8-2004

Accuracy of Pedometers and their use in a 10,000 Steps Per Day Intervention Study

Patrick L. Schneider

To the Graduate Council:

I am submitting herewith a dissertation written by Patrick L. Schneider entitled "Accuracy of Pedometers and their use in a 10,000 Steps Per Day Intervention Study." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

David R. Bassett, Major Professor

We have read this dissertation and recommend its acceptance:

Howley, Thompson, Truett

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a dissertation written by Patrick L. Schneider entitled "Accuracy of Pedometers and their use in a 10,000 Steps Per Day Intervention Study." I have examined the final paper copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

David R. Bassett, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor and Dean of
Graduate Students

ACCURACY OF PEDOMETERS AND THEIR USE IN A 10,000 STEPS PER DAY INTERVENTION STUDY

A Dissertation
Presented for the
Doctor of Philosophy Degree
The University of Tennessee

Patrick L. Schneider

August 2004

ACKNOWLEDGEMENTS

I would like to offer sincere thanks to my mentor, Dr. David Bassett, Jr., for his guidance and direction throughout the course of my doctoral studies. It was a privilege to have worked with him on a variety of projects and he undoubtedly invested more time into my education and development as a researcher than anyone else. I have great respect for his knowledge and feel fortunate to have worked under his supervision.

I would also like to extend thanks to my committee, Drs. Howley, Thompson, and Truett for their valuable input on my dissertation as well as their investment in my education in the classroom. I was blessed to have had the opportunity to work with such a great group of individuals.

A special thanks goes to Scott Crouter for all of his input throughout this process. His expertise in all areas made this project much easier.

I would also like to express my gratitude to all the participants in my studies. I am very thankful for the time and effort they invested into my research.

A final thanks goes out to my family. To my parents and sisters for their understanding and encouragement throughout my studies. Their support along the way has made this journey tolerable. And to my wife Erin, for her constant motivation, love, and sacrifice throughout my educational process. I couldn't have done it without her. It's been a long and road we've traveled together and there is nobody I would have rather done it with.

This research was supported by the James D.Moran and Monica Moran Dissertation Award and the Charlie and Mai Coffey Endowment in Exercise Science.

ABSTRACT

ACCURACY OF PEDOMETERS AND THEIR USE IN A 10,000 STEPS PER DAY INTERVENTION STUDY

This dissertation was designed to assess pedometer accuracy under both controlled and free-living conditions and to assess the efficacy and feasibility of the 10,000 steps per day exercise prescription in sedentary, overweight men vs. women. The specific aims were to 1) assess the accuracy of 10 electronic pedometers over the course of a 400-m walk; 2) compare the step values of multiple brands of pedometers over a 24-hour period; 3) compare the effects on body composition, cardiovascular risk factors and adherence in response to a 10,000 steps per day exercise prescription in overweight men vs. women.

First, the accuracy and reliability of 10 electronic pedometers was assessed over the course of a 400-m walk. Ten males and 10 females ranging in body mass index (BMI) from 19.8 to 33.6 $kg \cdot m^{-2}$ walked 400-m around an outdoor track while wearing two pedometers of the same model (one on the right and left sides of the body) for each of ten models. Four pedometers of each model were assessed in this fashion. The Kenz Lifecorder (KZ), New Lifestyles NL-2000 (NL), and the Yamax Digi-Walker SW-701 (DW) were the most accurate in counting steps, displaying values that were within ±3% of the actual steps taken, 95% of the time. The Sportline 330 (SL330) and Omron HJ-105 (OM) were the least accurate, displaying values that were within ±37% of the actual steps, 95% of the time. The reliability within a single model (Chronbach's alpha) was >0.80 for all pedometers with the exception of the SL330. The intra-model reliability was exceptionally high (>0.99) in the KZ, OM, NL, and the DW.

