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Reliability and Validity of Pedometers in a Free-living Environment

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ABSTRACT

An abstract of the thesis of Ernest Leroy Brown for the Master of Science in Teaching in Health Education, presented, May 15, 1995.

Title: Reliability and Validity of Pedometers in a Free-Living Environment.

In the field of exercise science there exists no single best method, or tool, for the measurement of physical activity, in particular, activity in everyday free-living conditions. The pedometer, a tool for recording the number of steps taken by an individual, could potentially measure this important component of free-living physical activity.

To establish the reliability and validity of the pedometer, 40 subjects wore two pedometers (same brand) in two consecutive 10-minute trials during normal daily activity. Both trials were videotaped. Each videotape segment was replayed, the number of steps were counted and this count served as the criterion measure of steps. In order to evaluate the reliability of the criterion measure the researcher recounted ten of the forty trials a second time and performed an intraclass reliability estimate and follow-up ANOVA comparing the two separate counts. This yielded an intra-observer reliability estimate of $R=0.99$ ($F=1.36$, $p=.27$).

Data analyses included trial-to-trial comparisons of pedometer recordings, left-to-right comparisons of pedometer recordings, and comparisons of pedometer recordings to the established criterion scores.

Results of trial-to-trial comparisons yielded intraclass reliability estimates of $R=0.87$ ($F=1.51$, $p=.23$) for the left side pedometer and $R=0.90$ ($F=.97$, $p=.33$) for the right side pedometer; no significant differences were found. Estimates of pedometer consistency (left versus right pedometer) yielded a correlation of $R=0.96$, with follow-up

ANOVA (F=6.46 and p=.02) indicating significant differences between left and right side pedometers. Comparisons of pedometers to the established criterion scores (validity) yielded correlations of R=0.84 (F=1.85, p=.18) for the left pedometer and R=0.79 (F=5.71, p=.02) for the right pedometer. Follow-up ANOVA indicated a significant difference between pedometer and criterion scores for the right pedometer but not the left.

Under the conditions of this study, the pedometer worn at the waist level directly above the left leg provided reliable and valid measures of walking steps taken during typical everyday activities. The pedometer worn on the right side of the body underestimated the number of steps taken. Further research on the influence of leg dominance, surface, shoe type, pedometer brand, and gait is needed.

RELIABILITY AND VALIDITY OF PEDOMETERS

IN A FREE-LIVING ENVIRONMENT

by

ERNEST LEROY BROWN

A thesis submitted in partial fulfillment of the
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TABLE OF CONTENTS

PAGE

LIST OF TABLES iv

LIST OF FIGURES v

CHAPTER

I INTRODUCTION 1

II REVIEW OF LITERATURE 2

III METHODS 5

SUBJECTS 5

DATA COLLECTION 5

DATA ANALYSIS 7

IV STATEMENT OF THE PROBLEM 9

V RESULTS 10

VI DISCUSSION 12

VII CONCLUSIONS 18

REFERENCES 19

APPENDICES

A Subject Information Summary

Sheet One 21

Sheet Two 23

PAGE

B Subject Medical History.. 24

C Informed Consent Form.. 26

D Employer Consent Form.. 28

E Standardized Instructions to Subjects...................................... 30

F Raw data from Pedometer Counts, Criterion Measure
and Recounted Criterion... 31

LIST OF TABLES

TABLE		PAGE
I	Summary of Statistical Results	10
II	Subjects and Type of Surface	14

LIST OF FIGURES

FIGURE PAGE

1. Placement of Pedometers... 6

CHAPTER I

INTRODUCTION

Physical activity and the role it plays in the prevention and treatment of disease has received increasing attention in the last several years. Evidence is continuing to accumulate describing the significant role of physical activity and physical fitness in the prevention and control of cancer, heart disease, diabetes, and osteoporosis (Blair, Kohl, Paffenbarger, Clark, Cooper, & Gibbons, 1989; Leon, Connet, Jacobs, & Rauramaa, 1987). An important question concerns the relationship between physical activity and physical fitness. Physical activity may be defined as movement of the body either intentionally during exercise, or unintentionally during the execution of free-living movements while physical fitness may be defined as the ability of the cardiovascular, respiratory and skeletal-muscular systems to support large muscle rhythmic exercise at an optimal capacity. In order to study this relationship, an accurate measurement tool is needed. To date, no single tool or method has been demonstrated to reliably quantify free-living activities, particularly the number of steps taken during a person's typical day. This shortcoming is due in part to the great variability in clothing, surface, shoe type, and type of activity. The present study was designed to evaluate how well pedometers, worn on the waist, measure the number of steps taken during activity in a typical free-living environment.

CHAPTER II

REVIEW OF LITERATURE

An association exists between the amount of regular exercise (activity), fitness level, and the health benefit received. As the amount and intensity of activity increases, so do the benefits to the body and its systems (Blair, et al. 1989). Coronary heart disease (CHD), cancer, osteoporosis, hypertension, diabetes, depression, as well as all-cause mortality are positively affected by physical activity and physical fitness (United States Centers for Disease Control and Prevention [CDC], and American College of Sports Medicine [ACSM], 1993; Blair, et al. 1989). Leon, et al. (1987) identified specific benefits of regular physical activity: it helps to maintain body weight, may be used as a substitute for smoking, improves high density lipoprotein (HDL) cholesterol level, decreases blood pressure, and improves the glucose-insulin dynamics.

