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Conventional vs smartphone app-based pedometers for measuring steps in healthy adults: A systematic review

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Abstract
Both conventional and smartphone app-based pedometers are said to be valid and reliable for measuring footsteps, but there is still very little evaluation of their use. We aimed to assess the accuracy of conventional and smartphone app-based pedometers for measuring steps count among healthy adults. The search for studies was carried out on four databases: PubMed; Cochrane Library; Science Direct; and Pro Quest, during June 2020, with a combination of keywords based on Boolean logic-commands, including: pedometers; population (healthy adults); and context (footsteps). Total of 1768 articles were identified and selected based on population, intervention, comparison and outcome (PICO). After eligibility assessment, there are 6 articles were met the inclusion criteria and were included for qualitative synthesis. The results show that the accuracy of conventional pedometers and smartphone app-based pedometers depends on the type and brand of each device, and how it is used (running or walking at different speed). Pedometers generally also measure other physical activities such as distance traveled or calories burned, so that the accuracy of the device is not limited to footsteps. Furthermore, systematic reviews and meta-analyzes with broader outcomes such as overall physical activity are recommended.

Keywords: steps, pedometer, smartphone

Introduction

Inadequate physical activity is a major risk factor for non-communicable diseases, as well as a leading cause of death worldwide. This made WHO member countries agree to reduce the number of inadequate physical activity by 10% by 2025 [1].

One of the recommended and easiest physical activities to follow for healthy adults is to take 10,000 steps per day to stay healthy and fit. Normative data show that healthy adults typically take between 4,000 and 18,000 steps per day, and 10,000 steps per day is a baseline recommendation for this population [2, 3].

The incessant promotion to increase physical activity has led to the emergence of many tools to track or measure individuals physical activity in the consumer market over the past five to ten years. Activity trackers are small, user-friendly devices that measure the number of steps taken and/or the amount of time spent doing physical activity at a certain intensity [2]. There are many types of activity trackers, but a special device that measures steps is called a pedometer [4].

Using activity tracking devices can increase an individual's awareness of his or her own physical activity behavior [2], but these tools have obstacles in their use, such as the complexity of the device that allows users to be confused, as well as the additional costs to buy the device [5]. The solution to this barrier is an activity tracker based on a smartphone application. Smartphones are growing at a faster rate than activity trackers, and are more attractive to the general public [5].

Both conventional and smartphone app-based pedometers are said to be valid and reliable measuring tools [5], but there is still very little evaluation of their use [6], so further research is needed to determine effectiveness of both tracking devices

Materials and Methods

This review follows Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines [7]. The search is delimited to articles published in English.

Study selection, inclusion and exclusion criteria

Study inclusion and exclusion criteria were developed in accordance with the PICO framework. The inclusion criteria in this review were:

1. Original articles published in peer reviewed journals.
2. English-language articles

Selection of the studies is based on Population, Intervention, Comparison, and Outcome (PICO) standard

1. P (population): Healthy adults (with no condition knowing)
2. I (intervention): The studies must Included conventional pedometer and smartphone app-based pedometer as its intervention.
3. C (comparison): The studies must have measurement criteria or gold standard.
4. O (Output): The studies need to report effectivity or accuracy of pedometers.

Meanwhile, the exclusion criteria included: 1) youth and elderly participants; 2) known to have certain diseases.

Search Strategy

The search was done by examining research articles from five electronic databases (Pub Med, Cochrane Library, Science Direct, and Pro Quest). A combination of keywords related to the pedometers, population of interest (healthy adults) and context (steps) were utilized under a Boolean logic-commands. The search strategy is outlined in the Table 1.

Table 1: Search strategies used in current review

Search Strategy Items	Details
Used keywords	Combination of two or three from the following: ▪ Pedometers OR Smartphone OR Application ▪ Steps OR Physical Acticity ▪ Adults
Searched databases	PubMed, Cochrane Library, ScienceDirect, ProQuest
Time filter	None
Language filter	English only
Document type filter	Articles in peer-reviewed journals
Inclusion criteria	Original article complying to the established PICO
Exclusion criteria	Reviews, Dissertation, Technical papers.

Data Extraction and Analysis

The resulting selected studies are summarized and describe the author; the location of the study; research methodology (objectives, design, and activities); and study inclusion criteria (population and number of samples, type of pedometer, measurement reference, and main outcome). Because of the large variation in study methods and measurements, a meta-analysis of methodological features and contextual factors associated with the frequency of data extraction methods was not possible. We therefore present a narrative synthesis of our findings.

