Validity of the Fitbit Ace and Moki devices for assessing steps during different walking conditions in young adolescents

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Original Article

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Running title: Validity of Fitbit Ace and Moki Devices

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Abstract

Purpose*:* Using wearable monitoring devices is increasingly ubiquitous, including amongst young people. However, there is limited evidence on the validity of devices which are aimed at children and adolescents. The purpose of this study was to evaluate the validity of Fitbit Ace and Moki monitors in healthy young people.

Methods*:* This cross-sectional study included 17 young adolescents (ages 11–13 years) ambulating between three different walking conditions (incidental (~6 minutes), controlled and treadmill (each 3 minutes), whilst wearing wrist-worn devices (Fitbit Ace, Moki) on each wrist (left and right, respectively). Data from the devices were compared with observer counts (criterion). Bland-Altman plots and mean absolute percent errors (MAPEs) were computed.

Results*:* Analyses identified that the Fitbit Ace showed higher levels of bias across conditions compared to the Moki device: (mean difference ± SD Fitbit Ace, 30.0±38.0, 3.0±13.0, 13.0±23.0 steps; Moki, 1.0±19.0, 4.0±16.0, 6.0±14.0 steps, incidental, controlled, and treadmill, respectively). MAPEs ranged from 3.1-9.5% for the Fitbit Ace and 3.0-4.0% for the Moki device.

Conclusion: The Fitbit Ace and Moki devices might not provide acceptable validity under all walking conditions, but the Moki provides more accurate estimates of incidental walking and might therefore be a good choice for free-living research or school-based interventions.

Introduction

Leading a physically active lifestyle leads to a number of physical and mental health benefits, and prevents a range of non-communicable diseases in both childhood and adulthood (27). Not all children and adolescents however achieve physical activity (PA) guidelines, and physical inactivity of youth and adolescents is a global challenge (1). Interventions to increase PA in children and adolescents are therefore a public health priority.

Walking is one of the oldest and simplest forms of physical activity (31), and is often referred to as ‘the activity closest to perfection’ (26). Encouraging people to walk is significant to public health because it represents an accessible, affordable, and familiar form of PA (17). There is growing evidence that walking and pedometer based interventions can be effective for children and adolescents to increase PA, especially in the school environment, and thus the encouragement of walking may lead to an increase in PA in children and adolescents (8, 9, 19, 20).

The opportunity to direct PA interventions to walking behaviour has more recently been enhanced via the rapid development and access to consumer-based activity monitors. Whilst some monitors purport to measure a range of behaviours, the most common function is step counting. Often referred to as ‘wearables’ or ‘wearable activity trackers’, these devices can be used by consumers to track personal PA behaviour, and have been used in clinical studies with adults and children (2). Devices, such as the Fitbit Zip for example, are small, long-lasting and convenient for consumers and researchers alike, and the data is typically easy to transfer to a computer for processing (25).

As people are paying more attention to self-quantification of health parameters and these devices are being adopted for research purposes, both as intervention tools and for the assessment of behaviour, there is an inherent need for confirming the accuracy of commercially available activity trackers (22).

Among dozens of brands in wearable activity monitors available on the market, Fitbit is among the most commonly purchased options (10, 11). The features of Fitbit activity devices, including their validity and reliability, have been investigated in a number of empirical studies with adults (11, 18). Findings generally suggest that with adults Fitbit devices demonstrate an overall tendency to underestimate steps during controlled testing conditions but may provide accurate step counts (within ±3%) approximately 50% of the time (11).

There is comparatively less evidence regarding the validity of these devices when worn by children and adolescents. So far there have been studies assessing, for example, the validity of Fitbit Flex (7), Fitbit One (15), Fitbit Zip (25, 28) and Fitbit Charge (30). The research findings have been mixed, generally suggesting that Fitbits may overestimate (15, 25, 30) rather than underestimate (28) step counts. Unlike previously mentioned devices, the recent Fitbit Ace (and now the Fitbit Ace 2 and 3) has been marketed for children and adolescents but, to the best of our knowledge, its validity has not yet been explored.

