7.0	1.90 ± 0.12	0.4 ± 1.6	0.01 ± 0.03	-0.3 to 1.1	-0.01 to 0.02	0.979**
Moderate/Walking	121.7 ± 7.7	2.03 ± 0.13	122.0 ± 8.3	2.03 ± 0.14	-0.4 ± 2.0	-0.01 ± 0.03	-1.3 to 0.6	-0.02 to 0.01	0.970**
Fast/Walking	136.7 ± 11.2	2.28 ± 0.19	136.4 ± 11.2	2.27 ± 0.19	0.4 ± 2.9	0.01 ± 0.05	-1.0 to 1.7	-0.02 to 0.03	0.967**
Slow/Running	83.3 ± 7.2	2.78 ± 0.24	82.6 ± 7.5	2.75 ± 0.25	0.6 ± 4.0	0.02 ± 0.13	-1.4 to 2.7	-0.05 to 0.09	0.857**
Moderate/Running	86.6 ± 5.4	2.89 ± 0.18	86.2±5.5	2.87 ± 0.18	0.4 ± 2.6	0.01 ± 0.09	-1.0 to 1.7	-0.03 to 0.06	0.888**
Fast/Running	88.9 ± 7.5	2.96 ± 0.25	88.3 ± 8.2	2.95 ± 0.27	0.5 ± 2.6	0.02 ± 0.09	-0.9 to 2.0	-0.03 to 0.06	0.948**

Data is shown as means ± SD. *p ≤ 0.001, **p ≤ 0.01

Table 2: Estimated number of steps and step frequency from video observations (gold standard) and Acti4 software from Actigraph data during three walking (n=20) and three running (n=17) speeds. Paired differences with 95 % confidence intervals and Pearson's correlations are shown.

