

SHORT REPORT

Open Access

The validation of Fitbit Zip™ physical activity monitor as a measure of free-living physical activity

Mark A Tully^{1,2*}, Cairmeal McBride¹, Leonnie Heron¹ and Ruth F Hunter^{1,2}

Abstract

Background: The new generation of activity monitors allow users to upload their data to the internet and review progress. The aim of this study is to validate the Fitbit Zip as a measure of free-living physical activity.

Findings: Participants wore a Fitbit Zip, ActiGraph GT3X accelerometer and a Yamax CW700 pedometer for seven days. Participants were asked their opinion on the utility of the Fitbit Zip. Validity was assessed by comparing the output using Spearman's rank correlation coefficients, Wilcoxon signed rank tests and Bland-Altman plots. 59.5% (25/47) of the cohort were female. There was a high correlation in steps/day between the Fitbit Zip and the two reference devices ($r = 0.91$, $p < 0.001$). No statistically significant difference between the Fitbit and Yamax steps/day was observed (Median (IQR) 7477 (3597) vs 6774 (3851); $p = 0.11$). The Fitbit measured significantly more steps/day than the Actigraph (7477 (3597) vs 6774 (3851); $p < 0.001$). Bland-Altman plots revealed no systematic differences between the devices.

Conclusions: Given the high level of correlation and no apparent systematic biases in the Bland Altman plots, the use of Fitbit Zip as a measure of physical activity. However the Fitbit Zip recorded a significantly higher number of steps per day than the Actigraph.

Keywords: Physical activity, Pedometer, Accelerometer, Validation

Findings

Introduction

The use of physical activity monitors have been shown to be an effective means to promote changes in physical activity [1]. These have evolved over time from relatively simple mechanical pedometers (that display but not record physical activity in steps), to more complex accelerometers (that record intensity and duration of movement). There has been a recent proliferation of a new generation of physical activity monitors that use accelerometer type mechanisms, but with a much simpler, user friendly interface, thus overcoming the need for technical expertise in analysing and reporting outcomes. These devices are produced by mainstream commercial companies and are designed to allow the user to upload their physical

activity record to a user's account via the internet or mobile phone application, allowing the user to review progress and share via social media.

Internet delivered physical activity interventions have emerged as an attractive option for health promotion, due to its potentially wide population reach [2]. In a systematic review, Davies et al. [3] demonstrated that internet delivered physical activity interventions are effective at producing small changes in physical activity. They recommended that future research should use validated instruments to measure study outcomes. Much of the previous research has involved the validation of energy expenditure in controlled environments [4-7]. There is therefore a need to assess the validity of this new generation of physical activity monitors as measures of free-living physical activity. One such device is the Fitbit Zip™ physical activity monitor which is a relatively cheap (\$60US) step counter that can wirelessly upload data to the users account via a USB dongle connected to their PC or a range of mobile applications. The aim of this

* Correspondence: m.tully@qub.ac.uk

¹Centre for Public Health, School of Medicine, Dentistry and Biomedical Sciences, Queens' University Belfast, Belfast, UK

²UKCRC Centre of Excellence for Public Health (Northern Ireland), Belfast, UK

study is to test the validity of the Fitbit Zip™ as a measure of free-living physical activity.

Methods

Participants

Staff employed in the School of Medicine, Dentistry and Biomedical Science, Queen's University Belfast were invited to participate via email. Individuals were encouraged to respond via email to indicate their willingness to participate. Participants were eligible to take part if they reported no known disease or injury that would prevent them taking regular physical activity and were willing to monitor their activity for a seven day period.

As previous data does not exist to inform a sample size calculation, it was planned to recruit a convenience sample of 50 participants. This is comparable to the sample size used in previous validation studies of physical activity monitors [8,9].

Data collection

All individuals who gave fully informed consent to participate were asked to wear a Fitbit Zip™ (Fitbit Inc, USA), with an ActiGraph GT3X accelerometer (Actigraph Inc, USA) and a Yamax CW700 pedometer (Yamax Inc, Japan). The Fitbit Zip™ devices were bought from an online retailer and not through the manufacturer. The manufacturers of the Fitbit Zip™ device had no role in the funding, design or conduct of the study, or analysis of the results.