The amount of physical activity that is needed to provide the protective benefits discussed above is under some debate. It has been recommended that a minimum of three days of aerobic activity per week with each session lasting at least 30 minutes and elevating the heart rate to 60%-80% of maximum is needed to achieve a positive effect on physical fitness (ACSM, 1990). However, the CDC and ACSM, in cooperation with the President's Council on Physical Fitness and Sports have recently announced a second set of recommendations (CDC & ACSM, 1993). The new recommendations state that "every American adult should accumulate 30 minutes or more of moderate intensity physical activity over the course of most days of the week" (CDC & ACSM, 1993). It is important to note that these new recommendations were developed to encourage the 78% of the American population who are sedentary or inadequately active to get more physical activity and not to replace the pre-existing recommendation regarding the development of physical fitness. More activity in the typical free-living environment is seen as one of the major ways to meet these revised recommendations.

Paffenbarger, Hyde, Wing, and Hsieh (1986) found that death rates in Harvard graduates declined steadily as energy expenditure on such activities as walking, stair climbing and sports play increased from 500 to 3500 kilocalories per week. In studies comparing the caloric cost of different speeds of walking for the average size Japanese male (165-170 cm tall and 60 kg body weight), Hatano (1993) found that fast walking (125 steps/min) caused 432 calories to be burned over 10,000 steps. Hatano (1993), identified walking 10,000 steps per day as an adequate daily activity target for the prevention of cardiovascular diseases.

Although the benefits of exercise are fairly well understood, researchers have not identified the best method in which to monitor the amount of incidental physical activity that people do. Various measurement tools have been employed to date including: pedometers (Gretebeck, & Montoye, 1992; Hatano, 1993; Tryon, Pinto, & Morrison, 1991; Washburn, Chin, & Montoye,1989), accelerometers (Haskell, Yee, Evans, & Irby, 1993; Klesges, Klesges, Swenson, & Pheley, 1985; LaPorte, Montoye, & Caspersen, 1985; Noland, Danner, Dewalt, McFadden, & Kotchen, 1990; Washburn, Janney, & Fenster, 1990), heart rate monitors (Gretebeck, & Montoye, 1992; LaPorte, et al, 1985), and journals, diaries, and self reports (LaPorte, et al, 1985; Paffenbarger, Blair, Lee, & Hyde, 1993).

Activity monitors must be affordable, convenient, and easily understood if they are to be of any practical benefit. Klesges et al. (1985) outlined four criteria that a measurement tool must meet in order to be considered useful in epidemiological research: (1) it must measure what it is supposed to measure, (2) it must be reliable and consistent,

(3) it must be practical, (4) and it must not alter the population or the behavior under study.

To date, no single measurement tool is known to meet all of the criteria listed above. Each type of measurement tool used to date has met with criticism which keeps it from being widely accepted. Further, the reliability and validity of many tools has not been established.

Pedometers are a tool that potentially can meet the four criteria described by Klesges et al. (1985). Of the variety of movements that most people do in the course of their normal day (e.g., arm movements, standing, walking, sitting, typing, eating, etc.), walking represents an important component of total daily activity. Pedometers provide more objective information about activity levels than do self-reports, questionnaires, or diaries since these methods rely on the memory and recall of the subject. Pedometers are relatively inexpensive and provide easy, understandable feedback on the number of steps that an individual takes. However, very little current work has been done to explore the efficacy of using pedometers to monitor daily physical activity.

If pedometers can be shown to accurately and reliably measure the incidental walking done throughout a typical day, the uses for this tool would be numerous: It could be used (1) in weight loss programs to monitor activity levels, (2) as a tool in epidemiological research, (3) in general research aimed at understanding activity and exercise in humans, and (4) in settings such as physical education classes to monitor student activity levels and provide feedback about the program, the student, and teacher effectiveness. In more general terms, the use of pedometers may help sedentary persons become more active by providing an accurate record of daily activity and enable the setting and monitoring of personal activity goals.

CHAPTER III

METHODS

This study was designed to evaluate how well pedometers measure the number of steps taken during activity in a typical free-living environment.

Subjects

Common occupations and/or activities were chosen in which there was a high probability that a subject would be physically active most of the time during the period of observation. Forty subjects, 21 male, and 19 female, were selected as representatives of people engaging in these occupations or while doing some other free-living activity. In an effort to recruit subjects a number of small businesses in the area of the researchers' residence were approached for volunteer's. Approximately one-half of the subjects were recruited in this manner; the remainder of subjects were co-workers, neighbors, and acquaintances of the researcher. For a breakdown of subjects by activity, shoe type, and gender see Appendix A (sheets one and two). Each subject completed a medical information form, and signed an informed consent prior to participation in the study (Appendices B and C). If a subject was at work while being observed, the researcher also obtained the employer's consent prior to the subjects' participation (Appendix D).

Data Collection

A standardized set of directions were read to each subject describing what was to take place during the observation (Appendix E). The subject was fitted with three brands of pedometers located at the waist level in a position anterior and superior to the iliac spine. Each pedometer was attached to the belt or waistband of the pants or skirt. For purposes of comparison, another pedometer of the same model was worn in the identical position on the other side of the body (see Figure 1 for pedometer positioning). This position was chosen for the pedometers after pilot work showed it to be an acceptably sensitive location.

