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# Cadence Feedback With ECE PEDO to Monitor Physical Activity Intensity

## *A Pilot Study*

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**Abstract:** The purpose of this study was to examine the monitoring capabilities of the equipment for clever exercise pedometer (ECE PEDO) that provides audible feedback when the person exceeds the upper and lower limits of the target step numbers per minute and to compare step counts with Yamax SW-200 (YX200) as the criterion pedometer.

A total of 30 adult volunteers (15 males and 15 females) were classified as normal weight (n = 10), overweight (n = 10), and obese (n = 10). After the submaximal exercise test on a treadmill, the moderate intensity for walking was determined by using YX200 pedometer and then the number of steps taken in a minute was measured. Lower and upper limits of steps per minute (cadence) were recorded in ECE PEDO providing audible feedback when the person's walking speed gets out of the limits. Volunteers walked for 30 minutes in the individual step count range by attaching the ECE PEDO and YX200 pedometer on both sides of the waist belt in the same session. Step counts of the volunteers were recorded. Wilcoxon, Spearman correlation, and Bland–Altman analyses were performed to show the relationship and agreement between the results of 2 devices.

Subjects took an average of 3511 ± 426 and 3493 ± 399 steps during 30 minutes with ECE PEDO and criterion pedometer, respectively. About 3500 steps taken by ECE PEDO reflected that this pedometer has capability of identifying steps per minute to meet moderate intensity of physical activity. There was a strong correlation between step counts of both devices ($P < 0.001$, r = 0.96). Correlations across all three BMI categories and both sex remained consistently high ranging from 0.92 to 0.95. There was a high level of agreement between the ECE PEDO and YX200 pedometer in the Bland–Altman analysis.

Although both devices showed a strong similarity in counting steps, the ECE PEDO provides monitoring of intensity such that a person can walk in a specified time with a desired speed.

(*Medicine* 95(10):e3025)

**Abbreviations**: BMI = body mass index, ECE PEDO = equipment for clever exercise pedometer, HR = heart rate, $VO_2$max = maximal oxygen uptake, YX200 = Yamax SW200.

## INTRODUCTION

Regular physical activity and exercise are associated with numerous physical and mental health benefits in men and women. Exercise and physical activity decrease the risk of developing coroner heart diseases, stroke, type 2 diabetes, and some forms of cancer (eg, colon and breast cancers). Exercise and physical activity lower blood pressure; improve lipoprotein profile, C-reactive protein, and other coronary heart disease biomarkers; enhance insulin sensitivity, and play an important role in weight management.[1] Currently, adults are encouraged to accumulate at least 30 minutes of moderate intensity physical activity on most days of the week for gain these health benefits.[1–3]

Guidelines from leading health organizations support physical activity and exercise to improve the health and quality of life.[1,2] All healthy adults need moderate-intensity aerobic physical activity for at least 30 minutes/day for 5 days each week or vigorous-intensity aerobic physical activity for at least 20 minutes/day for 3 days each week, according to updated physical activity guidelines by the American College of Sports Medicine (ACSM) and the American Heart Association (AHA).[1] U.S. Department of Health and Human Services (HHS) guideline recommends minimum 150 minutes of moderate physical activity in a week.[3] The ACSM Position Stand on this topic provides guidance for prescribing individualized exercise to healthy adults of all ages. These recommendations may also be helpful to adults with certain chronic diseases or disabilities, when appropriately evaluated and advised by a health professional.[4]

There are a variety of physical activities and exercises (eg, brisk walking, running, bicycling, jumping rope, dancing, climbing, and swimming) that can help persons expend energy and produce positive health and/or fitness benefits.[1] Walking is perhaps the easiest way for people to meet general physical activity needs. How to reach moderate intensity seems to be a promising intervention when associated with a pedometer using

Editor: Maria Gina-Garriga.
Received: September 18, 2015; revised: February 5, 2016; accepted: February 16, 2016.
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Authors' contribution: FA contributed to the conception and design, analysis and interpretation of data, and drafting of the article, revised it critically for important intellectual content; EG contributed to the conception and design of data. All authors gave approval to the final version to be published.
This study is funded by Pamukkale University Scientific Research Fund with project number: 2013TPF009.
Informed consent: Study protocol complied with the Helsinki declaration and was approved by the Ethics Committee of Pamukkale University. The subjects were informed of the organization and details of the study and signed an informed consent form.
Previous presentation of the research: None (This study was presented at the 25th National Congress of Physical Medicine and Rehabilitation, 2015, Turkey).
Cadence feedback with ECE PEDO to monitor physical activity intensity: A pilot study.
The authors have no funding and conflicts of interest to disclose.