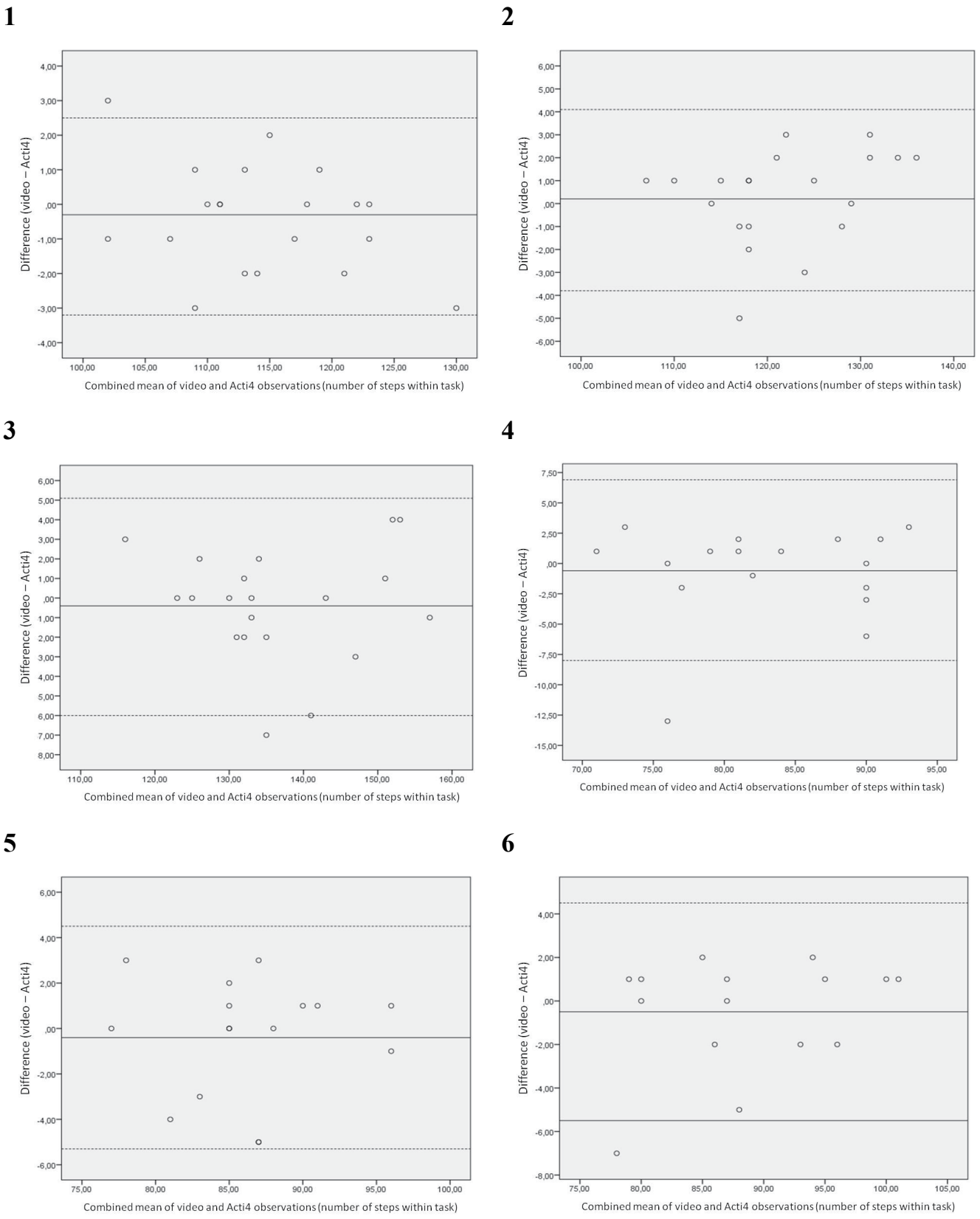

Figure 1: Bland-Altman plots showing the combined mean of the video observations and the custom made Acti4 software measures of the number of steps within the different slow, moderate and fast walking (1-3) and running (4-6) speeds on the x-axis, and the difference between the two assessment methods on the y-axis. Bias (mean difference) is presented as the middle horizontal line and the limits of agreements (± 1.96 SD) as the dashed lines.

