



10,000 Steps Working Paper Series

Paper 11: Pedometer Reliability, Validity and Feasibility Report, 2010

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EXECUTIVE SUMMARY

This study aimed to determine the reliability and accuracy of three pedometer models to monitor steps taken during four different walking speeds (3.2km/h, 4.8km/h, 5.6km/h and self-selected). Each person completed the walking trials twice in a random order, the three pedometer models tested in the current study the *YP2025*, *MK-365* and the *Yamax Digi-walker SW200*.

Inter-unit reliability refers to the ability of the different pedometer units within the same pedometer model type to acquire the same step count value in a trial. Intra-trial reliability is the ability of the pedometer unit to replicate the same step count values across multiple trials. The validity of a pedometer refers to its accuracy, i.e. the degree of error that is evident between the pedometer measured step count value and the actual step count.

A brief summary of results is provided below for each brand of pedometer:

YP2025

- Elicited poor inter-unit reliability, notably at slower speeds
- Showed excellent intra-trial reliability
- Validity was variable
- Left unit underestimated the number of steps taken
- Right unit overestimated the number of steps taken
- Produced highest percent error across all models and across repeat trials

Manpo MK-365

- Elicited acceptable inter-unit reliability ($p < 0.05$) and excellent intra-trial reliability ($ICC \geq 0.75$)
- High levels of variability in validity across both trials
- Left and right units underestimated the number of steps taken

Yamax Digiwalker SW200

- Elicited acceptable inter-unit reliability ($p < 0.05$) and excellent intra-trial reliability ($ICC \geq 0.75$)
- Variability observed within the validity measures between right and left units
- Produced lowest percent error across all models and across repeat trials
- Demonstrated the greatest validity across all models

Conclusions

- Manpo MK-365 and YP2025 models demonstrated variability in reliability and poor performance in validity
- Both models are affordable to adopt into 10,000 Steps
- Use of these models in 10,000 Steps is not recommended based on performance outcomes in the current study

INTRODUCTION

Background

10,000 Steps Rockhampton was Australia's first 'whole of community' health promotion physical activity project. Funded by Queensland Health, the Rockhampton region was chosen for a two year trial of the project in 2001. During this period, the 10,000 Steps Rockhampton Project was an exemplary model of an effective multi-strategy, multi-sector physical activity project. [1] The project was successful in motivating local communities, workplaces and individuals to increase their physical activity levels. As a result of the success in Rockhampton, Queensland Health provided funding for 10,000 Steps to be developed as a sustainable state-wide and beyond initiative.

10,000 Steps now disseminates physical activity information, materials, resources and support via the interactive 10,000 Steps website (www.10000steps.org.au). Since 2004, organisations and community groups have adopted and implemented the 10,000 Steps resources across Queensland and nation-wide to promote physical activity and raise awareness of the associated health benefits. Individuals are also involved in the program by using the interactive online Step Log to record and monitor their physical activity levels.

The pedometer has been identified as a cost effective, non-obtrusive, simple to use and effective tool for the measurement of physical activity. [2-11] The pedometer plays a significant role in the 10,000 Steps program as members are encouraged to wear their pedometer daily and to log their daily steps on the website using the Step Log or other means such as a paper-version of the Step Log. This enables them to monitor their progress and to participate in individual, team or workplace challenges. In 2001, when 10,000 Steps was initiated the Yamax SW series was the most reliable and accurate pedometer model available and was selected as the pedometer for use in the project. 10,000 Steps currently promotes two 10,000 Steps branded pedometers, the Yamax SW200 and SW700. The Yamax SW200 and SW700 were branded as a 10,000 Steps pedometers in 2004 in efforts to offer a reliable and accurate pedometer model for users at a lower price point to increase pedometer usage.

These pedometer models have been shown to be reliable and valid in several studies and vary only on functions offered (e.g. steps, or steps, calories and distance), and are therefore considered appropriate for promotion in the 10,000 Steps Program. [2-3, 5-6, 8, 11] Although pedometers are noted for being a cost-effective method to objectively monitor activity, cost can remain a barrier. Therefore, 10,000 Steps is investigating the possibility of providing pedometers at a reduced price point, without compromise to pedometer performance.

Purpose of Study

The purpose of this study was to test the reliability and validity of several pedometer models at a reduced price point in comparison to current 10,000 Steps branded Yamax SW200 pedometer. In addition, the retail price and expenses associated with customising these pedometer models for the 10,000 Steps program were considered to determine the feasibility of providing a 10,000 Steps branded pedometer at a cheaper price point.