Second, a comparison of 13 pedometer models was made over a 24-hour period. Ten males and ten females ranging in BMI from 19.8 to 35.4 $kg \cdot m^{-2}$ wore two pedometers for a 24-hour period. The criterion pedometer Yamax Digi-Walker SW-200 (YX200) was worn on the left side of the body and a comparison pedometer was worn on the right. Steps counted by each device were recorded at the end of the day for each of the thirteen pedometers. Subjects took an average of 9,244 $steps \cdot d^{-1}$. The KZ, YX200, NL, Yamax Digi-Walker SW-701 (YX701), and SL330 yielded mean values that were not significantly different from the criterion. The Freestyle Pacer Pro (FR), Accusplit Alliance 1510 (AC), Yamax Skeletone EM-180 (SK), Colorado on the Move (CO), and Sportline 345 (SL345) significantly underestimated steps ($P<0.05$) and the Walk4Life LS 2525 (WL), OM, and Oregon Scientific PE316CA (OR) significantly overestimated steps ($P<0.05$) when compared to the criterion. In addition, some pedometers underestimated by 25% while others overestimated by 45%.

Third, a comparison of the effects on body composition, cardiovascular risk factors and adherence was made in response to a 10,000 steps per day exercise prescription in sedentary, overweight males vs. females. Fifteen men (46 $\pm$ 7 yrs) (mean $\pm$ SD) and twenty-four women (48 $\pm$ 5 yrs) who were overweight or obese participated in a 10,000 steps per day intervention for 36 weeks. Body weight, BMI, percent body fat, fat mass, fat-free mass, waist circumference, hip circumference, systolic blood pressure, diastolic blood pressure, and heart rate were determined at baseline, after 20 weeks and again after 36 weeks. A blood lipid profile was assessed at baseline and after 36 weeks. Men and women given a 10,000 steps per day exercise prescription experienced similarly significant improvements in body weight, BMI, percent body fat, fat mass, waist and hip

circumferences, and HDL-C. When men and women were combined to explore the effect of adherence to the exercise prescription, the adherers significantly reduced body weight, BMI, percent body fat, fat mass, waist circumference, and hip circumference after 36 weeks while the non-adherers experienced little or no change in these variables. Thus, the 10,000 steps per day exercise prescription was effective at increasing daily walking volume which resulted in significant improvements in body weight and body composition in overweight, sedentary, middle-aged men and women.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

PART III: ACCURACY AND RELIABILTIY OF TEN PEDOMETERS FOR MEASURING STEPS OVER A 400-M WALK

PART IV: PEDOMETER MEASURES OF FREE-LIVING PHYSICAL ACTIVITY: COMPARISON OF 13 MODELS

PART V: EFFECTS OF A 10,000 STEPS PER DAY GOAL IN OVERWEIGHT MEN VS. WOMEN

LIST OF FIGURES

FIGURE PAGE

PART III: ACCURACY AND RELIABILTIY OF TEN PEDOMETERS FOR MEASURING STEPS OVER A 400-M WALK

PART IV: PEDOMETER MEASURES OF FREE-LIVING PHYSICAL ACTIVITY: COMPARISON OF 13 MODELS

PART I

INTRODUCTION

Numerous prospective epidemiological studies support the belief that a physically active lifestyle is associated with positive health related outcomes. Several studies confirm the beneficial impact that physical activity can have on a variety of health conditions including cardiovascular disease, hypertension, obesity, type 2 diabetes, osteoporosis, and certain types of cancers (2). Despite the large body of evidence supporting the multiple benefits of physical activity, most Americans are either inactive or insufficiently active. According to the 1996 Surgeon General's Report, 60% of U.S. adults do not engage in regular leisure-time activity and about 25% report no leisure-time physical activity (35). More recently, the Behavioral Risk Factor Surveillance System (BRFSS) indicated that approximately 55% of American adults are not sufficiently active to achieve health benefits (5). Healthy People 2010 has placed physical activity among its leading health indicators which reflect the major public health concerns of the United States and were chosen based on their ability to motivate action, the availability of data to measure their progress, and their relevance as broad public health issues (37). Two of the 14 physical activity and fitness goals of Healthy People 2010 are to reduce the proportion of adults who engage in no leisure-time physical activity and to increase the proportion of adults who are regularly active (37).

The most recent physical activity recommendations have shifted from the traditional exercise prescription that focused on vigorous intensity activity for the attainment of cardiorespiratory benefits to one of moderate intensity activity that has been shown to improve health outcomes. Evidence from prospective studies in the early 1990's showed that physical activity of lower intensity, duration, and frequency than required to improve cardiorespiratory fitness could produce significant improvements in health outcomes. The current recommendation issued by the American College of Sports Medicine (ACSM) and the Centers for Disease Control and Prevention (CDC) in 1995, encourages American adults to accumulate at least 30 minutes of moderate-intensity physical activity on most, if not all days of the week (24). It was thought that a recommendation that allowed for the accumulation of moderate intensity physical activity through lifestyle activities may decrease the proportion of sedentary adults in the United States.