Whilst Fitbit has had the market share of wearables (11), other devices are available, as are devices designed specifically for use in school based interventions and surveillance, and those that are arguably more affordable (the Fitbit Ace 3 is currently on the market in the UK for £69.99 (12)). Moki is a new activity-tracking wristband monitor and software application, aimed at providing a safe, simple and fun way for schools to support an active curriculum for their students, and currently priced at £132+VAT for 4 bands and a reader (24). The monitoring device can send users' step data to a computer and generate walking reports and analysis using software installed on a PC. Moki is being used in more than 250 Schools and with 7000 pupils in the UK, Europe and Canada (Moki, personal communication, Sept 2020). To the best of our knowledge, there has been no prior empirical research exploring the validity of this consumer-based activity monitor.

One of the challenges of assessing validity of wearable devices is ensuring ecological validity (5, 6). Assessing validity of devices during controlled treadmill walking is a commonly adopted approach (14, 23) , primarily as the treadmill is able to regulate walking speed. However, treadmill walking overestimates the energy cost of walking over ground in adolescents (21), and is a poor proxy for incidental ambulatory activity (e.g., unstructured play and stair climbing). Device validation in trials that replicate free-living conditions is paramount (5).

Therefore, the aim of the current study was to assess the validity of the Fitbit Ace and Moki devices in a population of healthy young adolescents under three different walking conditions.

Methods and Procedures

Study design

This study assessed the validity of Fitbit Ace (Fitbit Inc, San Francisco, CA, USA) and Moki (Moki Technology Ltd, UK) consumer-based PA monitors for young people, under the following three walking conditions: incidental walking, controlled walking, and treadmill walking. All testing was completed in a single high school in the Summer of 2019.

Participants

Participants were recruited from a high school located in Edinburgh, Scotland, using a purposive sampling method. Participants were eligible to be included if they were: (a) 11–13 years old; (b) no chronic diseases; (c) able to walk without an assistive tool, and (d) able to undertake moderate and vigorous PA. Eighteen students volunteered to take part in the study, of which one participant decided not to complete the data collection process.

Approval for the study was granted by the institutional research ethics committee and the local School authority. Participation was dependent upon informed consent being granted by participants and their parents.

Materials

Fitbit Ace (version 1) is an accelerometer, designed for youth ages six and above, that estimates step count, distance travelled, active minutes and sleep time. The weight of the wrist-worn accelerometer is 8gs. Steps are measured via microelectromechanical tri-axial accelerometer and proprietary algorithms. The data from the device are wirelessly uploaded to the software via Bluetooth.

Moki is an activity-tracking wristband and software application designed with the aim of enabling schools or groups to support an active curriculum for their students or members. It consists of two parts – a band and a reader. The Moki band comprises an accelerometer and battery housed inside a moulded wristband. The contactless (near-field communication) technology contained in the device means that the activity data is transferred to the app by tapping it on the Moki Reader. The Moki Reader (60 x 11 x 110mm) is then connected to a Windows desktop or laptop via a USB cable to allow transfer of data from the Moki bands to the Moki application.

Procedure

Pilot. To optimise validity of the criterion outcome (observer counts), pilot trials were conducted to familiarise the researchers with the counting procedure. A volunteer was recruited to walk a defined route, during which one researcher followed the volunteer and counted the number of steps taken. The walking (legs and feet only) was also video-recorded (iPhone 8 and a tripod). A second researcher counted the steps from the video recording. The results from the two researchers were compared and the tests were extensively practised until the difference was lower than two steps. Both devices (Fitbit Ace, Moki) were tested to assess time delays between walking activity and steps registering. A 60-second delay was concluded to be necessary to confirm accurate registration of steps taken.

Experimental Conditions. Participants attended the testing session in pairs. Each participant completed all three conditions sequentially before the other participant began their trial. The Fitbit Ace was always fitted to participants left wrist, and the Moki to participants rigtht wrist.

Condition 1: Incidental walking.

The participants were first shown the walking route, which included a corridor and two flights of stairs, and took approximately 4 minutes to complete including a short seated period. Once a participant was ready to start the test, the Fitbit Ace was attached to their left wrist and the Moki to their right wrist. The participant was then required to stand still for one minute to collect and record the current number of steps displayed by each band. Next, the participant was asked to follow the walking route. Two researchers followed the participant moving at a normal walking speed and counted their steps, with one researcher holding a stopwatch to record the time. The participant walked down the corridor and up two floors, then sat still for a period of at least 60 seconds before returning. After returning to the start, the participant was asked to stand still for one minute, with their arms naturally dropping to the sides of their body. The researchers then collected the step-count data displayed by the two bands and recorded the counted steps. A mean of the steps counted by the two researchers was considered the criterion.

