Using Pedometers to Estimate Ambulatory Physical Activity in Vietnam

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Background: Pedometer measurement of physical activity (PA) has been shown to be reliable and valid in industrialized populations, but its applicability in economically developing Vietnam remains untested. This study assessed the feasibility, stability and validity of pedometer estimates of PA in Vietnam. Methods: 250 adults from a population-based survey were randomly selected to wear Yamax pedometers and record activities for 7 consecutive days. Stability and concurrent validity were assessed using intraclass correlation coefficients (ICC) and Spearman correlation coefficients. Results: Overall, 97.6% of participants provided at least 1 day of usable recordings, and 76.2% wore pedometers for all 7 days. Only 5.2% of the sample participants were involved in work activities not measurable by pedometer. The number of steps increased with hours of wear. There was no significant difference between weekday and weekend in number of steps, and at least 3 days of recordings were required (ICC of the 3 days of recordings: men 0.96, women 0.97). Steps per hour were moderately correlated (men \( r = .42 \), women \( r = .26 \)) with record estimates of total PA. Conclusions: It is feasible to use pedometers to estimate PA in Vietnam. The measure should involve at least 3 days of recording irrespective of day of the week.

Keywords: walking, exercise, feasibility study, validation study, qualitative research

Physical inactivity, which has increased in prevalence in Vietnam in recent times,\(^1,2\) is likely to be an important contributor to the growing burden of noncommunicable disease (NCD) in the country.\(^1\) However, these reports are based on questionnaire measurements of physical activity. This method of measurement is subject to limitations including misclassification, recall bias, and floor effects (eg, activities that have intensity lower than brisk walking or have duration less than 10 minutes are not counted).\(^3\) An alternative approach is to measure physical activity by an objective method such as pedometers. Pedometers are increasingly being used to measure physical activity at the population level due to their ease of use, relatively low cost, and acceptable reliability and validity.\(^5-7\) To date, pedometers have been successfully used in population studies in Switzerland,\(^8\) the United States (US),\(^9,10\) Australia,\(^11\) and Brazil\(^12\) with pedometer wear period varying from 1 to 7 days. These studies suggest that it is feasible to use pedometers for large scale, population-based surveys under varying conditions in different countries. However, there are still some questions about their applicability for use in all parts of the world. In Vietnam, challenges include a higher prevalence of work activities involving contact with water, bumpy road conditions that can cause pedometers to erroneously register “steps” for those traveling by motor-vehicle, clothing with soft waist bands that may influence the accuracy of pedometer recording, and an uneven level of literacy that may impact on the ability of participants to accurately complete the pedometer diary.

This study assessed the feasibility of using pedometers to measure physical activity levels in a Vietnamese population and examined the stability and validity of the estimates obtained.

Methods

Sample

This study used a subsample of eligible subjects from a population survey of 25- to 64-year-old residents of Can Tho, Vietnam. The survey used the “STEPwise approach to surveillance of non-communicable diseases” (STEPS) methodology developed by the World Health Organization for use in member countries. The survey involved \( n = 1978 \) participants selected by stratified multistage sampling. Details of the survey have been reported elsewhere.\(^1,13\)

Subjects in the subsample were selected as follows. Three rural and three urban communes from the 8 rural and 8 urban communes surveyed were selected by simple random sampling. When eligible residents of these
communes were selected to participate in the survey, every third eligible subject (325 in total) was selected by systematic random sampling to participate in this study. Of them, 77.2% (251/325) participated in the survey and 99.6% (250/251) of them participated in this study. Characteristics of the participants in this subsample have been described elsewhere.14

Informed consent was obtained from participants. Those who could not sign the consent form provided verbal consent. The Ethics Committee of Can Tho University of Medicine and Pharmacy approved the study. Data collection occurred from July to December 2005.

**Measurements**

Each participant wore a pedometer for 7 consecutive days following the STEPS survey clinic and recorded steps and pedometer wear details in a pedometer diary. Participants also recorded their activities for each pedometer day in a physical activity record (PAR).