ISSN: 0025-7974
DOI: 10.1097/MD.0000000000003025

steps per minute (cadence). Bouchard et al[5] proposed using pedometer to estimate intensity and they concluded that this strategy needs to be improved to increase the amount of moderate-intensity aerobic exercise or the ability to identify moderate intensity.

In previous studies, the investigators attempted to solve this problem with general recommendations like ''Aerobic steps,'' ''step rate of 100 step $min^{-1}$,'' or ''3000 steps per 30 minute.''[6–8] But, the intensity of exercise is changing according to the aerobic capacity of each individual. So, intensity should be planned individually in physical activity and exercise prescription. We conducted the present study to evaluate the personalized number of steps required to meet current physical activity guidelines. While available pedometers only show the number of steps taken, and duration of physical activity, they are not able to measure intensity of physical activity and exercise. We developed a novel pedometer named as ECE PEDO (equipment for clever exercise) to eliminate this deficiency and monitor the exercise intensity. It provides audible cadence feedback when the person exceeds the upper and lower limits of the steps per minute.

The purposes of this study were to evaluate the capability of ECE PEDO to measure moderate intensity, comparing step counts with Yamax SW200 (YX200) as the criterion pedometer, and to show the importance of the feedback that guarantees to perform recommended intensity with pedometer-based walking cadence.

## METHODS

### Participants

Participants were recruited from healthy hospital staff who volunteered to participate in the study. Inclusion criteria were age older than 20 years and willing to participate. Exclusion criteria included extreme variance in weight (body mass index (BMI) $<20->35\,kg/m^2$), a medical condition for which exercise is contraindicated (atherosclerotic heart disease, musculoskeletal or systemic disease), and presence of psychiatric or neurological disease affecting cognitive functioning and cooperation.

A total of 30 volunteers (15 males and 15 females), age 23 to 55 years, participated in the study. The Ethical Review Board at the Pamukkale University approved the overall study protocol, and written informed consent was obtained from all participants.

### Anthropometric Measures

Height and weight were measured without clothes. Weight was measured with a standard scale (EKS, German). Height was assessed with a wall-mounted stadiometer. BMI was subsequently calculated as weight (kg) divided by height ($m^2$). On the basis of BMI, subjects were classified as normal weight (BMI of 18.5–24.9), overweight (BMI of 25.0–29.9), or obese (BMI of 30.0–34.9). There were 10 subjects in each group consisting of 5 women and 5 men. Participant characteristics by BMI category are shown in Table 1.

### Walking Cadence

Firstly, individuals underwent a submaximal exercise testing for maximal oxygen uptake ($VO_2max$), using incremental protocol on treadmill (Technogym Excite Med, Cesena, Italy). Heart rate (HR) was measured using a Polar monitor. Target HR responses, corresponding to values of 50% to 70% $VO_2max$ were determined for each person.

After resting for 10 minutes, the participants were instructed to walk on the treadmill, while maintaining their target HR. Number of steps taken in a minute was calculated using a criterion pedometer (YX200) when target HR responses were reached.

Based on a pilot of our study method, we determined the steps per minute required to moderate intensity walking for each participant. In this way, the number of steps limits in a minute needed to reach moderate intensity aerobic exercise were determined.

Then we tested the capabilities of the ECE PEDO pedometer for recording and giving audible feedback about upper and lower limits of individual target number of steps per minute. To compare 2 devices, the ECE PEDO and YX200 pedometer were attached on both sides of the waist belt in the same session and volunteers carried out exercise walk for 30 minutes in the determined steps count range. Step counts of the volunteers after 30 minutes of moderate-intensity walking were recorded.