Participants were asked to wear the device on their waist, at the right hand side. Participants were advised to remove the devices during water activities and sleeping. They completed a daily diary to record periods when the devices were removed.

After seven days, individuals were invited to return the devices and diary. Demographic information such as age and gender were recorded, and participants were asked for their written feedback on Fitbit Zip™, using a utility questionnaire adapted from previous research [10].

Data handling

Data was cleaned by removing non-wear time for the pedometers and Actigraph accelerometer by referring to the wear time diary. At least five days of valid data were required for the Actigraph data to be included in the analysis. A valid day was defined as a 24 hour period in which at least 10 hours of data wear time was recorded. Non-wear time was analysed as a run of zero counts lasting more than 60 minutes [11].

Data from the Fitbit Zip was recorded from the internet log of steps per day. The Yamax pedometer has a 7-day memory and this was accessed and the steps/day recorded in an electronic spreadsheet. These were both conducted by the researcher at the end of the 7-day wear period

Table 1 Descriptive characteristics of the cohort (n = 42)

Measure	Median (IQR)
Age	43 (24)
Fitbit measured steps per day	7477 (3597)
Actigraph measured steps per day	6774 (3851)
Yamax measured steps per day	7532 (4105)
Actigraph measured MVPA (mins/day)	42.23 (27.19)

and average steps/day was calculated. At the end of the study, the Actigraph data was analysed using Actilife 6.0 (Actigraph Inc, USA) to calculate average steps/day and minutes of moderate or vigorous physical activity (MVPA) per day using Freedson cutpoints (>1952 counts/min) [12].

Data analysis

Statistical analysis was performed using SPSS (Version 21). Descriptive statistics were calculated for each variable. As the Actigraph data was non-normally distributed, appropriate non-parametric statistical tests were used.

The validity of Fitbit Zip as a measure of free-living physical activity was assessed by comparing its output (steps/day) with that of the Actigraph accelerometer (steps/day and mins of MVPA) and Yamax pedometer (steps/day), according to the recommendations to Welk et al. [13] Firstly, to ascertain if the output from the Fitbit Zip™ was associated with that of the two reference devices, Spearman's rank correlation coefficients were calculated. To assess if the output from the devices yielded similar group estimates, the differences between the Fitbit Zip™ and the reference devices was assessed using Wilcoxon signed rank tests. Finally, Bland-Altman plots [14] were created to assess the level of agreement between the devices. The School of Medicine, Dentistry and Biomedical Sciences Research Ethics Committee, Queen's University, Belfast approved the study (October 2013; Ref: 13.32v2).

Results

Of the 582 people invited to participate by email, 48 (8%) agreed to take part. One of these individuals did

Table 2 Comparison of the Fitbit Zip™ with the Actigraph and Yamax devices (n = 42)

	Spearman correlation		Wilcoxon signed rank test
	r	p-value	p-value
Fitbit vs Actigraph (steps/day)	0.91	<0.001	<0.001
Fitbit vs Yamax (steps/day)	0.91	<0.001	0.11
Fitbit (steps/day) vs Actigraph (MVPA mins/day)	0.86	<0.001	.*

*It was not possible to compare differences between Actigraph measured MVPA with Fitbit steps/day as they are in different units.

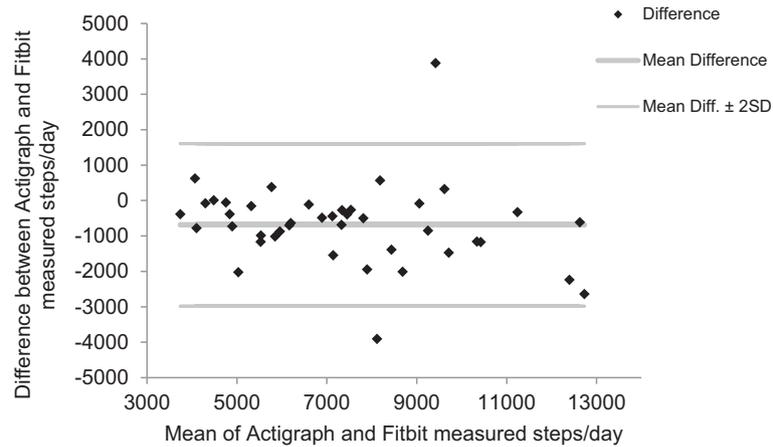


Figure 1 Bland-Altman plot for Fitbit vs Actigraph steps/day (n=42).

not start the programme. At the end of the one week recording period, valid data was available for 89% (n = 42/47) of those who participated. The characteristics of the cohort are provided in Table 1. 59.5% (n = 25) of the cohort were female.