In Vietnam, health volunteers (also called village health workers) are responsible for delivering basic health services such as contraceptives, vaccination reminders, and monitoring adherence to prescribed medication regimes for persons living in an assigned local area of their neighborhood.13 The health volunteers maintain and regularly update a list of the persons in their assigned area. In the STEPS survey, persons were selected at the final stage of sampling from these lists. In this study, the health volunteers assisted with the recruitment and data collection process. Their role included visiting and inviting eligible subjects to come to the study clinic, reminding participants to wear their pedometers, helping them to fill in the PAR if needed, acting as contact person for the researcher and participants, collecting the pedometer diary and PAR on completion, and distributing small gifts to participants when they had finished their pedometer recordings. The health volunteers received payment for their work in this study.

Yamax pedometers (models SW 200 and SW 700) were used. They have been shown to have the greatest reliability and validity of the commercially available pedometers.6,16–18 The pedometers were checked before and after each use by a research assistant. The test involved wearing the pedometer on the waist, walking for exactly 100 steps. Pedometers were removed from use if the reading recorded was 5% lower or 5% higher than the actual steps taken. At the clinic, participants were instructed to wear their pedometers fastened to their belt or waistband on the right midaxillary line of their waist. The pedometers were required to be reset each morning after recording the previous day’s steps in the diary. Participants were also asked to seek assistance from the health volunteers or the researcher if they encountered any problem. Participants who required special help (eg, to fill in the diary) were identified and their health volunteers were informed at the time of the clinic.

Instructions for pedometer wear, the pedometer diary, and PAR were integrated into 1 document based on the format of the logbook used in the Burnie Take Heart Project.11 The pedometer diary consisted of paper copy with columns for date, start time, stop time, and number of steps recorded. Participants were asked also to report the total amount of time spent riding on a motorbike or sitting on the back of a bicycle (behind another person who operated the pedals), traveling by bus on a bumpy road, and periods of time spent without the pedometer during the day (eg, when working in water). In the PAR, participants reported each activity performed including those activities undertaken while not wearing the pedometer. They were required to record the period of time, a short description of the activity, and the intensity (low, moderate or vigorous) of the activity. There was space for participants to add comments. Two example pages with common patterns of activities were included in the instructions.

**Statistical Methods**

Pedometer diaries and PARs were examined for their completeness, comprehensiveness and consistency. Each activity reported in the PAR was assigned the Metabolic Equivalent Task (MET) intensity of the most similar activity listed in the Compendium of Physical Activities.19 The MET intensity of an activity is the ratio of the metabolic rate of energy expenditure per kilogram per hour while undertaking the activity relative to a standard resting metabolic rate. The metabolic cost of each listed activity was obtained by multiplying the activity duration by its MET intensity. These were summed across all activities to calculate total MET-weighted hours of activities.

Pedometer data checking involved logical checks to identify implausible values, and outlier labeling using the Tukey method.20 Implausible values and outliers were cross-checked with the hard copy and corrected if a data entry error had occurred. Standardized residuals from the linear regression were then used to evaluate whether the outliers explained other indicators such as body mass index (BMI), waist, and waist to hip ratio of the participants. The dfbeta influence measure21 was used to evaluate the influence of these values on the model. Influential cases were identified as having dfbeta exceeding \[ \frac{2}{\sqrt{n}} \].21 These values were then excluded from the analysis. Appropriate transformations were used to remove skewness of data.

Assessment of the stability of the pedometer measurement included investigation of: how many hours per day to measure, which days of the week to measure, and how many days to measure. To examine whether there is a critical number of hours the pedometer should be worn in a day, we regressed steps recorded per day on hours worn allowing a change of slope and used a nonlinear algorithm to estimate the vertical ordinate at which the slope changes (the knot). The average steps for each day of the week and all 7 days were used to examine the difference in number of steps on weekdays and weekend days. This was done for urban and rural participants separately.
because urban participants were more likely to have office work, which may result in weekday and weekend differences in terms of physical activity. The number of measurement days required was assessed by estimating the mean and standard deviation (SD) of average steps per day and by calculating intraclass correlation coefficients (ICC). The formula used for the ICC of a mean of k ratings is denoted as ICC(1,k). For comparison, we also calculated ICC for a single rating and denoted it as ICC(1,1). Based on the results of the analyses of number of days needed (see Results), the validity analyses were restricted to participants who wore the pedometer for at least 3 days. Nine participants were excluded from these analyses.