As an alternative to the current ACSM/CDC physical activity recommendation, Dr. Hatano of Japan believes that taking 10,000 steps per day is the amount of physical activity needed for cardiovascular disease prevention (12). Hatano has found that increased ambulatory activity is associated with lower levels of blood pressure and subcutaneous fat (11). Hatano estimated that a 60 kg Japanese male would expend at least 333 kcal in walking 10,000 steps (12). Previous research indicates that this amount (>2000 kcals/wk) appears to be protective against heart attacks (23). In addition, longitudinal studies have demonstrated that walking 10,000 steps per day results in improvements in cardiovascular disease risk factors in sedentary, at-risk populations (20, 31). This particular physical activity recommendation has been rather highly publicized in popular periodicals (13, 26).

Physical activity can be viewed as a complex interaction between frequency, intensity, type and duration, which make it difficult to accurately measure. Thus, physical activity assessment has been a challenge for researchers attempting to accurately and objectively quantify this multifaceted behavior. Current methods for assessing physical activity include questionnaires, doubly labeled water, heart rate monitors, and motion sensors. It is well documented that each method has its own advantages and limitations (4, 34, 38).

Of the several methods that exist regarding physical activity assessment, motion sensors, which include accelerometers and pedometers, have some distinct advantages in regard to the objective measurement of physical activity. Accelerometers have the ability to monitor and store the actual magnitude of acceleration and deceleration of motion. However, although accelerometers provide a direct measure of physical activity, they are quite expensive and often do not provide the user with instant feedback. Pedometers are an additional type of motion sensor that have the benefit of being low in cost, unobtrusive to the subject, accurate for ambulatory activity (4, 7), and their output (steps or distance) is easily comprehendible. Although the early mechanical pedometers were once deemed unacceptable for physical activity assessment in research studies, the electronic pedometer has been shown to be accurate under various conditions (4). Despite the fact that pedometers are limited to the assessment of ambulatory activity, they have been used in a variety of studies, both interventional and cross-sectional in nature (20, 31-33). In addition to the abovementioned benefits of pedometers, they also have the potential to serve as a motivational tool providing immediate feedback to the user. Several electronic pedometers have been shown to be accurate in measuring distance walked as well as steps taken at various walking speeds (4, 7).

Physical inactivity is one factor that has contributed to the obesity epidemic. Overweight and obesity are also among the leading health indicators of Healthy People 2010. In 2001, the U.S. Surgeon General issued a call to action, that focused on decreasing the growing epidemic of overweight and obesity that is currently affecting the health of our nation (36). Recent evidence from the National Health and Nutrition Examination Survey (NHANES) indicates that the prevalence of overweight and obesity among U.S. adults is 64.5 and 30.5%, respectively (10). Compared with data from NHANES III (1988-1994), NHANES (1999-2000) data show that increases in the prevalence of overweight and obesity have been observed among males and females and across all ages and racial/ethnic groups (10). In fact, it has been estimated that by the year 2008, nearly 39% of the population will be considered obese (15).

Epidemiological studies show that overweight (defined for adults as a body mass index between 25.0 and 29.9 kg/m^2) and obesity (body mass index 30 kg/m^2 or above) are associated with increases in early mortality in addition to an increased risk for coronary heart disease, type 2 diabetes, certain types of cancers, and various musculoskeletal disorders (21). An estimated 300,000 deaths per year (1) and direct annual health care costs of approximately 70 billion dollars (6) may be attributable to obesity. In 2001, the Rand Institute reported that obese individuals have more overall health problems than smokers or drinkers (30). Currently, it appears that the obesity epidemic is progressing much faster than our understanding of the etiology of obesity and our ability to prevent and treat the disease (14).

Research suggests that even modest reductions in body weight of 5-10% will significantly improve health and thus, the achievement of an optimal body weight is not necessary for some health benefits to be realized (16). It is well known that an energy imbalance, generally considered to be a prerequisite for weight loss to occur, can be created by reducing energy intake and/or increasing energy expenditure. Several studies provide evidence to support the beneficial effects of reducing caloric intake on weight loss over the short-term (19, 28). However, an increase in energy expenditure appears to be an important component of long-term weight loss and/or weight maintenance (19, 28). Several interventional studies have demonstrated that an energy imbalance created solely by an increase in energy expenditure can result in a significant amount of weight loss (17, 18, 25, 27-29).