### Pedometers

The accuracy of the YX200 (Tokyo, Japan) is high and it is referred to as the criterion pedometer.[7,9] The SW200 model has a reset button to set the steps to ''0''; it has no memory and no other functions.

The ECE PEDO is a new pedometer which has a screen and control buttons that allows recording individualized steps per minute (cadence walking) to monitor the exercise intensity (Figure 1). ECE PEDO shows session and duration of exercise and the total number of steps. Additionally, it records lower and upper limits of target number of steps per minute and provides feedback when the person gets out of individualized step range. ECE PEDO gives audible feedback in different tones in case of

**TABLE 1.** Characteristics of the Subjects

| | Age (y) | Height (cm) | Weight (kg) | BMI ($kg\,m^{-2}$) |
|---|---|---|---|---|
| All (n = 30) | 38.1 ± 9.4 | 167 ± 7.6 | 76.9 ± 12.3 | 27.6 ± 3.8 |
| Women (n = 15) | 40.1 ± 9.9 | 161.4 ± 5.2 | 71.6 ± 12.3 | 27.6 ± 4.5 |
| Men (n = 15) | 36.1 ± 8.8 | 172.5 ± 5.2 | 82.1 ± 10.2 | 27.5 ± 3.2 |
| Normal weight (n = 10*) | 34.7 ± 11.9 | 168.2 ± 5.7 | 66.5 ± 8.1 | 23.6 ± 1.5 |
| Overweight (n = 10*) | 39.9 ± 8.7 | 167.0 ± 8.2 | 75.5 ± 8.0 | 27.0 ± 1.2 |
| Obese (n = 10*) | 39.8 ± 7.1 | 165.8 ± 9.2 | 88.7 ± 9.1 | 32.2 ± 1.5 |

Data are presented as mean ± SD.
BMI = body mass index.
* Five women and 5 men.


**FIGURE 1.** ECE PEDO: The session settings in the screen shows buttons of switching, recording and deleting to display lower limit, upper limit, number of steps, and walking time.

falling or exceeding the limits. If a person's walking speed falls below the target step range, it gives a warnings beep to speed up. If the person's walking speed is over the target step range, it gives a warning beep to slow down. Steps per minute can be adjusted by a health professional for each individual or the user can enter the general step recommendation like 100 step $min^{-1}$. The pedometer starts the time after the patient reaches the specified number of steps. It is programmed to begin recording steps after 4 consecutive steps have been taken. The device beeps after the start and end of the determined session and a buzzer is used for alerts. This particular pedometer has power button, USB input, sound system, digital sensor connection, a belt clip and has the capability to store data of 20 sessions and how many steps were taken in how many minutes. It is charged via an USB port. Patent and trademark application was made for ECE PEDO.

## Statistical Analysis

The SPSS version 17.0 for Windows (SPSS, Inc., Chicago, IL) was used for statistical analysis. Data from a total of 30 subjects were used in our analysis. Step counts were measured for both sexes and for different categories of BMI status. The relationship and agreement between the results of 2 devices were assessed using Spearman correlation and Bland–Altman analysis. Bland–Altman plots were constructed to show the level of agreement between the pedometers and the criterion measure.

Wilcoxon test was used to compare the mean step scores of 2 pedometers and to determine whether there was a significant difference in the mean scores of 2 pedometers at both sexes and different BMI groups. For all statistical analyses, $\alpha$ level of 0.05 was used to show significant differences, and all values are shown as mean $\pm$ SD.

## RESULTS

Descriptive characteristics are shown in Table 1. Mean values for BMI were 23.6, 27.0, and 32.2 $kg/m^2$ for normal, overweight, and obese participants, respectively.

ECE PEDO recorded an average of 3511 steps whereas criterion pedometer counted average of 3493 steps during 30 minutes. There were no significant differences between pedometers in step counts according to sex and BMI categories ($P > 0.05$). Strong Spearman correlations were found between mean step counts of ECE PEDO and YX200 in both sexes and all BMI groups ($P < 0.001$). Results are shown in Table 2.