Risk of Bias Assessment

We did not thoroughly assess risk of bias, including reporting bias, for these reports because the study designs did not match domains evaluated in commonly used instruments such as the Cochrane Risk of Bias tool [8], QUADAS-2 instrument used for systematic reviews of randomized trials and diagnostic test accuracy studies [9], or ROBINS-I used for non-Randomized Studies of Intervention [10].

Results & Discussion

Through the search of the four databases, 1768 potential articles were identified for this systematic review. Of this total, 700 duplicates were removed. The remaining 1068 articles' were screened by their titles and abstracts. 991 articles were removed because they were not in accord to the inclusion criteria. The remaining 77 potential studies needed further assessment. Of the 77 articles, 71 were removed because of wrong population (n=5) and wrong intervention (n=66). Consequently, 6 articles could be included for the qualitative synthesis. None of the articles qualified for a quantitative synthesis (meta-analysis). The search result is depicted in Figure 1. The 6 articles included in the study were presented in numerical order in table 1, and cited according to their respective numbers.

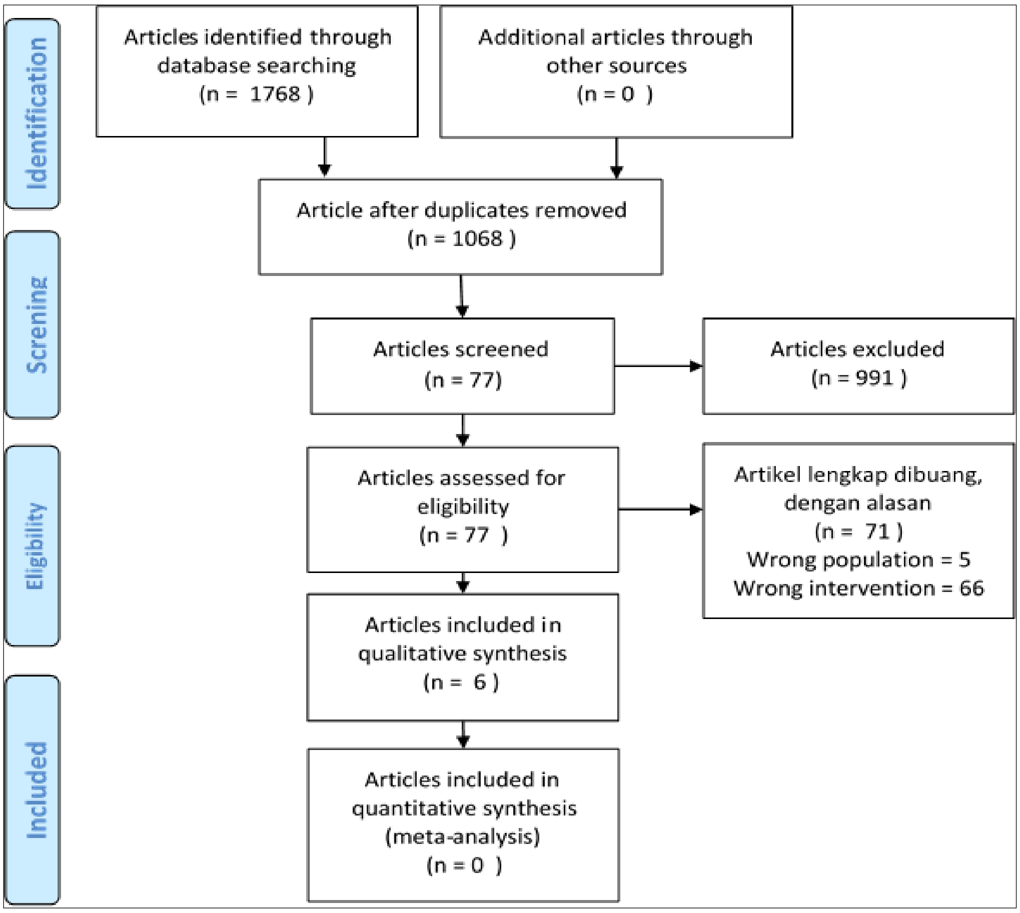

Fig 1: Article selection process. Based on Moher *et al.* (2009) [7]

Table 1: Characteristics of studies included in the systematic review (sorted by last name and year of publication)