Content validity was assessed by comparing average steps per hour for different groups of participants whose types of physical activity may influence pedometer readings. Groups whose occupations significantly influenced their pedometer readings were excluded from other validity analyses. Concurrent validity was assessed by the Spearman correlation coefficient between average steps per hour and average MET-hours per day of activity recorded by PAR. Predictive validity was examined by partial Spearman correlation coefficients between steps recorded and cardiovascular risk indicators adjusting for age and sex.

Qualitative Methods

Qualitative methods were used to gain a greater understanding of pedometer use among this population. Informants were all 15 health volunteers, and 26 study participants selected by maximum variation, unique cases and opportunistic sampling techniques to cover the range and depth of variation in informant experiences. Semistructured interviews, informal interviews, and review of pedometer diaries and the PAR were used. Data were recorded by field notes and notes taken during interviews. Triangulation of multiple sources of data was used to improve rigor of the findings. Data were analyzed thematically using Nvivo 7.

Results

The participants in the subsample consisted of 123 men and 127 women of average age 45.9 (SD 10.3) years. Their characteristics are summarized in Table 1. More than 50% of men and a third of women in this sample were farmers. In addition, one quarter of women were home-makers. In all these respects, the participants in the subsample were similar to the full sample of survey participants.

Feasibility of Using Pedometers

Six participants (2.4%) were found to be illiterate and many more needed some help from the health volunteers to record their activities. One or two participants at each site (6–12 in total) were wearing clothing with soft waistbands and were asked to change to clothing with a stiffer waistband when wearing the pedometers. Two participants altered the mode setting on their Yamax model SW700 pedometers, which resulted in unusable recordings. Two pedometers were lost and 4 others were damaged due to contact with water.

Other than 6 men whose occupation involved riding motorbikes, participants used motorbikes for only 20.1 (SD 51.6) minutes per day on average, and there was only a weak association \(r = 0.03\) between time spent on a motorbike and total steps recorded. The average time participants spent bicycle riding, as reported in the PAR, was 1.38 (SD 5.64) minutes per day.

Pedometer compliance and usage issues are presented in Table 1. The mean number of days of pedometer wear was 6.6 days. Overall, after removing unusable data, 97.6% (244/250) of participants provided at least 1 day of usable recording.

Findings From the Qualitative Study

The main qualitative finding was that wearing a pedometer was acceptable and most of the participants were compliant. Some problems related to compliance, issues with pedometers, activities that pedometers failed to capture, the influence of health volunteers, and issues with completing the PAR were identified (see discussion below). These were addressed during the data collection phase and thus had very little impact on the quality of data collected overall.

Participants were willing to wear pedometers and many were proud to have a pedometer, with one stating “I said it was a tape recorder.” They were enthusiastic and interested. For example, some commented when they were concerned about the readings, “Today the pedometer counted only 2000 steps when I have been active all day, so I think it is not working. Even walking around the rice field for 2 hours is more steps than that.”

However, some participants found wearing a pedometer to be worrying and did not always comply with instructions. One man was reluctant to wear “the machine” because he thought it was for “some experimental purpose for medical students.” A woman reported reducing the number of steps when her pedometer reading seemed unusually high, and stated that “. . . the number on the machine kept going up. I was scared, thought I had a disease.” Another man stopped wearing his pedometer when he changed into shorts after work because he felt it “looks awkward on the shorts.” A participant who worked at a fish market where she had to sit and bend over found that her pedometer “annoyed me every time I bent down.”

Instructions for pedometer wear did not always anticipate some of the situations described by participants. For example some described trying to wear the pedometer on the back of their waistband or covering it in plastic to wear under water. Participants hesitated to wear pedometers if their activities were likely to involve unexpected contact with water, such as drying rice in the wet season when impromptu downfalls are common, and fishing. Participants reported removing
pedometers in these situations. Others misunderstood instructions. For example, 2 participants described removing their pedometers when finishing work rather than at the end of the day, and others forgot to put on their pedometers in the morning. “I have twin babies, when they wake me in the morning I have no time to think about the pedometer.”