Figure 2 shows the Bland–Altman plots for pedometers. For the ECE PEDO, the Bland–Altman plot indicated a mean difference from the $18 \pm 93$ steps in 30 minutes of YX200 and limits of agreement ranging from $-168$ to 206 steps in 30 minutes (Figure 2).

## DISCUSSION

In this study, mean step counts of ECE PEDO during a 30-minute moderate-intensity walking were not significantly different from the criterion pedometer in normal weight, overweight, and obese individuals and in both sexes. To our knowledge, this is the first study examining the utility of a pedometer to monitor physical activity intensity.

The criterion pedometer selected for this study was the YX200. The YX200 is the most widely used pedometer in research studies.[9,10] Yamax SW series pedometers were identified as valid and reliable in well-designed multibrand comparison studies.[7,9] The YX200 has been used as a criterion against which other pedometers were compared; even Schneider et al[9] recommended the selection of YX200 pedometer model for research purposes. We showed that there were no differences between 2 pedometers in step counts for men and women and for people of different weight categories.

ACSM recommended to do same accumulating 30 minutes of moderate intensity exercise such as brisk walking. Current pedometers provide a useful indicator of daily step counting but they do not provide steps per minute as a display for measuring the intensity of the physical activity. So, it is difficult to establish step-counts guidelines that correspond with public health guidelines.[11] The public health impact of physical

**TABLE 2.** Step Counts at the 30-Minute Moderate-Intensity Walking and Correlation Coefficient Between ECE PEDO and YX200

| | Yamax SW-200, Mean ± SD (Minimum–Maximum) | ECE PEDO, Mean ± SD (Minimum–Maximum) | r |
|---|---|---|---|
| All (n = 30) | 3493 ± 399 (2709–4539) | 3511 ± 426* (2651–4527) | 0.96 |
| Women (n = 15) | 3271 ± 299 (2709–3804) | 3277 ± 341* (2651–3886) | 0.93 |
| Men (n = 15) | 3714 ± 368 (3267–4539) | 3746 ± 377* (3197–4527) | 0.93 |
| Normal weight (n = 10) | 3787 ± 429 (3171–4539) | 3827 ± 445* (3083–4527) | 0.95 |
| Overweight (n = 10) | 3464 ± 260 (2969–3947) | 3479 ± 284* (2904–3893) | 0.92 |
| Obese (n = 10) | 3227 ± 293 (2709–3655) | 3228 ± 325* (2651–3762) | 0.92 |

ECE PEDO = equipment for clever exercise pedometer.
* No significant difference between step counts of pedometers ($P > 0.05$); r, correlation coefficient.

activity increases by translating current physical activity recommendations into a pedometer-based guideline.[7] Pedometers are quite cheap, so they have rapidly become the center of interest of physical activity campaigns. Although current pedometers do not measure physical activity and exercise intensity, they are widely used as a physical activity-monitoring tool.

The most widely recognized step recommendation is to accumulate 10,000 steps per day.[12] Although determining step goals increase the pedometer use, the goal of 10,000 steps per day does not express physical activity intensity. A person could have many steps during normal daily living activities, but it is difficult to determine how many steps are needed to meet existing physical activity intensity recommendations. Le Masurier et al[13] also revealed that accumulating 10,000 steps a day does not guarantee meeting the guidelines in the bout lengths documented to confer the health benefits of physical activity. It is possible for an individual to accumulate a large number of steps daily but still be doing little or no moderate physical activity. Indeed, it is observed that the proportion of aerobic steps in daily number of steps could be achieved at a very low rate. Duchečková and Forejt[14] examined the relation between daily steps and aerobic steps defined as a step rate of at least 60 steps per minute in a period of over 10 minutes. The average daily number of steps and aerobic steps was 6758 ± 2874 and 966 ± 1399 as well as 7809 ± 2942 and 1337 ± 1612 for the subjects with high waist-to-hip ratio (WHR), and the subjects with normal WHR, respectively.[14]