Comparing the Fitbit Zip™ with the two reference devices demonstrated high correlation with steps/day measured with both the Actigraph accelerometer and Yamax pedometer (both $r = 0.91$) and MVPA measured with the Actigraph device ($r = 0.86$) (Table 2). No statistically significant difference between the Fitbit and Yamax was observed, however the Fitbit measured significantly more steps/day than the Actigraph (7477 vs 6774; $p < 0.001$) (Table 2).

Bland-Altman plots revealed no systematic differences between the Fitbit Zip™ and Actigraph (Figure 1) or Yamax

devices (Figure 2) measured steps/day. Overall there was a high acceptability of the Fitbit Zip™. Although only one participant had used a Fitbit Zip™ previously, the majority of respondents rated the Fitbit Zip™ as acceptable to use and easy to integrate into their daily routine (Table 3).

Discussion

The results indicate that the Fitbit Zip™ is a valid measure of physical activity. There is a significant correlation between the Fitbit Zip™ measured steps/day with that of both the mechanical pedometer (Yamax) and the Actigraph accelerometer. Given the high level of correlation and no apparent systematic biases in the Bland Altman plots, the use of Fitbit Zip™ as a measure of physical activity is recommended, according to the guidance

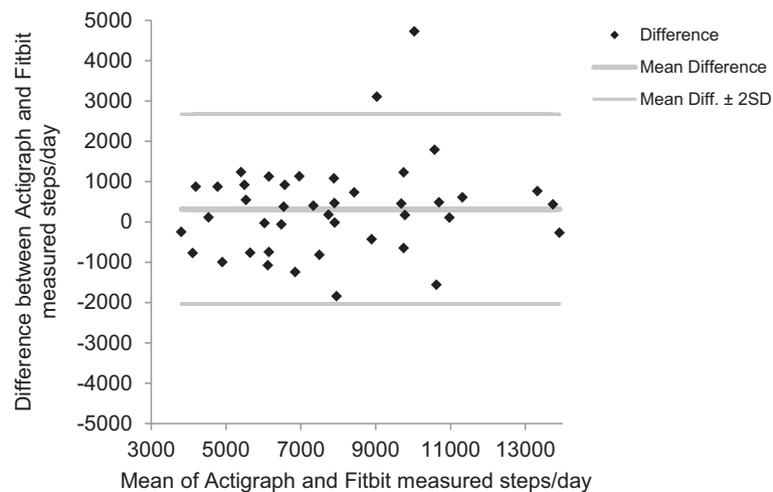


Figure 2 Bland-Altman plot for Fitbit vs Yamax steps/day (n=42).

Table 3 Utility of the Fitbit Zip™ physical activity monitor

Question	Response
Have you ever used a Fitbit to measure physical activity in the past?	Yes 2.4% (n = 1)
	No 97.6% (n = 41)
Was using the Fitbit every day for 7 days an acceptable method to measure your daily activity?	No acceptable (n = 0)
	Neither 21.4% (n = 9)
	Very acceptable 78.6% (n = 33)
How easy was it to remember to use the Fitbit Zip every day?	Difficult to remember 2.4% (n = 1)
	Neither 9.5% (n = 4)
	No problem 88.1% (n = 37)
Did using the Fitbit interfere with your daily routine?	Interfered greatly (n = 0)
	Neither 11.9% (n = 5)
	Did not interfere at all 88.1% (n = 37)
Was the Fitbit annoying to use?	Extremely annoying (n = 0)
	Neither 16.7% (n = 7)
	Not annoying at all 83.3% (n = 35)
Would you wear the Fitbit again as part of a research study?	No 0% (n = 0)
	Maybe 9.5% (n = 4)
	Yes 90.5% (n = 38)

of Welk et al. [13] This is supported by the finding that most of the participants favourably rated the utility of the Fitbit Zip™.