The same pedometers were used on all subjects. Pedometers used on the left side of the body on the first subject were used on the same side in all subjects and vice-versa.

When ready to begin, all pedometers were zeroed. At a signal the video recorder was started and the subject was told to begin doing his/her normal activity for a 10-minute period. The researcher followed the subjects' movements with the video recorder wherever he/she went. At the end of the 10-minute trial the subject was asked to stop and stand still. The video camera was turned off and the researcher recorded the number of counts from each pedometer. After the counts were recorded the pedometers were reset to zero, and a second 10-minute trial was repeated using the same procedure.

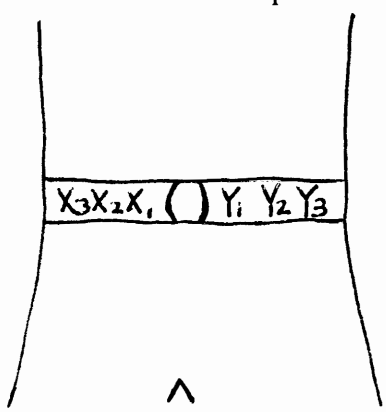

Figure 1. Pedometer Placement (Front view)

X_1, X_2, X_3=Placement of pedometers 1, 2, 3 on the right side; Y_1, Y_2, Y_3= Placement of pedometers 1, 2, 3 on the left side.

Subjects were videotaped using average grade video cassettes. All segments were taped with a Sony Slim Cam camera on normal (SP) speed.

After data had been collected on all subjects, the videotapes were replayed using a model GYYR time lapse video recorder and a Panasonic CT 1330m color video monitor. Steps were counted during each 10-minute segment with the aid of a hand-held counter. To minimize bias when counting steps separate data sheets for the field trials and the videotape counts were used.

For purposes of this study, one step was defined as a movement which satisfied any two of the following three criteria: (1) The foot was raised off of the ground and traveled approximately one foot in any direction. (2) The center of gravity of the subject moved approximately one foot in any direction. (3) The foot was lifted in the air and struck the ground heel first. False steps and gather steps were not recorded from the video analysis based on pilot work which showed these movements to not affect pedometer counts. A false step was defined as a step which did not travel the specified distance and/or did not involve a heel strike. A gather, or balance, step was defined as a movement whereby the subject's trail leg moved even with the lead leg, usually in a slow and controlled manner to help regain balance and posture.

Data Analysis

For this study, data were analyzed from only one of the three brands of pedometers (X_2, and Y_2, Figure 1). Also, data on leg length were not utilized in this study. Data from the other pedometers will be analyzed and included in a more comprehensive study at a future date.

Data was analyzed using SPSS for Windows, release 6.0. An intra-observer reliability analysis was performed to evaluate observer reliability when determining the criterion counts. Intra-observer reliability was calculated as follows: The researcher recounted, independently, the number of steps taken on 10 randomly selected videotaped trials. The results of count number one and count number two were analyzed using intraclass correlation (R) with follow-up ANOVA. Intra-observer reliability was completed before any other data analysis in an effort to document the stability of the criterion measurement scores.

Pedometer counts were then analyzed for reliability. The first reliability analysis investigated trial-to-trial variance. Trial 1 pedometer counts (first 10-minute segment) were compared to trial 2 pedometer counts (second 10-minute segment) from the same pedometer using intraclass correlation (R) with follow-up ANOVA. This established the amount of error variance between two trails involving the same subject, under similar conditions. Knowledge of the error variance between trials assisted in further analyses of reliability and validity.

The second reliability analysis was calculated to determine the consistency of the two pedometers using intraclass correlation (R) with follow-up ANOVA. The sums of counts from the left side pedometer for trials one and two were compared with similar sums from the right side pedometer using intraclass correlation with follow-up ANOVA.

Criterion validity was calculated using intraclass correlation (R) with follow-up ANOVA. For each pedometer, the sum of each subject's trial 1 and trial 2 counts was compared with the sum of each subject's trial 1 and trial 2 video counts.

An alpha level of .05 was accepted as significant on all ANOVA trials.

CHAPTER IV

STATEMENT OF THE PROBLEM

The question of interest focused on the ability of a pedometer to accurately represent the number of steps taken in a variety of common daily activities.

It was hypothesized that: (1) The intraclass reliability estimates for trial-to-trial variance would be greater than or equal to R=0.80 and there would be no statistically significant difference between trials; (2) the intraclass reliability estimates for pedometer consistency would be greater than or equal to R=0.80 and there would be no statistically significant difference between pedometers; and (3) intraclass correlation between pedometer counts and actual steps made by subjects during two 10-minute videotaped trials would be greater than or equal to R=0.80 and there would be no statistically significant difference between measures.

CHAPTER V

RESULTS

The statistical results of this study are summarized in Table 1. The raw data from the pedometer counts, including the intra-tester data can be found in Appendix F.