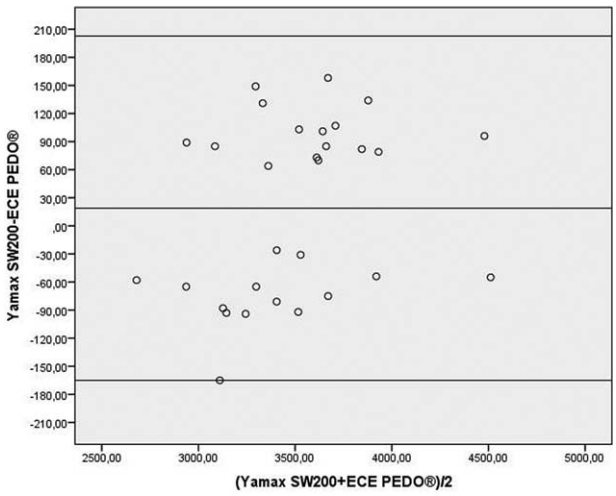


**FIGURE 2.** Bland–Altman plots of limits of agreement in individual steps count between ECE PEDO and YX200. Parallel lines indicate the mean difference ± 2 SD.

Our new pedometer records time-stamped step goals range unlike simple pedometers that only show total number of steps. After lower and upper limits of target number of steps per minute are uploaded to ECE PEDO, a personal report about the step counts in certain durations that reflects the intensity of walking is displayed by the device. The majority of pedometer studies recommend ''daily step goals'' in walking. Without a time-based indicator, it is not possible to determine the intensity of the physical activity. Goal setting and activity monitoring were demonstrated as effective self-management strategies to improve exercise adherence.[15] With the ECE PEDO, health professionals or users can review the data about step counts for 20 sessions, assess the duration of walking and are able to see if enough walking to meet the steps per minute goals are done.

Rider et al[16] suggested that ''Aerobic steps'' can identify the adequate aerobic intensity and investigated the monitoring capabilities of the Omron HJ-720ITC pedometer. Daily wear time and aerobic steps per day (ie, those taken at a cadence of >60 steps per minute for ≥10 consecutive minutes) were computed, providing an assessment of physical activity intensity during continuous walking bouts.[16] The pattern of physical activity was based on the number of steps and aerobic steps taken. The pedometer stored the number of aerobic steps in its memory when a step rate of minimum 60 steps per minute in a period of over 10 minutes was performed. In our study, step range per minute feedback was used as an intensive and objective monitoring tool. Lower and upper limits of steps per minute corresponding to the target hearth rate were recorded by ECE PEDO providing audible feedback when the person gets out of step range. Comparing the step counts of this study, the step rate (approximately 1800 steps during 30 minutes) was quite lower than the step rate of our study (approximately 3500 steps during 30 minutes). Furthermore, there is no evidence that would support the claim that a step rate of minimum 60 steps per minute in a period of over 10 minutes leads to improved health for everybody. We examined the relationship between HR intensity and pedometer step counts to promote physical activity of sufficient intensity. Rider et al suggested a step rate of minimum 60 steps per minute in a period of over 10 minutes for aerobic steps, but our study showed that minimum 88 steps per minute are required to meet adequate moderate aerobic intensity. How many steps per minute for a moderate intensity walk needed should be calculated. Individuals with low fitness need lower training intensities than individuals with higher baseline fitness.[17] In our study, minimum steps per minute were 88 for women and obese people whereas 151 steps per

minute for men and normal weight people. However, there were differences in the same subgroup, for example, some men needed 109 steps per minute whereas some men needed 151 steps per minute to meet the moderate intensity. This study shows the importance of setting goals based on fitness levels of each individual's aerobic capacity.

There are some reports in the literature on how many steps are needed to meet the moderate physical activity recommendation. Recent studies[6,18] suggested that moderate intensity walking appears approximately equal to at least 100 step $min^{-1}$. Tudor-Locke et al[19] have reported that 96 and 107 step $min^{-1}$ represented the minimum threshold for moderate-intensity walking. Marshall et al[7] proposed that individuals must be motivated to walk a minimum of 3000 steps in 30 minutes on 5 days each week to meet current physical activity recommendations. Because fixed ''step counts per minute'' is a poor indicator for $VO_2$ max, same recommendations are not suitable for all persons. One hundred step $min^{-1}$ should be used only as a general physical activity promotion heuristic. All of these authors have suggested to use a fixed value for everybody to determine the intensity. Unlike these approaches, individualized moderate activity intensity and related pedometer step counts were calculated in our study. Determining the individualized intensity of physical activity by a pedometer has not been done previously.