Although exercise has been shown to be an effective tool for weight management, its effects may be influenced by gender. A meta-analysis of 40 studies by Ballor and Keesey (3) provided evidence that males lost more body mass than females in response to run/walk exercise interventions. Additional studies that have examined the impact that similar exercise programs can have on body composition in males and females (17, 29, 9) have shown that men respond more favorably than women in regard to body weight changes. Interestingly, this gender effect on weight loss has also been supported in studies using male and female rats (8, 22).

In 2001, the ACSM issued a Position Stand (16) that offered strategies for weight loss and the prevention of weight regain. It was suggested that for long-term weight loss, overweight and obese adults should eventually progress to 200-300 $min \cdot wk^{-1}$ of leisure-time physical activity. If for example, a 30-minute walk added to a sedentary individual's normal daily walking is necessary for them to meet the 10,000 steps per day recommendation (39), a full week of walking this amount would require a minimum of 210 $min \cdot wk^{-1}$, which is consistent with the aforementioned guidelines issued by the ACSM for weight loss. Although the effects of the 10,000 steps per day recommendation on various cardiovascular risk factors has been assessed, no studies have compared its feasibility and efficacy in sedentary, overweight men vs. women.

Statement of the Problem

Although electronic pedometers have been validated in a 1996 publication (4), many newer models have emerged on the market since then. Therefore, it necessary to determine which of these new models are most accurate under both controlled and free-living conditions. Also, a popular pedometer based recommendation encourages individuals to accumulate 10,000 steps on a daily basis. However, few studies have examined the efficacy and feasibility of this recommendation as it pertains to improving health outcomes, and none have compared the responses of sedentary, overweight males vs. females to this recommendation.

Statement of Purpose

The purpose of this dissertation is to examine the accuracy of various pedometers under controlled and free-living conditions and to use one of these devices in an intervention aimed at comparing the adherence and cardiovascular risk factor responses of overweight men vs. women to the 10,000 steps per day recommendation. First, Part III determines the accuracy and reliability of 10 electronic pedometers over the course of a 400-m walk at a self-selected pace. Second, Part IV compares 13 different pedometers to a previously validated criterion over a 24-hour period. Finally, Part V compares the effects on cardiovascular risk factors and adherence in response to a 10,000 steps per day recommendation in overweight males vs. females.

Significance of these Studies

The electronic pedometer is a device that has been previously shown to be accurate under a variety of conditions. However, since 1996, no study has been done to assess accuracy and reliability of these devices. Therefore, it would be of significant benefit to the scientific community to validate the newest models of these devices under both controlled and free-living conditions.

With the continued publicity of the 10,000 steps per day recommendation, it would also be valuable to assess both the feasibility and the efficacy of this recommendation, particularly as it pertains to body weight, body composition, and cardiovascular risk factors in overweight men and women. It would be especially interesting to compare the health related changes of males and females in response to this popular recommendation.

References

1. Allison, D. B., K. R. Fontaine, J. E. Manson, J. Stevens, and T. B. VanItallie. Annual deaths attributable to obesity in the United States. *JAMA*. 282:2207-2212, 1999.
2. American College of Sports Medicine. Benefits and risks associated with exercsie. In: *ACSM's Guidelines for Exercise Testing and Prescription*. B. A. Franklin (Ed.) Baltimore, MD: Lippincott Williams & Wilkins, 2000, pp. 5-7.
3. Ballor, D. L. and R. E. Keesey. A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass and fat-free mass in males and females. *Int. J. Obes.* 15:717-726, 1991.
4. Bassett, D.R., B. E. Ainsworth, S. R. Leggett, et al. Accuracy of five electronic pedometers for measuring distance walked. *Med. Sci. Sports Exerc.* 28:1071-1077, 1996.
5. Centers for Disease Control and Prevention - Morbidity and Mortality Weekly Report. *Prevalence of Physical Activity, Including Lifestyle Activities Among Adults - United States, 2000-2001*, 2003, pp. 764-769.
6. Colditz, G. A. Economic costs of obesity and inactivity. *Med. Sci. Sports Exerc.* 31:S515-S521, 1999.
7. Crouter, S. E., P. L. Schneider, M. Karabulut, and D. R. Bassett. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med. Sci. Sports Exerc.* 35:1455-1460, 2003.