Method

Pedometers

The reliability and validity of three pedometer models (Yamax Digiwalker SW-200, Y-P2025 and Manpo MK-365) were examined in the current study. The Yamax Digi-walker

SW200 (retail \$40/unit) was included as a current 10,000 Steps branded pedometer to re-test its performance and to provide a model for comparison with the reduced price point pedometers. The Manpo MK-365 (retail \$30/unit) pedometer model was selected for this study as it is also manufactured by Yamax while having a lower cost. The Y-P2025 (retail \$15/unit) pedometer model had been previously identified as a potential option by Queensland Health due to its reduced price per unit, and was therefore included in the testing to investigate its performance value. Both the Manpo MK-365 and the Y-P2025 have physical designs and dimensions that would allow branding of the 10,000 logo to be applied.

Participants

A total of 11 adults (five male and six female) completed the study. Participants provided basic demographic information and project staff measured mass, height, waist and hip circumference. Stride length was acquired by measuring the total distance that each participant walked covered in 20 strides and dividing the distance by 20. The testing received ethical clearance from the Human Research Ethics Committee at CQ University Australia.

Procedures

Participants completed four separate trials at different speeds (3.2km/h, 4.8km/h, 5.6km/h and self-selected) on a treadmill, each lasting five minutes. These speeds were selected to reflect a variety of walking speeds and also compared to those used in previous studies. [2, 5, 6, 7] The trials were repeated twice and the order between participants was randomised. At the completion of each trial participants ceased walking and staff opened the pedometer whilst participants remained stationary and values were recorded. Actual steps taken were manually recorded by research staff using hand counters. All subjects completed a familiarisation trial on the treadmill prior to testing.

Two units of each pedometer model were worn during all trials. A single unit for each pedometer model was positioned on the right and left side of the subject's body worn on the waist band of firmly fastened clothes above the knee. Each subject wore six pedometer units throughout the testing. The positioning of pedometer units in the lateral, central and medial aspects on the waistband above the knee was randomised within the sample group to minimise the effect of pedometer unit positioning on pedometer step count.

Statistical Analyses

The data was analysed to assess the inter-unit reliability, intra-trial reliability and the validity for each pedometer model. Inter-unit reliability refers to the ability of the different pedometer units within the same pedometer model type to acquire the same step count value in a trial. Intra-trial reliability is the ability of the pedometer unit to replicate the same step count values across multiple trials. The validity of a pedometer refers to its accuracy, i.e. the degree of error that is evident between the pedometer measured step count value and the actual step count.

To determine the inter-unit reliability of the pedometer models, a paired sample t-test ($p < 0.05$) was conducted to examine the differences between the same model worn on right and left sides of the body. Intraclass correlations (ICC) were performed on the pedometer measured step counts for each speed to examine the intra-trial reliability of the pedometer models (see table 2.0 for ICC guidelines). Absolute Percent Error (APE) was calculated for left and right units of each pedometer model, at each speed and across trials one and two. APE was calculated using the formula; $APE = \frac{|(\text{pedometer}$

steps – actual steps) / actual steps] x 100. Mean APE was then determined for each unit of each pedometer model for all speeds and across all speeds, to provide a measure of the validity of the pedometer models. For the purpose of this study, the allowed margin of error was less than 3% for a pedometer to be classified as sufficiently valid. This guideline was outlined by the Ministry of Industry and Trading regulations of Japan, and has been used in other studies. [3, 7] Data analyses were performed using SPSS Version 18 and Microsoft Excel 2007 software.

RESULTS

The Sample

The sample had a mean age of 26.82 ± 3.66 years and a mean BMI of 23.21 ± 2.16 , indicating in general the sample group had a healthy body composition. Refer to Table 1.0 for more descriptive statistics.

Table 1.0 Descriptive statistics of the sample (n = 11)

| <i>Variable</i> | <i>N</i> | <i>Mean (Standard Deviation)</i> |
|-------------------|----------|----------------------------------|
| Age (yr) | 11 | 26.82 (3.66) |
| Stride Length (m) | 11 | 0.73 (0.08) |
| BMI | 11 | 23.21 (2.16) |
| Waist/ Hip ratio | 11 | 0.77 (0.05) |

Table 2.0 ICC guidelines [12]

| <i>Value of r_1</i> | <i>Interpretation</i> |
|----------------------------------|-----------------------|
| <0.40 | Poor |
| 0.40 – 0.75 | Fair to good |
| 0.75 – 1.00 | Excellent |

Reliability

Inter-unit reliability

The testing for inter-unit reliability of the pedometer models (i.e. the reliability between measures from units of the same pedometer model) showed that there was no significant difference in step count between Yamax Digi-Walker SW200 and MK-365 units worn on the right and left sides at any of the tested speeds. Alternatively, at 3.2km/hr and at the self-paced speed within the sample group, a significant difference ($p < 0.05$) was observed between step count measures in units one and two of the YP-2025 pedometer model. Refer to Table 3.0 for more information.