TABLE I

SUMMARY OF STATISTICAL RESULTS

	Intra-Observer Reliability	Trial to Trial Variance		Pedometer Consistency	Pedometer Validity	
		Left Side	Right Side		Left Side	Right Side
Intraclass Correlation (R)	0.99	0.87	0.90	0.96	0.84	0.79
Follow-up ANOVA						
F	1.36	1.51	0.97	6.46	1.85	5.71
p	0.27	0.23	0.33	0.02*	0.18	0.02*

* = significant

Intra-observer reliability was high (R=0.99), and follow-up ANOVA indicated there was no statistically significant difference between means (F=1.36, p=.27).

In the analysis of trial-to-trial variance it was hypothesized that intraclass reliability estimates would be greater than R=0.80 with a non-significant difference between trials on follow-up ANOVA. Intraclass reliability estimates indicated a correlation of R=0.87; (F=1.51; p=.23) for the left side pedometer. For the right side pedometer, R=0.90, (F=.97; p=.33).

The intraclass reliability estimate for pedometer consistency, hypothesized to be equal to or greater than R=0.80 with no significant differences between means, was calculated to be R=0.96. A significant difference between left and right side trials

(F=6.46; p=.02) was found. The mean for pedometers on the left side was higher than the mean for pedometers on the right.

Criterion validity of each pedometer was hypothesized to be equal to or greater than R=0.80 with no significant difference on follow-up ANOVA. Intraclass reliability estimates indicated correlations of R=0.84 for the left pedometer (F=1.85; p=.18). The right side pedometer had a correlation of R=0.79 (F=5.71; p=.02). Again, right side pedometer measures were lower on average than the criterion counts.

CHAPTER VI

DISCUSSION

Three major considerations were used in the design of this study: (1) Occupations/situations that were chosen for observation were expected to involve standing or walking activities during approximately 70% of the trials; this was done merely as a attempt to be economical with gathering data. Subjects were not studied if they spent a majority of their time in a non-active state. (e.g., seated, standing still, or rarely moving from their seat). (2) Occupations/activities observed were representative of those which people typically engage in while doing various free-living situations; this was done to increase criterion validity of the study. (3) No subject was used if he/she had a noticeable irregularity in their gait pattern such as a limp.

The outcome of the intra-observer reliability analysis indicated very high internal consistency in counting steps from the videotape. These results allowed the researcher to have confidence when using the criterion measure during subsequent reliability and validity analyses.

Trial to trial reliability estimates were also good and the research hypothesis was supported. Under the conditions of this study pedometers appear to give reliable results during repeated trials on the same side of the body. However, the analysis of pedometer consistency, in which counts from one side of the body were compared to counts from the other side, showed a different outcome. While the consistency correlation was high, a significant difference was found between trials on the left and right pedometers in terms of total number of steps that each recorded.

Reasons for this outcome are unclear. The influence of leg dominance may potentially be a contributing factor. The left side pedometer, in most cases, recorded a higher absolute value than did the right side pedometer. This may be due to the influence of the dominant leg in the gait pattern of the subject and should be investigated further. Another possibility is that an instrument bias may have been introduced inadvertently through the consistent placement of the same pedometer on the same side of the body in all subjects. Thus, if one of these pedometers had been manufactured poorly, data from this pedometer would be faulty in all subjects. This possibility can not be ruled out but may be resolved when data on other pedometers is analyzed in a future study.

During the analysis of validity the issue of significant differences during follow-up ANOVA arose again. The significant difference occurred when the sum of the counts for the right side pedometer was compared to the sum of the criterion counts. Reasons for this are unclear.

A number of variables may have contributed to pedometer error in this study. One source of error is from the instrument itself. The pedometer used in this experiment ("Walking Friend" TW10 by Citizen) was readily available at the time of the study. Results from this study pertain only to this brand and model, and they cannot be generalized to all brands of pedometers. Further, various studies have found mechanical errors with pedometers, particularly arising from the spring used in the counting mechanism (Gretebeck, & Montoye, 1992; Haskell, et al. 1993; Tryon, et al. 1991). However, Tryon et al. (1991), has criticized this research for classifying all pedometers as invalid simply because some models have proven unreliable. This is an important point, as with any mechanical instrument quality control is very important. Some brands of pedometers are bound to be more accurate and useful than others.

Other sources of error, not controlled for, are the effects of extraneous variables such as clothing, floor surface, shoes, and non-detected gait abnormalities. Subjects with unusual gait patterns such as a limp, or subjects who walk primarily on their toes or heels were not included in the study. Surfaces were typical for the occupation/situation being observed and as such varied from one subject to another. See Table II below for a list of subjects by the type of surface in which activity took place.

TABLE II

SUBJECTS AND TYPE OF SURFACE

Type of Surface	Number of Subjects
Linoleum	6
Carpet with pad	1
Carpet without pad	14
Carpet / Linoleum	5
Dirt	3
Grass	2
Grass / Dirt	1
Asphalt	3
Concrete	1
Gravel / Asphalt	1
Concrete / Dirt	2
Dirt / Gravel	1

Shoes worn for the study were the same shoes that subjects wore on the day of the trial and varied from person to person. These potential sources of variability were not controlled for.

A number of unforeseen, and confounding issues arose which potentially affected the recording ability of the pedometer. These included: kneeling down, getting up from a kneeling position, going up and down ladders, shuffling, side stepping, and walking backwards. On average these movements occurred in no more than 10% of the time that subjects were observed. Also of concern is the influence of short, soft, and fast steps on pedometer accuracy. Clearly each of these locomotive patterns need to be accurately counted by pedometers if they are to be useful in practical terms. Further research should examine each of these gait patterns in a controlled environment.