No	Author (year)	Country	Research methodology			Inclusion criteria				
			Purposes	Design	Activity	Population (n)	Intervention (Pedometer): Conventional	Intervention (Pedometer): Smartphone app	Comparation (measurement reference)	Main outcome
1	Balmain *et al.* (2019) [11]	Australia	Measure the accuracy of the devices	Not mentioned	3 minutes walking at the speed of: 1. 1,3 km/h 2. 2,2 km/h 3. 3,0 km/h 4. 3,8 km/h 5. 4,7 km/h	Healthy adults (36)	Omron HJ-720ITC	Smartphone with pedometer app	Manual counting with tally counter	Smartphone apps show a lower percentage of errors when walking at 1.3 km/h. At a speed of 2.2 km/h, both the smartphone and conventional pedometers show the same different results compared to the manual count. At 3.0 km/h, the smartphone exceeds manual counting, while conventional pedometer is the same as manual counting. Both the smartphone and conventional pedometer are the same as manual counting at 3.8 and 4.7 km/h.
2	Battenberg *et al.* (2017) [12]	USA	Measure the accuracy of the devices	Not mentioned	1. 400 m walking 2. 400 m running 3. 10 m walking 4. 10 steps ascend and descend stairs	Healthy adults (30)	1. FitBit One™ 2. Omron HJ-321 3. Sportline 340 Strider 4. FitBit Force™ 5. Nike+ Fuelband SE 6. StepWatch™ Activity Monitor	1. Argus Motion and Fitness Tracker by Azumio (iPhone 5) 2. Runtastic Pedometer Step Counter and Walking Tracker by Runtastic in (iPhone 5) 3. Noom Walk: Pedometer (Samsung Galaxy S IV) 4. Runtastic Pedometer Step Counter and Walking Tracker by Runtastic (Samsung Galaxy S IV)	Manual counting with tally counter	The accuracy of FitBit One™ and Omron HJ-321 is > 90% for all activities, while smartphone application is <90% for all activities.
3	Höchsmann *et al.* (2018) [13]	Switzerland	Measure the accuracy of the devices	Not mentioned	Walking on treadmill	Healthy adults (20)	1. Garmin Vivofit 2 2. ActiGraph wGTX+	1. iPhone SE 2. Samsung Galaxy S6 Edge 3. Moves 4. Runtastic 5. Accupedo 6. Pacer	Not mentioned	iPhone SE and Garmin Vivofit 2 are accurate tools for counting footsteps.
4	Kooiman *et al.* (2015) [2]	Netherlands	Measure the validity and reliability of the devices	Not mentioned	30 minutes treadmill	Healthy adults (33)	1. Lumoback™ 2. Fitbit Flex™ 3. Jawbone UP™ 4. Nike+ Fuelband SE™ 5. Misfit Shine™ 6. Withings Pulse™ 7. Fitbit Zip™ 8. Omron Walking Style III™ (type HJ-203) 9. Yamax Digiwalker SW-20™	Moves^{R} (iPhone 4S)	ActivPAL	The results of the running test on the treadmill show that 5 devices (Lumoback, Jawbone Up, Misfit Shine, Withings Pulse, and Fitbit Zip) obtained MAPE values below 1% error deviation, and are considered accurate. 2 tools (Digiwalker and Omron) obtained MAPE values slightly above the 1% (1.2% and 2.5%, respectively). The Moves app received a score of 9.6%, but it is still smaller than Nike + Fuelband which scored 18%.
5	Orr *et al.* (2015) [14]	Canada	Measure the validity of the devices	Not mentioned	1. 20-steps test 2. 40-step stair climbing 3. Treadmill walking and running 4. Driving 5. 3-day free-living	Healthy adults (11 for laboratorium; 18 for free-living	Yamax Digi-Walker SW-200	1. Accupedo 2. Moves 3. Runtastic	Manual based on observation and Yamax SW-200 pedometer.	The analysis results showed an unacceptable error for all applications compared to the pedometer.
6	Simonsen *et al.* (2020) [15]	Denmark	Measure the validity of the devices	Not mentioned	1. Treadmill 2. Field	Healthy adults (30)	Dunlop Sport	Samsung Galaxy S9 (Versi 9) dengan Aplikasi Samsung Health (Versi 6.5.0.039)	Manual counting	Smartphones are more accurate on both treadmill and field tests. All devices performed poorly at a speed of 2 km/h on the treadmill. Only the smartphone performed well at a speed of 3 km/h. High validity for field tests compared to treadmill tests at a speed of 4 km/h for all devices.