8. Dance, D. M., B. Bromley, R. J. Barnard, and R. A. Gorski. Sexually dimorphic effects of forced exercise on food intake and body weight in the rat. *Physiol. Behav.* 19:155-158, 1977.

9. Donnelly, J. E., J. O. Hill, D. J. Jacobsen, et al. Effects of a 16-month randomized controlled exercise trial on body weight and composition in young, overweight men and women. *Arch. Intern. Med.* 163:1343-1350, 2003.

10. Flegal, K. M., M. D. Carroll, C. L. Ogden, and C. L. Johnson. Prevalence and Trends in Obesity Among U.S. Adults, 1999-2000. *JAMA*. 288:1723-1727, 2002.

11. Hatano, Y. Prevalence and use of pedometer. *Res. J. Walking*. 1:45-54, 1997.

12. Hatano, Y. Use of the pedometer for promoting daily walking exercise. *ICHPER J.* 29:4-8, 1993.

13. Helmrich, N. Journey to better fitness starts with 10,000 steps. *USA Today*. June 29, 1999.

14. Hill, J. O. A new way of looking at obesity. *Nutrition* 17:975-976, 2001.

15. Hill, J. O., H. R. Wyatt, G. W. Reed, and J. C. Peters. Obesity and the environment: Where do we go from here? *Science*. 299:853-855, 2003.

16. Jakicic, J. M., K. Clark, E. Coleman, et al. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. *Med. Sci. Sports Exerc.* 33:2145-2156, 2001.

17. Kirk, E. P., J. E. Donnelly, D. J. Jacobsen, and C. Gibson. Time-course and gender effects in aerobic capacity and body composition for overweight individuals: Midwest exercise trial (MET). *Med. Sci. Sports Exerc.* 34:S120 [abstract], 2002.

18. Leon, A. S., J. Conrad, D. B. Hunninghake, and R. Serfass. Effects of a vigorous walking program on body composition, and carbohydrate and lipid metabolism of obese young men. *Am. J. Clin. Nutr.* 33:1776-1787, 1979.

19. Miller, W. C., D. M. Koceja, and E. J. Hamilton. A meta-analysis of the past 25 years of weight loss research using diet, exercise, or diet plus exercise intervention. *Int. J. Obes.* 21:941-947, 1997.

20. Moreau, K. L., R. Degarmo, J. Langley, et al. Increasing daily walking lowers blood pressure in postmenopausal women. *Med. Sci. Sports Exerc.* 33:1825-1831, 2001.

21. National Institutes of Health, National Heart, Lung, and Blood Institute. *Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults*: U.S. Department of Health and Human Services, Public Health Service, 1998, pp. 12-19.

22. Oscai, L. B. The role of exercise in weight control. *Exerc. Sports Sci. Rev.* 1:103-123, 1973.

23. Paffenbarger, R. S., A. L. Wing, and R. T. Hyde. Physical activity as an index of heart attack risk in college alumni. *Am. J. Epidemiol.* 108:161-175, 1978.

24. Pate, R. R., M. Pratt, S. N. Blair, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 273:402-407, 1995.

25. Pollock, M. L., H. S. Miller, R. Janeway, A. C. Linnerud, B. Robertson, and V. R. Effects of walking on body composition and cardiovascular function of middle-aged men. *J. Appl. Physiol.* 30:126-130, 1971.

26. Quittner, J. High-Tech Walking. *Time.* 156:77, 2000.

27. Ross, R., D. Dagnone, P. J. H. Jones, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. *Ann. Epidemiol.* 133:92-103, 2000.

28. Skender, M. L., G. K. Goodrick, D. J. DelJunco, et al. Comparison of 2-year weight loss trends in behavioral treatments of obesity: Diet, exercise and combination interventions. *J. Am. Diet. Assoc.* 96:342-346, 1996.

29. Snyder-Heelan, K. A., D. J. Jacobsen, J. O. Hill, S. Johnson, and J. E. Donnelly. Differences in body weight changes between males and females in response to exercise. *Med. Sci. Sports Exerc.* 33:S138 [abstract], 2001.