Physical activity monitors that allow individuals to upload their data to the internet may offer significant advantage over traditional devices, as they can integrate more easily into internet delivered physical activity interventions. Internet delivered interventions are an attractive mode of delivering public health interventions as they can be offered to large numbers of people at one time, at minimal cost [3].

It should however be noted that the Fitbit Zip™ records a significantly higher number of steps per day compared to the Actigraph. Differences in output from accelerometers and mechanical pedometers [15] and internet enabled pedometers [16] have been reported previously, and our findings suggest this is also true for the new generation of piezoelectric pedometers such as the Fitbit Zip™. Tudor-Locke et al. [15] concluded that these differences could arise from differences in instrument sensitivity thresholds or the method of attaching the device when wearing them. This suggests although the devices are reporting physical activity with the same units (steps/day), they are not equivalent and therefore caution should be exercised in future research seeking to combine information from accelerometers and pedometers in future analyses.

Strengths and limitations

The study participants were university employees, therefore validation in other population groups may be required. However the included participants undertook a wide range of physical activity levels (ranged from 3756 to 14050 steps/day), suggesting they are representative of the general population.

The manufacturers recommend that the Fitbit Zip™ can be used in a number of body placements such as shirt pocket, bra, pants pocket, belt, or waistband. This paper only includes validation of the Fitbit Zip™ worn on the waistband [17].

Conclusion

The Fitbit Zip™ is a valid measure of free-living physical activity in healthy adults which offers the advantage of being able to wirelessly upload pedometer data to a website or mobile application. However, caution should be exercised when synthesising with accelerometer data in future research.

Competing interests

The authors declare that they have no competing interests. The manufacturers of the Fitbit Zip™ device had no role in the funding, design or conduct of the study, or analysis of the results. The research team have no existing or ongoing relationship with the manufacturer.

Authors' contributions

CMcB and LH conducted the field work for this study as part of a BSc undergraduate research project, Queen's University Belfast. MT & RH conceived the idea of the study. MT conducted the analysis of the data and prepared the manuscript. All authors approved the final manuscript.

Acknowledgement

MAT is co-funded by the Centre of Excellence for Public Health (Northern Ireland), a UKCRC Public Health Research Centre of Excellence. The UKCRC Public Health Research Centres of Excellence are funded by British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, Research and Development Office for the Northern Ireland Health and Social Services and the Wellcome Trust, under the auspices of the UK Clinical Research Collaboration. RH is funded by the National Prevention Research Initiative. The Funding Partners are (in alphabetical order): Alzheimer's Research Trust; Alzheimer's Society; Biotechnology and Biological Sciences Research Council; British Heart Foundation; Cancer Research UK; Chief Scientist Office, Scottish Government Health Directorate; Department of Health; Diabetes UK; Economic and Social Research Council; Engineering and Physical Sciences Research Council; Health and Social Care Research and Development Division of the Public Health Agency (HSC R&D Division); Medical Research Council.

RFH is funded by a project grant from the National Prevention Research Initiative. The Funding Partners are (in alphabetical order): Alzheimer's Research Trust; Alzheimer's Society; Biotechnology and Biological Sciences Research Council; British Heart Foundation; Cancer Research UK; Chief Scientist Office, Scottish Government Health Directorate; Department of Health; Diabetes UK; Economic and Social Research Council; Engineering and Physical Sciences Research Council; Health and Social Care Research and Development Division of the Public Health Agency (HSC R&D Division); Medical Research Council; The Stroke Association; Welsh Assembly Government and World Cancer Research Fund.