From 6 studies: 2 studies aim to measure the accuracy of the tool [11, 13]; 2 studies measure the validity of the tool [14, 15]; and only 1 study measured the validity and reliability of the tool [2]. All studies did not clearly state the research design used. While the activities used to measure the accuracy of the devices are entirely different: Kooiman *et al*. (2015) [2] used time (30 minutes treadmill); Battenberg *et al*. (2017) [12] used the distance (400m walking, 400m running, 10m walking, and 10 steps ascend and descend stairs); Balmain *et al*. (2019) [11] used pace in a specific time (walking 3 minutes at different speeds); Simonsen *et al*. (2020) [15] compared treadmills and fields; Orr *et al*. (2015) [14] counting steps in different activities (walking, climbing stairs, walking and running on a treadmill, driving, and 3 days free-living); and Höchsmann *et al*. (2018) [13] walking on a treadmill.

The gold standard used as a reference for measuring pedometer accuracy varies: 3 studies used manual counting with a tally counter; 1 study only used a conventional pedometer because it was considered more accurate; 1 study using manual counting and a conventional pedometer; and 1 study did not mention measurement references.

The most widely used conventional pedometer for research is Omron [2, 11, 12], followed by Fitbit, Nike, and Yamax with 2 studies each. While the smartphone application-based pedometer that is most widely used in research is the Moves and Runtastic application with 3 studies [2, 13, 14], followed by Accupedo with 2 studies [13, 14]. Based on the type of smartphone, the most widely used types are the iPhone and Samsung.

Höchsmann *et al*. (2018) [13] stated that both smartphones and conventional pedometers are equally accurate for measuring footsteps. However, Balmain *et al*. (2019) [11] stated that the accuracy depends on the speed of walking. The smartphone app shows a lower percentage of errors when walking 1.3 km/h. At a speed of 2.2 km/h both smartphones and conventional pedometers show different results compared to manual calculations. At a speed of 3.0 km/h the pedometer is more accurate than a smartphone. At speeds of 3.8 and 4.7 km / h, both smartphones and conventional pedometers are equally accurate.

Balmain's findings are in line with the findings of Simonsen *et al*. (2020) [15]. Simonsen said that both conventional pedometers and smartphone applications showed poor performance at 2 km/h, but performance improved at 4 km/h. Overall, Simonsen added that smartphone apps are more accurate than conventional pedometers.

The 3 other studies in this review show the opposite results, Battenberg *et al*. (2017) [12] show that the accuracy of a smartphone app-based pedometer is only > 90%, while the accuracy of conventional pedometers is more than 90%. Research by Orr *et al*. (2015) [14] shows that both smartphone applications show a large percentage of errors (unacceptable), compared to conventional pedometers, while Kooiman *et al*. (2015) [2] suggest that conventional pedometers are more accurate than smartphone applications.

The results show that there are very few studies that specifically measure the effectiveness of pedometers for measuring footsteps. Most studies use physical activity as its primary outcome. As far as we are concerned, this is the first systematic review to synthesize the effectiveness of conventional pedometers and smartphone app-based pedometers, and the lack of data is a limitation of this review. A similar review was conducted by Evenson *et al*. (2015) [4], but the aim was to summarize the validity and reliability of conventional pedometer activity tracking devices (Fitbit and Jawbone). Evenson mentioned similar limitations in their review, including the variety of methods and results reported by the study. So it can be concluded that there is still no agreement (consensus) between researchers for the methodology of measuring the accuracy/validity of a pedometer, both conventional and smartphone application-based.[4]

Research conducted by Case *et al*., (2015) [6] states that there are many smartphone applications and conventional pedometers that are accurate for recording footsteps, but because footsteps are also often used to assess other measurements of physical activity such as distance or calories, then the accuracy of these devices is not limited to just footsteps [6].

Apart from the various types of pedometers (both conventional and smartphone application-based), and the accuracy of each devices is still unclear, their use still has implications as a strategy to improve public health. Moreover, smartphone technology is still developing, as well as the application.

Conclusions

Both conventional and smartphone app-based pedometer have their respective advantages and disadvantages. The variety and variety of both makes it difficult to conclude which is more accurate. However, based on the results of this review, it can be concluded that the accuracy of conventional pedometers and smartphone app-based pedometers is highly dependent on the type and brand of each device, and how it is used. Each devices generally also measure other physical activities such as distance traveled or calories burned, so that the accuracy of the device is not limited to footsteps. Furthermore, systematic reviews and meta-analyzes with broader outcomes such as overall physical activity are recommended.

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