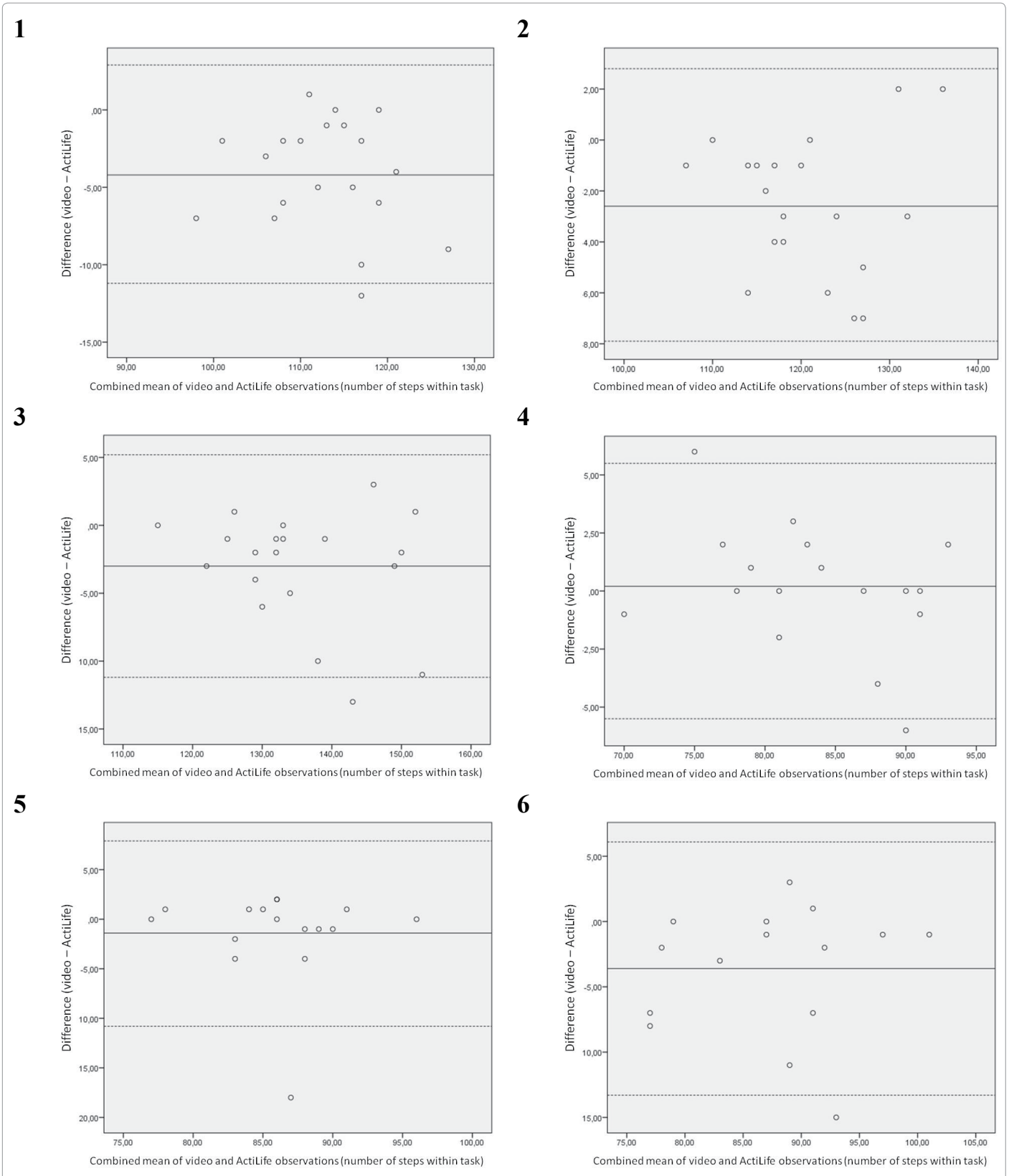

Figure 2: Bland-Altman plots showing the combined mean of the video observations and the ActiLife software measures of the number of steps within the different slow, moderate and fast walking (1-3) and running (4-6) speeds on the x-axis, and the difference between the two assessment methods on the y-axis. Bias (mean difference) is presented as the middle horizontal line and the limits of agreements (± 1.96 SD) as the dashed lines.

Speed/Activity	Video observations		ActiLife estimations		Mean Difference±SD		95 % Confidence Interval		Pearson's correlation
	Step count	Steps/s	Step count	Steps/s	Step count	Steps/s	Step count	Steps/s	*r*-value
Slow/Walking	114.7 ± 7.5	1.91 ± 0.12	110.5 ± 6.9	1.84 ± 0.11	4.2 ± 3.6*	0.07 ± 0.06*	2.5 to 5.8	0.04 to 0.10	0.879**
Moderate/Walking	121.7 ± 7.7	2.03 ± 0.13	119.1 ± 7.6	1.98 ± 0.12	2.6 ± 2.7*	0.05 ± 0.01*	1.3 to 3.8	0.02 to 0.06	0.937**
Fast/Walking	136.7 ± 11.2	2.28 ± 0.19	133.7 ± 10.2	2.23 ± 0.17	3.0 ± 4.2**	0.05 ± 0.07**	1.0 to 5.0	0.02 to 0.08	0.928**
Slow/Running	83.3 ± 7.2	2.78 ± 0.24	83.5 ± 6.2	2.78 ± 0.21	-0.2 ± 2.7	-0.01 ± 0.09	-1.6 to 1.2	-0.05 to 0.04	0.929**
Moderate/Running	86.6 ± 5.4	2.89 ± 0.18	85.1 ± 5.1	2.84 ± 0.17	1.5 ± 4.7	0.05 ± 0.16	-1.1 to 4.0	-0.04 to 0.13	0.585***
Fast/Running	88.9 ± 7.5	2.96 ± 0.25	85.3 ± 7.9	2.84 ± 0.26	3.6 ± 5.0***	0.12 ± 0.16***	-0.9 to 6.3	0.03 to 0.21	0.791**

Data is shown as means ± SD. * $p \leq 0.001$, ** $p \leq 0.01$, *** $p \leq 0.05$.

Table 3: Estimated number of steps and step frequency from video observations (gold standard) and ActiLife software from Actigraph data during three walking (n = 20) and three running (n = 17) speeds. Paired differences with 95 % confidence intervals and Pearson's correlations are shown.

although we observed somewhat stronger relationships between our custom made Acti4 software estimates and the video observations.

Limitations

We consider the main limitations to be the relatively few and homogeneous participants, which may limit the generalizability to other populations. Another limitation is that the walking and running were performed in a semi-standardized setting, and therefore may not be directly applicable for more complex settings of walking and running like in heavy terrain or in sports.

Conclusion

We found the Acti4 to give valid estimates of the number of steps and step frequency during walking and running with three different speeds. This finding is of importance as it has been a limitation of previously used uniaxial accelerometers. Combined with the ability to detect the type of activity (i.e. walking or running), present accelerometers are shown to have a good ability to produce valid objective measures of step counts and frequency. Valid measurements of steps also during high walking and running speeds would provide the opportunity to better investigate their prospective associations with different health outcomes in larger study populations. The latter is important as self-administered questionnaires has been shown to be imprecise and biased.

Acknowledgements

We thank Luke Connolly for editing the manuscript. The authors have no conflicting interests. No external financial support was given to this study.