Received: 19 June 2014 Accepted: 18 November 2014
 Published: 23 December 2014

References

1. Heath GW, Parra DC, Sarmiento OL, Andersen LB, Owen N, Goenka S, Montes F, Brownson RC, Lancet Physical Activity Series Working Group: **Evidence-based intervention in physical activity: lessons from around the world.** *Lancet* 2012, **380**(9838):272–281.
2. Kolt GS, Rosenkranz RR, Savage TN, Maeder AJ, Vandelanotte C, Duncan MJ, Caperchione CM, Tague R, Hooker C, Mummery WK: **WALK 2.0 - using Web 2.0 applications to promote health-related physical activity: a randomised controlled trial protocol.** *BMC Public Health* 2013, **13**:436.
3. Davies CA, Spence JC, Vandelanotte C, Caperchione CM, Mummery WK: **Meta-analysis of internet-delivered interventions to increase physical activity levels.** *Int J Behav Nutr Phys Act* 2012, **9**:52.
4. Sasaki JE, Hickey A, Mavilia M, Tedesco J, John D, Kozey Keadle S, Freedson PS: **Validation of the Fitbit Wireless Activity Tracker® for Prediction of Energy Expenditure.** *J Phys Act Health* 2014, [epub ahead of print].
5. Dannecker KL, Sazonova NA, Melanson EL, Sazonov ES, Browning RC: **A comparison of energy expenditure estimation of several physical activity monitors.** *Med Sci Sports Exerc* 2013, **45**(11):2105–2112.
6. Takacs J, Pollock CL, Guenther JR, Bahar M, Napier C, Hunt MA: **Validation of the Fitbit One activity monitor device during treadmill walking.** *J Sci Med Sport* 2014, **17**(5):496–500.
7. Adam Noah J, Spierer DK, Gu J, Bronner S: **Comparison of steps and energy expenditure assessment in adults of Fitbit Tracker and Ultra to the Actical and indirect calorimetry.** *J Med Eng Technol* 2013, **37**(7):456–462.
8. Dowd KP, Harrington DM, Donnelly AE: **Criterion and concurrent validity of the activPAL™ professional physical activity monitor in adolescent females.** *PLoS One* 2012, **7**(10):e47633.
9. De Cocker K, Cardon G, De Bourdeaudhuij I: **Validity of the inexpensive Stepping Meter in counting steps in free living conditions: a pilot study.** *Br J Sports Med* 2006, **40**(8):714–716.
10. Hale LA, Pal J, Becker I: **Measuring free-living physical activity in adults with and without neurologic dysfunction with a triaxial accelerometer.** *Arch Phys Med Rehabil* 2008, **89**(9):1765–1771.
11. Bassett DR, Mahar MT, Rowe DA, Morrow JR: **Walking and measurement.** *Med Sci Sports Exerc* 2008, **40**(7 Suppl):S529–S536.
12. Freedson PS, Melanson E, Sirard J: **Calibration of the Computer Science and Applications, Inc. accelerometer.** *Med Sci Sports Exerc* 1998, **30**(5):777–781.
13. Welk GJ, McClain J, Ainsworth BE: **Protocols for evaluating equivalency of accelerometry-based activity monitors.** *Med Sci Sports Exerc* 2012, **44**(1 Suppl 1):S39–S49.
14. Bland JM, Altman DG: **Measuring agreement in method comparison studies.** *Stat Methods Med Res* 1999, **8**(2):135–160.
15. Tudor-Locke C, Ainsworth BE, Thompson RW, Matthews CE: **Comparison of pedometer and accelerometer measures of free-living physical activity.** *Med Sci Sports Exerc* 2002, **34**(12):2045–2051.
16. Dondzila CJ, Swartz AM, Miller NE, Lenz EK, Strath SJ: **Accuracy of uploadable pedometers in laboratory, overground, and free-living conditions in young and older adults.** *Int J Behav Nutr Phys Act* 2012, **9**:143.
17. Fitbit Inc: **How do I wear my Zip?** [http://help.fitbit.com/articles/en_US/Help_article/How-do-I-wear-my-Zip/]. Accessed 30 Apr 2014.

doi:10.1186/1756-0500-7-952

Cite this article as: Tully et al.: The validation of Fitbit Zip™ physical activity monitor as a measure of free-living physical activity. *BMC Research Notes* 2014 **7**:952.

Submit your next manuscript to BioMed Central and take full advantage of:

- Convenient online submission
- Thorough peer review
- No space constraints or color figure charges
- Immediate publication on acceptance
- Inclusion in PubMed, CAS, Scopus and Google Scholar
- Research which is freely available for redistribution

Submit your manuscript at
www.biomedcentral.com/submit