The instant audible feedback available in ECE PEDO also makes it particularly useful to provide the target step counts to meet public health guidelines. As previously stated, adult public health guidelines promote $\geq$30 minutes of at least moderate-intensity daily physical activity.[2] Accumulated evidence suggest that 30 minutes of moderate intensity walking translates to 3000 to 4000 steps in healthy adults.[8,11,19] In our study, walking cadence feedback with ECE PEDO provided that mean number of steps taken during a 30-minute walking was approximately 3500 steps. This shows that ECE PEDO has the capability of identifying steps per minute to meet moderate intensity of physical activity. Rice et al[20] showed that many individuals are unable to determine their intensity of physical activity and exercise. This brings a challenging problem, because health benefits are dependent on the intensity of activity.[7] ECE PEDO sets the tempo by giving audible warnings to people to enable them to adjust brisk walking speed allowing them to determine the exercise intensity easily.

ECE PEDO can be used either according to general recommendations programmed at a rate of 100 steps per minute for moderate-intensity which would equate to walking at least 3000 steps in 30 minutes, or even better by means of personal intensity. Individualized programming allows to determine the exercise intensity by regulating to walk a special step range corresponding to the target range of the HR. Individual exercise prescription, a relative measure of intensity is more appropriate, especially for older and deconditioned persons.[4]

Lubans et al[15] showed the relationship between step counts and exercise intensity as measured by HR in adolescents. The participants were told to maintain their HR between 65% and 75% of their maximum HR while running or walking on a treadmill. The Yamax SW700 pedometer was used in their study to calculate steps. In their method, total steps taken on pedometer treadmill trial for 10 minutes were divided by 10 to find an estimate of steps per minute. They suggested that exercising at a target HR corresponds to 146 steps per minute for boys and 137 steps per minute for girls. They recommended that step targets should be tailored to existing fitness levels because of fitter adolescents taking more steps than less fit adolescents. In our study, we determined the number of steps intervals in a minute needed to reach aerobic exercise at moderate intensity. We also measured the personal aerobic capacity to determine step count targets according to existing fitness levels. Conferring target step counts, the ECE PEDO provided instructions to the participants to walk the calculated step range corresponding to the target HR.

In a recently published article, investigators in PACE-Lift trial proposed to measure the physical activity intensity by accelerometers.[21] They reported increase in physical activity in older people and this success was explained by nurse consultations and the use of pedometer and accelerometer and activity diary. Accelerometer data require computer processing and analysis, and do not provide any direct feedback to participants. The output from the accelerometer shows the periods where users were physically inactive and active using standard cut-offs. In the trial, the nurse downloaded data to a computer and showed the recorded time spent in different physical activity intensities to participants at each visits. This provided visual feedback to participants retrospectively whereas in our study we used a pedometer giving instant personalized audible feedback about physical activity intensity.

Limitations of this study include the small sample size and correlation analysis has been done only in a 30-minute duration of walking. In addition, the current data were collected under controlled conditions (treadmill walking), but 30-minute walking period was done in natural environment. However, it was shown that walking on a treadmill and walking over ground are equivalent kinetically and cinematically in healthy subjects.[22] Future research should investigate the utility of ECE PEDO in different intensity walking and explore to the long-term effectiveness in different populations and chronic diseases. We have already carried out a research on the effectiveness of ECE PEDO in obese people.

In summary, ECE PEDO appears to give similar values for steps per 30 minutes compared with the criterion (YX200). Intensity of exercise can be monitored with a present invented pedometer. ECE PEDO provides monitoring of exercise intensity such that person can walk in a specified time with a desired speed, and the device also has the ability giving audible feedback in case of any deviation from range of steps per minute. Thus, people will be able to do aerobic exercise in specified individualized intensity anywhere. As a conclusion, ECE PEDO is a practical, simple to use and wearable activity monitor that is feasible for use in clinical and research settings.

## ACKNOWLEDGMENT

*The authors would like to thank Nuray Akkaya for the statistical analysis.*

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