It is the opinion of the researcher that the influence of various types of waistbands and belts should also be explored further. Thickness, tension, and position of the waistband potentially may influence pedometer accuracy. Observation suggests that loose waistbands tend to reduce the effectiveness of the pedometers to record steps because of more "give" on foot impact. The influence of waistband or belt tension also should be explored in a more controlled environment.

Another influence on the ability of the pedometer to record steps taken was the waist size of the person. Pedometers are activated by oscillating vertical movements of the center of gravity only if the pedometer is in a vertical position itself. Based only on observation, it is the opinion of the researcher that pedometers on larger waisted individuals tended to under-record the actual number of steps taken in any given ten-minute segment. Such an underestimate of steps is believed to be caused by the pedometer being tilted out horizontally by the waist in such persons, causing the spring in the pedometer to lose its ability to react to the forces associated with the impact of the foot upon the ground.

The influence of shoe type and ground surface are also not fully understood. In some cases soft carpet, grass, and soft dirt surfaces may play a major role in the accuracy of the pedometer by reducing the impact force of the foot upon the ground. In other situations (e.g., hard carpet, linoleum, gravel, hard dirt, asphalt, and concrete) the influence of surface on the pedometer was not as easily observable. Shoe type may have different effects depending on the stiffness of the shoe and amount of cushioning. Again, to fully understand these influences each of these variables should be explored in a controlled environment.

Other suggestions for future research would be to explore the possible role of pedometers in the field of exercise science. Is the pedometer a tool that will play a positive role in behavior change? Can the pedometer be a motivation tool which encourages people to be more active? Is the pedometer a tool that lends itself to long term use by individuals? These are all questions that should be explored.

There are a number of areas in which the pedometer may be useful at the present time before the previously stated questions are answered: The pedometer can be a useful tool in studies designed to explore the impact of the amount of free-living activity on health and wellness. Pedometers can be used by people interested in monitoring their overall daily activity levels and using this information in weight loss or fitness programs. Pedometers may also be used by instructors in physical education or fitness classes to monitor the activity levels of the group or of certain individuals. This information could in turn be used for evaluating the program or the participants compliance to the program.

There were two issues specifically related to subject involvement that need to be addressed if others intend to duplicate the methods of data collection and analysis used in this study. The first issue is one of subject recruitment. In order to observe subjects in a free-living environment the researcher initially began subject recruitment by approaching larger businesses in a typical metropolitan area. Two problems with this approach became readily apparent. First, businesses were reluctant to give permission for the researcher to approach employees regarding their involvement in the study. It appeared that business owners and managers held the perception that the research methods would be to disruptive to the work environment as well as to potential customers. In large businesses there were also issues surrounding the researcher's appearance in the place of business, such as possibly being in the way of customers and/or making customers nervous. There was also difficulty finding people in larger businesses willing, or able, to give permission for the research to occur. The perception that problems may occur was a negative influence on obtaining subjects. In actuality, no problems associated with the researchers appearance or disrupting effect seemed to occur. More cooperation was found when private individuals and smaller businesses were approached regarding their participation.

The second issue involved the inhibiting effects on some subjects of being videotaped. All forty subjects were given specific instructions to disregard the camera and carry on with tasks normally. However, a small minority of the subjects seemed to be hesitant; these subjects seemed to change their gait patterns or slow down. This situation may have occurred because some subjects felt that the researcher could not keep up with them if they moved normally. When this occurred the researcher would remind the subject to move naturally; in nearly all cases the subject would comply. It is not known why this occurred or what influence it had on the results of the study.

CHAPTER VII

CONCLUSIONS

Under the conditions of this study, pedometers worn at the waist level directly above the left leg appear to provide reliable and valid measures of walking steps taken during typical everyday activities. Pedometers worn on the right side of the body underestimate the number of steps taken. Further research should be undertaken to explore the influence of leg dominance, surface, shoe type, pedometer brand, and gait pattern on pedometer reliability, consistency, and validity.

REFERENCES

American College of Sports Medicine. (1990). Position stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Medicine and Science in Sport and Exercise, 22, 265-274.

Blair, S. N., Kohl, H. W., Paffenbarger, R. S., Clark, D. G., Cooper, K. H., & Gibbons, L. W. (1989). Physical fitness and all-cause mortality: A prospective study of healthy men and women. Journal of the American Medical Association, 262, 2395-2341.

Dishman, R. K. Darracott, C. R., & Lanbert, L. T. (1992). Failure to generalize determinants of self reported physical activity to a motion sensor. Medicine and Science in Sport and Exercise, 24, 904-910.

Gretebeck, R. J., & Montoye, H. J. (1992). Variability of some objective measures of physical activity. Medicine and Science in Sport and Exercise, 24, 1167-1172.

Haskell, W. L., Yee, M. C., Evans, A., & Irby, P. J. (1993). Simultaneous measurement of heart rate and body motion to quantitate physical activity. Medicine and Science in Sport and Exercise, 25, 109-115.

Hatano, Y. (1993). Use of the pedometer for promoting daily walking. ICHPER, 29, 4-8.