Condition 2: 3 minute controlled walking

Each participant was led to a square walking path, which was arranged in an empty dance room, with a level floor and no obstacles. The devices were fitted following the same protocol as in Condition 1. On the researcher's signal, the participant was asked to walk around the square course for three minutes. One researcher counted the steps, while the other researcher controlled the camera and tripod to record the walking. The camera was set up to only record the participants' legs and feet from below the knees. At three minutes, the participant was asked to stop walking at once and stand for one minute so the number of steps counted by each band could be recorded. A mean of the steps counted in real time and by the video recording was considered the criterion.

Condition 3: 3 minute treadmill walking.

Following treadmill familiarisation, the participant was asked to straddle the moving treadmill while the devices were prepared as they were in the previous conditions. The participant was then asked to walk on the treadmill at a speed of 1.2 km/h for three minutes. Their steps were also recorded by camera, as above. At three minutes, the participant immediately straddled the treadmill and stood still for one minute, and the step-count data were recorded. As before, a mean of the observer counts and the video recording was considered the criterion.

Data analysis

Analyses were undertaken in Excel (Version 16.37). Descriptive statistics were presented as means ± standard deviations. The Bland-Altman approach was used to investigate the agreement between measurements (device and criterion; 4, 13). Mean percent errors (MPEs) and mean absolute percent errors (MAPEs) were calculated for each condition in order to enable comparison between the devices and explore overall measurement error. Smaller MAPEs were interpreted as representing better accuracy, with a value of less than 3% as the acceptable level of accuracy (3, 16).

Results

The final sample included 17 young adolescents (59% girls; 12.97±0.28 years of age). Table 1 presents the descriptive statistics (mean ± SD), levels of agreement and MAPE for each device and walking condition.

The MAPE values in Table 1 demonstrate the error rates for Fitbit Ace and Moki devices across the three walking conditions. Neither device under or overcounted participant's steps by more than 10%. The Fitbit device consistently undercounted across conditions. The greatest difference between criterion and the Fitbit Ace and Moki devices was in the incidental walking condition (9.5% and 4.0%, respectively), both of which were greater than the 3% level of acceptable accuracy. The Fitbit Ace controlled condition and the Moki treadmill condition were both 3.1 and 3.0% respectively.

[Table 1 here – see page 19]

Bland-Altman plots comparing the criterion with Fitbit Ace and Moki are provided in Figure 1. Analyses demonstrated the incidental and treadmill walking conditions of the Fitbit Ace showed the greatest bias (30.0±38 and 13.0±23.0, respectively). The Fitbit Ace had the widest 95% limits of agreement (-104.1, 44.1, incidental walking).

[Insert Figure 1 here]

Discussion

The aim of the current study was to assess the validity of the Fitbit Ace and Moki devices in young people. This is the first study to examine the validity of these specific consumer-based activity devices in this population and under different walking conditions (incidental, controlled and treadmill walking). Our results indicate that both devices may provide a valid meaure of step counts in young adolescents aged 11-13 years in some conditions. Findings also suggest there may be a tendency for the FitBit Ace to undercount during specific PA conditions. In particuar this may be the case with incidental walking conditions and treadmill walking (see Table 1 & Figure 1).

Our findings indicated that the Fitbit Ace had greater bias and wider limits of agreement compared to Moki, whilst the majority of all data fell within the 95% limits of agreement, which is consistent with previous studies in children (28). As this is the first study to evaluate the vailidty of the Moki device it is not yet possible to compare current findings with previous studies. It is interesting to note, however, that the Moki device may provide a more valid estimate of step count under certain types of PA (i.e., incidental and treadmill walking) compared to the Fitbit Ace. In the main, the Moki device appears to undercount less than the Fitbit Ace, and have very limited bias, although MAPE was marginally above 3% for both incidental and controlled walking. In practical terms, if a young adolescent took 12,000 steps in a day (29) the error may be in the region of 1140 steps for the Fitbit, rather than 480 steps for the Moki. Thus the Moki device may be a preferable choice for intervention and research studies, as well as school use. Difference in functionality and cost may also contribute to the choice of device. For example, at present the Moki does not provide immediate step count feedback on the device in the way that the Fitbit does, but needs to be used with the classroom reader to provide step counts. The Moki is however considerably cheaper per unit.