Table 3.0 Average Step counts for units worn on right and left hips. (Trial one)

| <i>Pedometer Model</i> | <i>Right</i> | <i>Left</i> |
|---------------------------|------------------|------------------|
| | <i>Mean (SD)</i> | <i>Mean (SD)</i> |
| Yamax Digi-walker | | |
| 3.2km/h | 345.36 (150.17) | 401.73 (92.59) |
| 4.8km/h | 550.09 (58.13) | 571.55(28.51) |
| 6.4km/h | 644.27 (30.40) | 644.55 (28.34) |
| Self-selected (4.62km/hr) | 534.82 (114.15) | 554.73 (93.21) |
| Y-P2025 | | |

| | | |
|---------------|-----------------|-----------------|
| 3.2km/h | 480.45 (77.35)* | 236.00 (173.53) |
| 4.8km/h | 580.55 (39.16) | 464.55 (172.26) |
| 6.4km/h | 652.91 (28.06) | 592.27 (97.50) |
| Self-selected | 564.00 (88.76)* | 398.73 (208.50) |
| MK-365 | | |
| 3.2km/h | 346.18 (147.50) | 282.64 (168.24) |
| 4.8km/h | 523.64 (107.90) | 507.18 (92.55) |
| 6.4km/h | 665.36 (48.73) | 634.09 (26.73) |
| Self-selected | 499.91 (165.51) | 467.91 (144.70) |

Mean (SD).

* p < 0.05. Significant difference between right and left sides.

Intra-trial reliability

The testing for intra-trial reliability found that all three pedometer models showed excellent agreement in step count measures across repeated trials, eliciting ICC values of >0.75 across trials one and two at all speeds. Refer to Table 4.0 for more information.

Table 4.0 Intra-trial reliability of pedometer models (Trial one Vs. Trial two)

| Pedometer Model | Right Trial | | | Left Trial | | |
|--------------------|-----------------|-----------------|---------|-----------------|-----------------|---------|
| | 1 Mean (SD) | 2 Mean (SD) | ICC (r) | 1 Mean (SD) | 2 Mean (SD) | ICC (r) |
| Yamax SW200 | | | | | | |
| 3.2km/h | 345.36 (150.17) | 372.00 (131.59) | 0.96 | 401.73 (92.59) | 412.73 (94.66) | 0.99 |
| 4.8km/h | 550.09 (58.13) | 568.45 (51.49) | 0.87 | 571.55 (28.51) | 572.45 (52.94) | 0.80 |
| 6.4km/h | 644.27 (30.40) | 645.45 (33.97) | 0.97 | 644.55 (28.34) | 638.64 (27.80) | 0.95 |
| Self-selected | 534.82 (114.15) | 543.00 (128.25) | 0.99 | 554.73 (93.21) | 552.64 (103.28) | 0.98 |
| Y-P2025 | | | | | | |
| 3.2km/h | 480.45 (77.35) | 480.64 (78.86) | 0.97 | 236.00 (173.53) | 247.36 (170.96) | 0.99 |
| 4.8km/h | 580.55 (39.16) | 578.00 (37.36) | 0.99 | 464.55 (172.26) | 471.18 (176.95) | 0.99 |
| 6.4km/h | 652.91 (28.06) | 647.27 (27.90) | 0.97 | 592.27 (97.50) | 577.55 (118.47) | 0.98 |
| Self-selected | 564.00 (88.76) | 575.27 (96.19) | 0.98 | 398.73 (208.05) | 412.36 (204.45) | 0.99 |
| MK-365 | | | | | | |
| 3.2km/h | 346.18 (147.50) | 338.45 (136.49) | 0.99 | 282.64 (168.24) | 315.09 (203.28) | 0.94 |
| 4.8km/h | 523.64 (107.90) | 543.27 (109.66) | 0.96 | 507.18 (92.55) | 519.45 (79.98) | 0.91 |
| 6.4km/h | 665.36 (48.73) | 654.64 (45.42) | 0.92 | 634.09 (26.73) | 632.18 (29.94) | 0.96 |
| Self-selected | 499.91 (165.51) | 503.82 (168.44) | 1.0 | 467.91 (144.70) | 478.45 (140.56) | 0.98 |