Klesges, R. A., Klesges, L. M., Swenson, A. M., & Pheley, A. M. (1992). A validation of two motion sensors in prediction of child and adult physical activity levels. American Journal of Epidemiology, 122, 400-410.

Laporte, R. E., Montoye, H. J., & Caspersen, C. J. (1985). Assessment of physical activity in epidemiologic research: Problems and prospects. Public Health Reports, 100, 131-146.

Laporte, R. E., Kuller, L. H., Kupfer, D. J., McPartland, R. J., Mathews, G., & Caspersen, C. (1979). An objective measure of physical activity for epidemiologic research. American Journal of Epidemiology, 109, 158-168.

Leon, A. S., Connett, J., Jacobs, D. R., & Rauramaa, R. (1987). Leisure-time physical activity levels and risk of coronary heart disease and death. Journal of the American Medical Association, 258, 2388-2395.

Norland, M., Danner, F., Dewalt, K., McFadden, M., & Kotchen, M. (1990). The measurement of physical activity in young children. Research Quarterly for Exercise and Sport, 61, 146-153.

Paffenbarger, R. S., Blair, S. N., Lee, I. M., & Hyde, R. T. (1993). Measurement of physical activity to assess health effects in free-living populations. Medicine and Science in Sport and Exercise, 25, 60-70.

Paffenbarger, R. S., Hyde, M. A., Wing, A. L., Hsieh, C. C. (1986). Physical activity, all-cause mortality, and longevity of college alumni. The New England Journal of Medicine, 314, 605-613.

Tyron, W. W., Pinto, L. P., & Morrison, D. F. (1991). Reliability assessment of pedometer activity measurements. Journal of Psychopathology and Behavior Assessment, 13, 29-44.

U. S. Centers for Disease Control and Prevention, & American College of Sports Medicine. (1993). Summary statement; workshop on physical activity and public health. Sports Medicine Bulletin, 28, 7.

Washburn, R. A., Chin, M. K., & Montoye, H. J. (1980). Accuracy of pedometer in walking and running. Research Quarterly for Exercise and Sport, 51, 695-702.

Washburn, R. A., Janney, C. A., & Fenster, J. R. (1990). The validity of objective physical activity monitoring in older individuals. Research Quarterly for Exercise and Sport, 621, 114-117.

Washburn, R. A., & Laporte, R. E. (1988). Walking behavior: Effect of speed and monitor position on two objective physical activity monitors. Research Quarterly for Exercise and Sport, 59, 83-85.

APPENDIX A

SUBJECT INFORMATION SUMMARY

SHEET ONE - SUBJECTS LISTED BY OCCUPATION OR ACTIVITY

Subject	Activity	Shoe Type	Surface	Gender
1	Painting	Tennis	Linoleum	M
2	Floor Waxing	Tennis	Linoleum	M
3	Vacuuming Floor	Tennis	Carpet	F
4	Retail-Cleaning	Dress-Loafer	Hard Carpet	F
5	Retail-Cleaning	Dress-Flats	Hard Carpet	F
6	Cooking	Tennis	Linoleum	F
7	Stocking Shelves	Women's Casual	Hard Carpet	F
8	Cleaning	Slippers	Hard Carpet	M
9	Copying, Misc.	Dress-Flats	Hard Carpet	F
10	Walking in Garden	Tennis	Grass & Dirt	F
11	Shopping	Birkenstock	Gravel & Asphalt	M
12	Cooking	Tennis	Linoleum	F
13	Cleaning Classroom	Male Casual	Linoleum	M
14	Electrician	Tennis	Concrete & Dirt	M
15	Drywall mudding	Tennis	Concrete & Dirt	M
16	Mail Store-Misc.	Women's Flats	Hard Carpet	F
17	Construction	Tennis	Dirt & Gravel	M
18	Cooking-Cleaning	Tennis	Linoleum	F
19	Vacuum-Janitorial	Tennis	Hard Carpet	M
20	Cleaning	Tennis	Hard Carpet & Linoleum	M
21	Organizing Classroom	Tennis	Hard Carpet	M
22	Moving	Tennis	Carpet & Linoleum	F
23	Organizing Classroom	Tennis	Carpet & Linoleum	M
24	Moving	Tennis	Hard Carpet	F
25	Moving	Tennis	Carpet & Linoleum	M
26	Inventory	Running	Concrete	F
27	Computer Maintenance	Birkenstock	Hard Carpet	F

APPENDIX A

SUBJECT INFORMATION SUMMARY

SHEET ONE - SUBJECTS LISTED BY OCCUPATION OR ACTIVITY (CONTINUED)

Subject	Activity	Shoe Type	Surface	Gender
28	Cleaning Room	Running	Hard Carpet	M
29	Mail Store-Misc.	Keds	Hard Carpet	F
30	Mail Store-Misc.	Sandals	Hard Carpet	F
31	Stocking Shelves	Tennis	Hard Carpet	M
32	Golf	Tennis	Grass	M
33	Lawn Mowing	Tennis	Grass	M
34	Walking at Zoo	Sandals	Asphalt	M
35	Walking at Zoo	Tennis	Asphalt	F
36	Landscaper	Boots	Dirt	M
37	Landscaper	Boots	Dirt	M
38	Landscaper	Hiking Shoe	Dirt	M
39	Washing a Trailer	Bare Feet	Asphalt	F
40	Cooking-Misc. House	Stocking Feet	Carpet & Linoleum	F