We found that the Fitbit Ace consistently undercounted steps across conditions. This trend of undercounting is consistent with Sharp et al. (28), who evaluated the validity of the Fitbit Zip in a sample of preschool children during a 3-min walking task. Further, this is consistent with the evidence from Fitbit studies with adults (11). In constrast, most previous studies with children have shown Fitbit devices may overestimate step counts in this age group (15, 25, 30), regardless of whether they are hip (25) or wrist worn (30). Mooses et al. (25) reported the Fitbit Zip (worn by 147 children for 5 school days, aged 9-10 years) had a tendency to overestimate step counts throughout the day, particularly during physical education class.

To our knowledge, this is the first study with children or adolescents to validate the devices under different walking states designed to simulate the walking patterns that this population may display in everyday life. For example, the incidental walking condition simulated daily living activities such as how children and adolescents walk around school, while the controlled and treadmill conditions aimed to reflect daily exercise as well as laboratory conditions. Whilst device validation trials during free-living are also needed with children and adolescents (5), this type of protocol may make it challenging to delineate how a device might perform during specific types of walking activity. For example, current findings suggest the device may perform differently under the different conditions, and neither device achieved 3% MAPE during incidental walking. To help address the associated challenges of measuring ecological validity, further research with these walking conditions and in free-living conditions is needed for these devices that have been purposely designed for young people.

It is unclear why the Fitbit Ace under incidental walking condition showed the greatest bias, error and limits of agreement in the current study. Extraneous factors such that effected arm movement during normal ambulation may have impacted the step-count registered. In contrast, the Moki device appears to have been less effected in this condition compared to the Fitbit. Future replication studies are warranted to better understand the present results.

This study had a number of limitations. The study included a small sample of participants (n=17) from one urban school thus replication is needed to generalise the findings to other samples. The Fitbit Ace was always fitted to participants left wrist, and the Moki to participants rigtht wrist, with no adjustments for hand dominance despite this being an option in the Fitbit setup. Whilst it is unlikely that during normal ambulation this will have effected validity, future studies should counterbalance the placement of the devices on each wrist to minimize potential confounders associated with dominant versus non-dominant wrists. Finally, the current study examined the validity of the Fitbit Ace, which has now been superceded by more recent models. The extent to which the validity of the first generation Fitbit Ace represents the validity of subsequent models is not known.

Conclusion

Using wearable monitoring devices is increasingly ubiquitous but there is mixed evidence on the validity of these devices and limited evidence for those designed specifically for young people. This is the first study to validate the use of the Fitbit Ace and Moki devices in young adolescents aged 11-13 years. The Fitbit Ace and Moki devices might not provide acceptable validity under all walking conditions, but the Moki provides more accurate estimates of incidental walking and might therefore be a good choice for free-living research or school-based interventions.

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Table 1. Mean difference, levels of agreement, and absolute percentage errors of Fitbit Ace & Moki-estimated step counts relative to observed criterion counts in three different walking conditions.

Device	Condition	Mean SC Criterion (SD)	Mean SC Device (SD)	Difference (SD)	Lower LoA	Upper LoA	MAPE % (SE)	MPE % (SE)
Fitbit Ace	Incidental	342 (51)	312 (64)	-30 (38)	-104.1	44.1	9.5 (2.7)	-9.0 (2.8)
	Controlled	337 (28)	334 (22)	-3 (13)	-27.9	21.3	3.1 (0.6)	-0.8 (0.95)
	Treadmill	324 (23)	312 (31)	-13 (23)	-57.3	32.3	5.3 (1.4)	-3.8 (1.7)
Moki	Incidental	342 (51)	342 (52)	-1 (19)	-37.3	36.2	4.0 (1.0)	-0.1 (1.4)
	Controlled	337 (28)	341 (21)	4 (16)	-27.2	35.9	3.9 (0.8)	1.6 (1.2)
	Treadmill	324 (23)	330 (26)	6 (14)	-20.6	33.4	3.0 (0.8)	2.0 (1.0)

Note: SC - step counts, SD - standard deviation, MAPE – mean absolute percentage error, MPE – mean percentage error, LoA – limits of agreement. SE -standard error of the mean.

Figure legend –

Figure 1. Bland-Altman plots representing the comparisons between the criterion observer count and Fitbit Ace or Moki device across (A) Incidental walking, (B) Controlled walking, and (C) Treadmill walking conditions. Solid lines indicate the mean difference between observer count and device, and dashed lines indicate limits of agreement (±1.96 SD).