Health volunteers occasionally influenced the data in the PAR and the pedometer diary. Participants with poor literacy required help with reading and writing and at times health volunteers also assisted participants to improve the completeness and thoroughness of the data. However, some participants reported that health volunteers had fabricated information to replace missing data. For example, one health volunteer took away a participant’s pedometer after he accidentally immersed his pedometer in water on the third day “he came to check the next day and was upset so he took everything back.” However, the record for this participant showed 7 days of data and the first 2 days had different hand-writing to the later 5 days.

Health volunteers did not always understand the differences between fabricating data and recording the actual activities of the participant. For example a health volunteer showed the researcher an empty PAR and asked “Can I just fill it in? I know very well what she does.” Another health volunteer said that “you can’t just make it up by guessing, you need their first day to do that!”

### Stability of Pedometer Measurement

**How Many Hours per Day Are Needed?** The average wear time was 14.8 hours (SD 1.8) for men and 14.9 hours (SD 1.6) for women. Daily steps were significantly correlated with wear time ($r = .14$, $P < .01$ for men, $r = .18$, $P < .01$ for women). Steps increased with hours of wear for men, but plateaued at 14.4 (95% confidence interval 13.5 to 15.3) hours for women (Figure 1).
Figure 1 — Plot of steps per day recorded by pedometer on up to 7 days by 244 participants (119 men, 125 women) and the number of hours that the pedometer was worn each day for men and women. The boxes represent average steps recorded for each 2 hour time interval.
were 32% of daily recordings by women with less than 14.4 hours of wear time.

Which Days to Measure? There was no evidence of a consistent pattern of difference in steps per day across days of week in either urban or rural locations (Table 2). In additional analyses, we investigated the influence of day order (whether more steps were recorded on the first day of wear, for example) and again found no consistent differences.

How many Days Are Needed? Average steps per day changed little when taken over more days of recordings (Table 3). The ICC comparing the average of successively more days of recording with the average of all 7 days increased substantially when the number of recording days was expanded from 1 to 2 days, and increased further when it was expanded from 2 to 3 days. There were only minor increases by adding further days of recordings.

When steps for each day separately were compared with the average of 7 recordings (data not shown), the highest correlations were for day 4 ($r = .91$) and day 3 ($r = .88$) for men, and day 3 ($r = .89$) and day 5 ($r = .87$) for women. Discarding recordings on day 1 and day 2 to allow a run-in period, the ICC(1,k) for day 3, 4, and 5 with the mean of 7 days was not higher (0.98 for men and 0.98 for women).

Validity of Pedometer Measure

Content Validity. Among 235 participants who wore pedometers for at least 3 days, the 6 men who rode motorbikes as their occupation recorded more ($P = .004$) steps per day (mean = 15811, SD = 6442), and the 7 men who worked in water recorded fewer ($P = .024$) steps per day (mean = 6142, SD = 2621), than the other male participants (mean = 9180, SD = 4247). Their PAR revealed the motorbike riders were doing

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### Table 2: Average Steps for Each Day of Week for All Participants*

<table>
<thead>
<tr>
<th>Day of week</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
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<th>Sat</th>
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<td>All</td>
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<tr>
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<td>8814.9</td>
<td>8617.7</td>
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<td>8448.1</td>
<td>8814.1</td>
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<td>5540.8</td>
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<td>5549.2</td>
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</table>

*a This table excludes participants who rode motorbikes as their occupation or worked in water.

*b Mean of all 7 days.
little else than riding their motorbikes and those who worked in water were more active than their recordings suggested. These 2 groups comprised 5.5% (13/235) of participants with at least 3 days of recordings, and 5.2% (13/250) of the total sample. Excluding these 13 men from the assessment of measurement stability made little difference. The average steps per day for women was 9539 (SD 4290).

**Concurrent Validity.** The correlations for the association between average steps per hour and the PAR estimate (Figure 2) was moderate for men ($r = .42, P < .01$) and modest for women ($r = .26, P < .01$). The associations calculated with total steps per day were weaker for men ($r = .28, P < .01$) and women ($r = .24, P < .01$). The 6 motorbike riders and 7 water workers were excluded because their pedometer recordings did not reflect the activities recorded by the PAR.