APPENDIX A

SUBJECT INFORMATION SUMMARY

SHEET TWO - NUMBER OF SUBJECTS LISTED BY OCCUPATION OR ACTIVITY

Occupation or Activity	Number of Subjects
Janitors	4
Maid	1
Retail Clerk	2
Cook	2
Video Store Clerk	2
Secretary	1
Tourist	4
Teachers	10
Electrician	1
Drywall Mudder	1
Postal Store Employee	3
Construction	1
Housework	2
Golf	1
Lawn Mowing	1
Landscaper	3
Washing a trailer	1

APPENDIX B

SUBJECT MEDICAL HISTORY

Portland State University 11/89
Exercise Physiology Laboratory

MEDICAL HISTORY

Please indicate by checking which of the following conditions, if any, you have experienced previously. For any "yes" answers, please use the space at the bottom of this form to supply additional information including nature of the event, date, and/or any other relevant information.

Have you ever experienced or been told you had:

heart attack	yes	______	no	______
coronary bypass surgery	yes	______	no	______
other cardiac surgery	yes	______	no	______
chest discomfort - especially with exertion	yes	______	no	______
high blood pressure	yes	______	no	______
extra, skipped, or rapid heart beats (palpitations)	yes	______	no	______
heart murmurs, clicks, or unusual cardiac findings	yes	______	no	______
rheumatic fever	yes	______	no	______
ankle swelling	yes	______	no	______
peripheral vascular disease	yes	______	no	______
phlebitis	yes	______	no	______
embolism	yes	______	no	______
unusual shortness of breath	yes	______	no	______
lightheadedness or fainting	yes	______	no	______
pulmonary disease including				
asthma	yes	______	no	______
emphysema	yes	______	no	______
bronchitis	yes	______	no	______
abnormal blood lipids	yes	______	no	______
diabetes	yes	______	no	______
stroke	yes	______	no	______
emotional disorders	yes	______	no	______

APPENDIX B

SUBJECT MEDICAL HISTORY
(CONTINUED)

recent illness, hospitalization or surgery	yes	______	no	______
drug allergies	yes	______	no	______
orthopedic problems, arthritis	yes	______	no	______
parents, siblings, grandparents, aunts, uncles with history of:				
coronary disease - at what age? __________	yes	______	no	______
sudden death - at what age? _________	yes	______	no	______
congenital heart disease	yes	______	no	______

Are you currently taking any medications? If so, please specify:

Which of these, if any, do you regularly use?

caffeine including cola drinks	yes	______	no	______
when last?_______ how much? _______				
alcohol	yes	______	no	______
when last?_______ how much? _______				
tobacco	yes	______	no	______
when last?_______ how much? _______				
other unusual habits of dieting	yes	______	no	______
please explain if any:				

Please provide a brief history of your habitual level of activity:

type of exercise:
frequency:
duration:
intensity:
how long:

ADDITIONAL COMMENTS:

APPENDIX C

INFORMED CONSENT FORM

The Validity and Reliability of Pedometers in a Free-Living Environment.

I, ______________________________________ , agree to take part in this experimental research project conducted by researchers in the Department of Public Health Education at Portland State University investigating the accuracy of pedometers in measuring activity in a free-living environment.

I understand that the study involves wearing six pedometers and being video taped while I carry out my normal, daily tasks. The entire process will take no more that one hour of my time.

I understand that, because of this study, there is very little in the way of hazards or risks that I may experience. I may become distracted while being video-taped but I have been cautioned against this.

Ernest Brown has told me that the purpose of the study is to determine the ability of a pedometer to accurately measure the number of steps taken when a subject is engaged in free-living activities.

I may not receive any direct benefit from taking part is this study, but the study may help to increase knowledge that may help others in the future.

Ernest Brown has offered to answer any questions I have about the study and what I am expected to do.

He has promised that all information I give will be kept confidential to the extent permitted by law, and that the names of all people in the study, including my employer, will be kept confidential.

I understand that I do not have to take part in this study, and that this will not affect my relationship with Portland State University. I also understand that I may stop the video or withdraw from this study at any time without affecting my relationship with Portland State University.

APPENDIX C

INFORMED CONSENT FORM
(CONTINUED)

I have read and understand the above information and agree to take part in this study.

Date:________________________ Signature:__________________________________

Date:________________________ Signature:__________________________________

If you have concerns or questions about this study, please contact the Chair of the Human Subjects Research Review Committee, Office of Grants and Contracts, 105 Neuberger Hall, Portland State University, 503/725-3417.

APPENDIX D

EMPLOYER CONSENT FORM

The Validity and Reliability of Pedometers in a Free-Living Environment.

I, ______________________________, agree to allow my employee to take part in this experimental research project conducted by researchers in the Department of Public Health Education at Portland State University investigating the accuracy of pedometers in measuring activity in a free-living environment.

I understand that the study involves the subject wearing six pedometers and being video taped while carrying out normal, daily tasks. There will be two 10 minute video segments with a slight pause between them to record data. The entire process will take no more that one hour of my employee's time.