Validity

As there was intra-trial reliability was high the APE values are only reported for each pedometer model at all walking speeds for trial one. There was variation in the APE for all models worn on the right and left sides of the body, particularly at the slowest speed, however this variation was the smallest for the Yamax Digi-Walker SW200. Across the entire data set, only two mean APE values were considered sufficiently valid according to the guidelines. [3, 7] These APE values were for trial one in the Yamax Digi-Walker SW200 left unit, and in the YP-2025 right unit. Refer to Table 5.0 for more information. Across all walking speeds and units worn on either left and right hand side of the body the Yamax Digi-Walker SW200 appeared to be the unit with the lowest magnitude of error.

Table 5.0 Absolute percent error of right and left pedometer units trial 1 only (Pedometer measure Vs. Actual measure)

| <i>Pedometer Model</i> | <i>Yamax Digi-Walker SW200</i> | | <i>YP-2025</i> | | <i>MK-365</i> | |
|------------------------|--------------------------------|----------|----------------|----------|---------------|----------|
| | <i>Trial</i> | | <i>Trial</i> | | <i>Trial</i> | |
| | <i>1</i> | <i>2</i> | <i>1</i> | <i>2</i> | <i>1</i> | <i>2</i> |
| 3.2km/h | -25.44 | -19.06 | 3.96 | 4.97 | -26.09 | -26.73 |
| 4.8km/h | -3.56 | 0.63 | 1.99 | 2.50 | -8.13 | -3.74 |
| 6.4km/h | 0.07 | 0.70 | 1.40 | 1.02 | 3.32 | 2.16 |
| Self-selected | -3.03 | -1.24 | 3.0 | 5.68 | -9.93 | -8.81 |
| Mean Absolute % Error | -7.99 | -5.06 | 2.59 | 3.54 | -10.21 | -9.28 |

Feasibility

A range of costs have been taken into consideration to determine the total cost of preparing and promoting the YP-2025 and Manpo MK-365 pedometer models in the current 10,000 Steps pedometer range.

The total cost for each pedometer model consists of the;

- initial stock outlay that would need to be purchased so that a stock of pedometers were available when clients first ordered the pedometer,
- cost of branding the pedometers on the front cover with the 10,000 Steps logo in keeping with the 10,000 Steps current pedometer range,
- packaging that would be needed to best display the pedometers,
- expense of marketing the pedometers to workplaces and the general public to help establish interest in the new pedometer, and
- after sales costs which is based on replacement costs, including postage.

The start up costs outlined (table 6.0) show that if the YP-2025 and Manpo MK-365 pedometer models were found to be reliable and valid, it would be feasible to adopt either of these into the current 10,000 Steps pedometers range as the start up costs are not prohibitive. Refer to table 6.0 for more information.

Table 7.0 Start up costs for a new brand of pedometer

| <i>Costs</i> | <i>Pedometer YP-2025</i> | <i>Pedometer MK-365</i> |
|---------------|--------------------------|-------------------------|
| Initial Stock | \$15,000 | \$30,000 |
| Branding | \$5,000 | \$3,000 |
| Packaging | \$5,000 | \$3,000 |
| Marketing | \$2,000 | \$4,000 |
| After Sales | \$5,000 | \$3,000 |
| TOTAL | \$32,000 | \$43,000 |

DISCUSSION

The current study yielded several findings related to the reliability and validity of the pedometer models.

The testing for inter-unit reliability of the pedometer models showed no significant difference in step count between units of the Yamax Digi-Walker SW200 and MK-365 pedometer models. However, the YP-2025 elicited a significant difference ($p < 0.05$) between step count measures in left and right units at the slowest speed and for the self-paced speed. The average self-paced speed elicited across the sample group was 4.62km/h, the highest speed being 7km/h and the lowest speed being 3.4km/h. Eight out of 11 self-selected walking speeds were equal to or below 5km/h. This indicates that within unit variation may be an issue for the YP-2025 at slower walking speeds. This may be an issue for older adults or other population groups that may walk at slower speeds.