**Predictive Validity.** The association with cardiovascular risk indicators was marginally stronger when calculated with steps per day than when calculated with steps per hour. For men and women combined, the age- and sex-adjusted correlations with steps per day were $r = −0.10$ (BMI), $r = −0.11$ (waist circumference), $r = −0.11$ (waist-to-hip ratio), $r = −0.09$ (systolic blood pressure), $r = −0.11$ (fasting blood glucose), and $r = −0.13$ (fasting total cholesterol).

### Table 3: Average Steps per Day and Intraclass Correlation Coefficient (ICC) Values at Increasing Number of Days of Recording for Participants Who Completed All 7 Days of Recordings (93 Men and 93 Women)

<table>
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<th>Number of days recording</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tr>
<td>Mean</td>
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<td>5144.3</td>
<td>4942.6</td>
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<td>0.95</td>
<td>0.97</td>
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<td>0.99</td>
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<td>ICC(1,1)</td>
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<td>0.91</td>
<td>0.95</td>
<td>0.96</td>
<td>0.98</td>
<td>0.98</td>
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<td><strong>Females</strong></td>
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<td>1.00</td>
</tr>
<tr>
<td>ICC(1,1)</td>
<td>0.82</td>
<td>0.92</td>
<td>0.94</td>
<td>0.97</td>
<td>0.98</td>
<td>0.99</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Figure 2** — Plot of MET-hours per day recorded by PAR and number of steps recorded per hour obtained from 222 participants (101 men, 121 women) who wore pedometers for at least 3 days.
Discussion

To the best of our knowledge, this study is the first attempt to assess the use of pedometers as a measure of physical activity in Vietnam. Despite some minor operational issues, we found that it was feasible to use pedometers to measure ambulatory physical activity in Vietnam. Even though just 1 day of pedometer wear provided a high ICC, 3 days of wear provided a stable measure and there was no improvement in providing a run-in period. There was no evidence to support a requirement of a minimum number of hours of wear per day. In addition, the pedometer recordings provided a reasonably valid indicator of total physical activity in this population as evidenced by the comparison of pedometer estimates against PAR estimates.

Our findings demonstrate the feasibility and acceptability of pedometer use in Vietnam. Firstly, 78% of the local population participated in the survey and nearly all of them (250/251) subsequently participated in this study. Studies in other populations have reported response proportions ranging from 17% to 69%. Secondly, there was excellent compliance in this study with 98% wearing pedometers for at least 3 days. Thirdly, failure to take proper care of pedometers and to return them was rare in this study. A key contributor to this excellent compliance was the supportive role of the health volunteers. These local identities assisted with recruitment, encouraged continued participation, assisted with recording, and advocated the return of pedometers. Health volunteers are an integral component of the Vietnamese health system and the use of pedometers in large-scale surveys in Vietnam appears feasible with their assistance. They require training and continuing supervision, however, because some proved to be over-zealous and had fabricated records on occasion while others were not highly motivated.

Attesting to the feasibility and validity of pedometer measurement in Vietnam, it was rare to find persons in our sample whose activities were such that pedometer usage was inappropriate. These persons included those whose occupation involved riding motorbikes and those working in water, but together they comprised only 5% of our sample. Based on this sample, pedometer measurement of ambulatory activities would be possible for 95% of the population.

In relation to the number of hours the pedometer must be worn, we found a positive association between steps recorded and wear time. For women, this association disappeared after 14.4 hours, but 32% of recordings by our sample of women would be lost if a minimum wear time requirement of 14.4 hours was imposed. We therefore recommend no cut point be used for both men and women in this population. These findings are consistent with an investigation of this issue by our own group in a similarly aged sample of Australians. Further, we do not recommend that pedometer counts be adjusted for hours of wear when the purpose of the measure is to predict cardiovascular risk. While the differences were not large, the predictions were marginally stronger when made using steps per day than when using steps per hour.