I understand that, because of this study, there is very little in the way of hazards or risks that I may experience. My employee may become distracted while being video-taped but they have been cautioned against this.

Ernest Brown has told me that the purpose of the study is to determine the ability of a pedometer to accurately measure the number of steps taken when a subject is engaged in free-living activities.

I may not receive any direct benefit from taking part is this study, but the study may help to increase knowledge that may help others in the future.

Ernest Brown has offered to answer any questions I have about the study and what my employee is expected to do.

He has promised that all information gathered will be kept confidential to the extent permitted by law, and that the names of all people in the study will be kept confidential.

I understand that I do not have to allow my employee to take part in this study, and that this will not affect my relationship with Portland State University. I also understand that I may stop the video or withdraw my employee from this study at any time without affecting my relationship with Portland State University.

APPENDIX D

EMPLOYER CONSENT FORM
(CONTINUED)

I have read and understand the above information and agree to allow my employee to take part in this study.

Date:________________________ Signature:__________________________________

Date:________________________ Signature:__________________________________

If you have concerns or questions about this study, please contact the Chair of the Human Subjects Research Review Committee, Office of Grants and Contracts, 105 Neuberger Hall, Portland State University, 503/725-3417

APPENDIX E

STANDARDIZED INSTRUCTIONS TO SUBJECTS

The following instructions were read to each subject prior to placement of the pedometers on the waistband and commencement of videotaping.

- Remain standing until the signal to move is given.
- Once the signal to move is given, proceed with your tasks in the manner you typically would. Do not pay attention, or be concerned with, the camera or the researchers appearance. I will video-tape your activities, focusing the video-tape on your feet, for ten minutes.
- When you are given the signal to stop, please hold your position without moving your feet. At this time I will record the numbers from the pedometers and reset them. Please stand still throughout this process.
- You will then be given a signal to continue with your activities. I will video-tape your activities for ten more minutes.
- At the end of the second ten-minute segment you will be given another signal to stop. Again, please stand still until the numbers are recorded and pedometers are returned to the researcher.
- If you feel uncomfortable at any time during this process you may withdraw. Also, let the researcher know if any concerns arise.

APPENDIX F

RAW DATA FROM PEDOMETER COUNTS, CRITERION MEASURE, AND RECOUNTED CRITERION

	Trial 1			Trial 2			Recount	Sum		
Subject	Left	Right	Crite-rion	Left	Right	Crite-rion	Crite-rion*	Left	Right	Crite-rion
1	233	172	126	208	190	113		441	362	239
2	163	223	168	100	113	160		263	336	328
3	8	14	57	19	26	92		27	40	149
4	103	129	117	55	72	61		158	201	178
5	161	105	159	104	107	159		265	212	318
6	237	275	257	167	108	250		404	383	507
7	201	143	233	195	138	269		396	281	502
8	140	174	106	224	195	198		364	369	304
9	193	171	210	87	92	70	85(2)	280	263	280
10	236	236	184	300	283	220		536	519	404
11	217	311	369	163	201	231		380	512	600
12	347	307	303	218	212	188		565	519	491
13	352	306	274	187	155	128		539	461	402
14	155	143	129	183	178	159		338	321	288
15	228	243	206	111	112	144	146(2)	339	355	350
16	133	143	137	85	85	82	139(1)	218	228	219
17	4	148	126	129	109	66		133	257	192
18	125	128	148	184	173	186	153(1)	309	301	334
19	164	168	241	159	154	201		323	322	442
20	183	176	247	292	272	272		475	448	519
21	312	249	334	79	35	68		391	284	402
22	429	408	350	561	550	485		990	958	835
23	74	84	433	49	93	667		123	177	1100
24	913	713	1010	723	691	760		1636	1404	1770
25	366	374	712	458	491	515	701(1)	824	865	1227
26	156	117	110	290	243	203		446	360	313
27	151	139	146	130	141	131	146(1)	281	280	277
28	130	81	137	126	111	159		256	192	296
29	134	84	138	238	157	219	204(2)	372	241	357

APPENDIX F

RAW DATA FROM PEDOMETER COUNTS, CRITERION MEASURE, AND RECOUNTED CRITERION (CONTINUED)

	Trial 1			Trial 2			Recount	Sum		
Subject	Left	Right	Crite-rion	Left	Right	Crite-rion	Crite-rion*	Left	Right	Crite-rion
30	54	38	58	65	47	67		119	112	125
31	268	249	226	160	163	160	209(1)	428	412	386
32	454	384	426	515	471	509		969	855	935
33	57	3	495	46	2	473		103	5	968
34	501	486	532	390	384	397	519(1)	891	870	929
35	279	2	320	247	57	332		526	59	652
36	168	197	123	185	173	114		353	370	237
37	476	222	255	121	105	104		597	327	359
38	117	131	77	206	227	130	124(2)	323	358	207
39	91	56	97	211	163	187		302	219	284
40	166	164	171	77	71	61		243	235	232
Mean	221.98	197.40	248.68	201.18	183.75	224.75	242.60	423.15	381.15	473.42
SD	165.67	139.10	187.49	149.08	147.24	168.95	201.51	296.47	272.78	341.57
SE	26.19	21.99	29.64	23.57	23.28	26.71	63.72	46.88	43.13	54.01

* Number in the parentheses indicates which trial was recounted trial