References

1. Tully MA, Cupples ME, Hart ND, McEneny J, McGlade KJ, et al. (2007) Randomised controlled trial of home-based walking programmes at and below current recommended levels of exercise in sedentary adults. J Epidemiol Community Health 61: 778-783.
2. Lee IM, Buchner DM (2008) The importance of walking to public health. Med Sci Sports Exerc 40: S512-518.
3. Wilkin LD, Cheryl A, Haddock BL (2012) Energy expenditure comparison between walking and running in average fitness individuals. J Strength Cond Res 26: 1039-1044.
4. Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, et al. (2004) Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. Am J Med 116: 682-692.
5. Blair SN, Cheng Y, Holder JS (2001) Is physical activity or physical fitness more important in defining health benefits? Med Sci Sports Exerc 33: S379-399.
6. Jolliffe JA, Rees K, Taylor RS, Thompson D, Oldridge N, et al. (2001) Exercise-based rehabilitation for coronary heart disease. Cochrane Database Syst Rev. CD001800.
7. Hall CW, Holmstrup ME, Koloseus J, Anderson D, Kanaley JA (2012) Do overweight and obese individuals select a "moderate intensity" workload when asked to do so? J Obes 2012: 919051.
8. Tudor-Locke C, Bassett DR Jr (2004) How many steps/day are enough? Preliminary pedometer indices for public health. Sports Med 34: 1-8.
9. Tudor-Locke C, Burkett L, Reis JP, Ainsworth BE, Macera CA, et al. (2005) How many days of pedometer monitoring predict weekly physical activity in adults? Prev Med 40: 293-298.
10. Yamanouchi K, Shinozaki T, Chikada K, Nishikawa T, Ito K, Shimizu S, et al. (1995) Daily Walking Combined with Diet Therapy Is a Useful Means for Obese Niddm Patients Not Only to Reduce Body-Weight but Also to Improve Insulin Sensitivity. Diabetes Care 18: 775-778.
11. Iwane M, Arita M, Tomimoto S, Satani O, Matsumoto M, et al. (2000) Walking 10,000 steps/day or more reduces blood pressure and sympathetic nerve activity in mild essential hypertension. Hypertens Res 23: 573-580.
12. Hall C, Figueroa A, Fernhall B, Kanaley JA (2004) Energy expenditure of walking and running: comparison with prediction equations. Med Sci Sports Exerc 36: 2128-2134.
13. Falls HB, Humphrey LD (1976) Energy cost of running and walking in young women. Med Sci Sports 8: 9-13.
14. Fellingham GW, Roundy ES, Fisher AG, Bryce GR (1978) Caloric cost of walking and running. Med Sci Sports 10: 132-136.
15. Howley ET, Glover ME (1974) The caloric costs of running and walking one mile for men and women. Med Sci Sports 6: 235-237.
16. King GA, Torres N, Potter C, Brooks TJ, Coleman KJ (2004) Comparison of activity monitors to estimate energy cost of treadmill exercise. Med Sci Sports Exerc 36: 1244-1251.
17. Kwak L, Proper KI, Hagströmer M, Sjöström M (2011) The repeatability and validity of questionnaires assessing occupational physical activity--a systematic review. Scand J Work Environ Health 37: 6-29.
18. Hansson GA, Balogh I, Byström JU, Ohlsson K, Nordander C, et al. (2001) Questionnaire versus direct technical measurements in assessing postures and movements of the head, upper back, arms and hands. Scand J Work Environ Health 27: 30-40.
19. Crouter SE, Churilla JR, Bassett DR Jr (2008) Accuracy of the Actiheart for the assessment of energy expenditure in adults. Eur J Clin Nutr 62: 704-711.
20. Skotte J, Korshøj M, Kristiansen J, Hanisch C, Holtermann A (2012) Detection of Physical Activity Types Using Triaxial Accelerometers. J Phys Act Health .
21. Rowlands AV, Stone MR, Eston RG (2007) Influence of speed and step frequency during walking and running on motion sensor output. Med Sci Sports Exerc 39: 716-727.
22. John D, Tyo B, Bassett DR (2010) Comparison of four ActiGraph accelerometers during walking and running. Med Sci Sports Exerc 42: 368-374.
23. Patterson TL, Sallis JF, Nader PR, Rupp JW, McKenzie TL, et al. (1988) Direct observation of physical activity and dietary behaviors in a structured environment: effects of a family-based health promotion program. J Behav Med 11: 447-458.
24. Shrout PE, Fleiss JL (1979) Intraclass correlations: uses in assessing rater reliability. Psychol Bull 86: 420-428.
25. Portney LG, Watkins MP (2009) Foundations of clinical research. Applications to practice. Upper Saddle River, NJ: Pearson/Prentice Hall, USA.