In this Vietnamese sample, the number of steps per day did not differ by day of the week. This finding is similar to that from a study of women in South Carolina. On the other hand, Tudor-Locke et al found a significant difference in steps recorded on weekdays and weekends in a sample from South Carolina of similar ages to our participants but, in a subsequent analysis, concluded that the differences by day of the week were not of practical importance. Similar weekend effects have been reported in a population-based Australian study. The inconsistencies with our results may be due to the different populations being studied. The majority of our participants were self-employed and involved in activities such as farming that, in Vietnam, are not dependent on the day of the week.

Three days of wear were required to obtain a stable estimate of physical activity in our study. This finding is consistent with that from a US study (with ICC = 0.79 for 1 day, 0.89 for 2 days, and 0.94 for 3 days). Another study reported that 5 days were needed to obtain stable estimates for 10 to 14 year olds, whose activities were highly variable, but only 2 days of recordings were sufficient for post menopausal women with diabetes who tended to be inactive. Similar to the finding of the US study mentioned above, we found that single day recordings on day 3, 4, or 5 were most strongly correlated with the mean of all 7 days. This may suggest that best practice would be to allow a run-in period of 2 days, thereby requiring 5 days of recordings, but doing so did not produce stronger associations in our study and does not weaken our conviction that 3 days is adequate.

While pedometers measure ambulatory activity only, that activity is a major component of total physical activity, and it was reassuring that the recordings were at least modestly correlated with the PAR estimates. That the correlation was higher for men than women mirrors a previous finding of ours for a similarly-aged population-based Australian sample, and may be due to several reasons. Firstly, the activity of men was usually of higher intensity, whereas women’s activities were usually of lower intensity and more fragmented. Higher-intensity activities may be more salient and recorded with less error. Secondly, pedometers are not designed to measure upper body movements involved in activities such as household work, which were more commonly undertaken by women in this sample. Thirdly, male participants generally had higher levels of education than did female participants, and may have been more adept at accurately recording their activities in the PAR without requiring help. Pedometers may have a particular advantage in measuring physical activity in populations with low levels of literacy.

The average steps per day for men (9180) and women (9539) in this sample are similar to the mean estimate from a meta-analysis summarizing all 42 studies that used pedometers (9501 for men and women combined). The figures in our sample are higher than those reported...
for population samples from US population in Colorado (men: 7028, women: 6602) and South Carolina (men: 7192, women: 5210) and comparable to estimates reported for a Swiss sample (men: 10400, women: 8900), lower than those of an Australian sample (men: 10900, women: 11200), and much lower than a sample of Old Order Amish farmers (men: 18425, women: 14196) who abstain from using modern farm equipment and other conveniences.

The strengths of this study are its population-based sample recruited with a high response rate, the intensive training and supervision of staff and health volunteers during data collection, the rigorous procedures used in data checking, and the use of qualitative methods as an adjunct methodology to provide a deeper understanding of pedometer usage issues in the local population. These features provide some confidence that our findings present a comprehensive and accurate picture of issues involved in recording physical activity by pedometer in Vietnam.

This study has a number of limitations, however. Firstly, the lack of a gold standard measure of physical activity limited the assessment of concurrent validity to the PAR. The use of more accurate methods, such as doubly-labeled water or heart rate monitoring, were not feasible in this population-based study. Accelerometers provide a more comprehensive measure of physical activity than do pedometers, but are more expensive and less practical for large-scale population-based surveys. They also suffer from similar usage restrictions for the 5% of our sample who worked in water or spend the day riding motorbikes on bumpy roads. Moreover, pedometer measurements have been shown to be strongly correlated with accelerometer estimates of ambulatory physical activity. Secondly, our study did not take into account the inadequacy of pedometers in capturing activities such as riding bicycles. The amount of time spent on activities such as bicycling by our participants was minimal, however. Thirdly, the MET intensities used to calculate total MET-weighted hours of activity from the PAR in this study were based on the Compendium of Physical Activity, which was developed for the US population. We assigned MET intensities using the activities most similar to those undertaken by our participants, but could not find good matches for several of the local activities. Nevertheless, this is a problem in any study seeking to use this approach.

Conclusion

Pedometers can be used to obtain a reasonably valid estimate of physical activity in the Vietnamese population. At least 3 days of recording are needed to obtain a stable estimate of habitual activity.

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References