Across all walking speeds all pedometer models demonstrated excellent levels of intra-trial reliability ($ICC \geq 0.75$). [12] Overall, the Yamax Digi-Walker and MK-365 pedometer models proved to be the most reliable eliciting high levels of both inter-unit and intra-trial reliability. Although the YP-2025 exhibited sufficient intra-trial reliability, the between-unit reliability of the YP-2025 pedometer model was not sufficiently reliable.

The validity testing revealed some unexpected findings with some variability observed between the two units for each pedometer model, each positioned on opposing sides of the participant's body. The allowed margin of error was less than 3% for a pedometer to be classified as valid. [3,7] Mean APE values across all speeds revealed that in units positioned on the left hand side, the Yamax Digi-Walker SW200 elicited the lowest APE followed by the MK-365 and then the YP-2025 pedometer models. The Yamax Digi-Walker SW200 pedometer model was the only model with $< 3\%$ APE across all speeds, and therefore was the only model considered valid across all walking speeds when worn on the left side of the body. Within pedometer units positioned on the right hand side of the participant's body, the YP-2025 pedometer model elicited the lowest APE across all speeds, followed by the Yamax Digi-Walker SW200 and then the MK-365 pedometer model. The only valid APE value obtained in this selection of pedometer units was produced by the YP-2025 model.

In the current study observed variability in validity the validity measures between right and left units of the Yamax Digi-Walker SW200 pedometer model. Such findings are inconsistent with the results of many other studies which highlight the high accuracy of this pedometer model. [4, 5, 10] Although the Yamax Digi-Walker SW200 model demonstrated variability in validity measures, when examining APE values for right and left sides at individual walking speeds it consistently recorded lower APE values compared to the other pedometer models.

While the positioning of pedometer units in the lateral, central or medial aspects of the thigh was randomised to minimise the effect associated with the unit not being worn in the recommended 'central' position. It is possible that this variation in position may have affected the sensitivity of the pedometer units and therefore influenced the step counts measured. However this variation in position was required to allow study objectives to be achieved and similar unit positioning protocols have been undertaken previously. [5]

Apart from these discrepancies, there were some consistent findings in validity between the pedometer models. APE values indicate greater accuracy as speed increases. This is consistent with previous research. [4-6, 8] Although this trend was observed in the current study, not all mean APE values at 6.4km/h were within the recommended $< 3\%$ guideline, indicating that although validity appears greater at higher speeds, pedometer validity at higher speeds can not always be assumed.

A limitation of the current study is that all tests were conducted on a treadmill. Walking on a treadmill does not reflect the true nature of walking in everyday life as gait and speed are not always as consistently maintained. Consequently, further investigation into pedometer performance during free-living activity is encouraged.

The total costs associated with adapting the YP-2025 and Manpo MK-365 pedometer models to be included in the current 10,000 Steps pedometer range are considered acceptable. Although this is the case, the variability observed in the reliability and validity measures from the current research does not support the use of these models in the current program. Although at a cheaper price point and more economically attractive, the performance of these models is not considered of sufficient standard. Consequently, when taken as a whole the inclusion of the YP-2025 or Manpo MK-365 pedometer models in the current 10,000 Steps pedometer range is not considered feasible.

CONCLUSIONS AND RECOMMENDATIONS

The cheaper pedometer models proved to be inconsistent in terms of reliability and validity in the current study. The YP-2025 pedometer model elicited poor inter-unit reliability, notably at slower speeds, however showed excellent intra-trial reliability. Its validity was variable, with the left unit tending to underestimate the number of steps taken by subjects, while the right unit tended to overestimate the steps taken. Consequently, overall this model showed poor reliability due to its lack of consistency in pedometer measured step count between units, and low validity due to its inconsistency in measuring the true step count of participants.

The MK-365 and Yamax Digi-Walker SW200 pedometer models elicited acceptable inter-unit reliability and excellent intra-trial reliability, and were therefore both considered reliable models. The MK-365 model displayed high levels of variability across both trials. Due to this high level of variability the MK-365 pedometer was not considered accurate enough to promote its use in the 10,000 Steps program.

While it is affordable to adopt either the YP-2025 and Manpo MK-365 pedometer models into the current 10,000 Steps pedometer range, it is not favourable based on the outcomes of the pedometer reliability and validity testing that was carried out.

Future Recommendations

Based upon the inconsistent results observed in the current study, neither the YP-2025 nor MK-365 pedometer models are considered feasible and are therefore not recommended to be used within the 10,000 Steps program. Further investigation into the reliability and validity of pedometer models at the cheaper price point is encouraged to determine the best alternatives for future use in the 10,000 Steps program.

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