30. Sturm, R. and K. B. Wells. Does obesity contribute as much to mortality as poverty or smoking? *Public Health.* 115:229-235, 2001.

31. Swartz, A. M. and D. L. Thompson. Increasing daily walking improves glucose tolerance in overweight women. *Prev. Med.* 37:356-362, 2003.

32. Thompson, D. L., J. Rakow, and S. M. Perdue. Relationship between accumulated walking and body composition in middle-aged women. *Med. Sci. Sports Exerc.* 36:911-914, 2004.

33. Tudor-Locke, C. E., B. E. Ainsworth, M. C. Whitt, R. W. Thompson, C. L. Addy, and D. Jones. The relationship between pedometer-determined ambulatory activity and body composition variables. *Int. J. Obes.* 25:1571-1578, 2001.

34. Tudor-Locke, C. E. and A. M. Myers. Challenges and opportunities for measuring physical activity in sedentary adults. *Sports Med.* 31:91-100, 2001.

35. U.S. Department of Health and Human Services. *Physical activity and health: a report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.

36. U.S. Department of Health and Human Services. *The Surgeon General's call to action to prevent and decrease overweight and obesity.* Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Office of the Surgeon General, 2001, pp. 1-60.

37. U.S. Department of Health and Human Services. Understanding and Improving Health. In: *Healthy People 2010* Washington, DC: U.S. Government Printing Office, 2000.

38. Ward, D. S. and R. Evans. Physical activity, aerobic fitness, and obesity in children. *Med. Exerc. Nutr. Health.* 4:3-16, 1995.

39. Wilde, B. E., C. L. Sidman, and C. B. Corbin. A 10,000-Step Count as a Physical Activity Target for Sedentary Women. *Res. Q. Exerc. Sport* 72:411-414, 2001.

PART II

REVIEW OF THE LITERATURE

Physical Activity on Health

The benefits of physical activity are well established. Several epidemiological and interventional studies have served to quantify the numerous health benefits associated with leading a physically active lifestyle. Some of these benefits include but are not limited to a decreased risk of cardiovascular disease (61, 71, 109) and all-cause mortality (65, 84) along with lower incidence rates for hypertension, obesity, type 2 diabetes, osteoporosis, anxiety, depression and certain types of cancers (2). A review of the physiological, epidemiological, and clinical evidence suggests that regular, moderate-intensity physical activity can result in substantial health benefits (87). In addition, it has been found that even a slight increase in fitness, a byproduct of increased physical activity, can significantly reduce the relative risk of death from all causes (14).

Physical Activity Assessment

Despite the abundance of literature supporting the health benefits of leading a physically active lifestyle, our ability to accurately measure this multi-faceted behavior remains a challenge. Currently, various subjective and objective methods exist for quantifying physical activity. Physical activity questionnaires/interviews, physical activity diaries, and physical activity recall are among the most common subjective methods. Although these forms of physical activity assessment are easy to administer, inexpensive, and noninvasive, they are limited in their ability to assess ubiquitous, unstructured physical activity (1, 91). Objective measures of physical activity focus principally on body motion or physiological responses to exercise. Heart rate monitors, doubly labeled water, indirect calorimeters and motion sensors are some of the more common means for objectively assessing physical activity. Pedometers and accelerometers are the two predominant forms of motions sensors. Accelerometers are relatively expensive devices designed to quantify vertical acceleration and deceleration of the body and the output is often in the form of activity counts accessible by downloading the data. Although accelerometers can estimate with some degree of accuracy, energy expended in various activities, these devices are limited in their ability to estimate energy expenditure during activities such as lifting or carrying objects, walking up a grade, or climbing stairs. In these activities involving upper body movement, load carrying or changes in surface or terrain, accelerometers tend to underestimate energy expenditure (9, 39, 120). Pedometers are also limited in their ability to estimate energy expenditure during non-ambulatory activity. However, these devices are much less expensive than accelerometers, provide the user with constant feedback on steps taken and are effective in measuring steps and calculating distance walked (8, 10).

Pedometers

The pedometer is a device designed to measure steps and estimate distance walked while walking or running (129). Although pedometers were originally used for surveying land and measuring walking distance (10), it wasn't until the 1960's that these devices became increasingly popular for researchers interested in assessing habitual physical activity (115). However, these early mechanical pedometers were found to be unacceptable for the precision needed for research purposes primarily due to the fact that they were invalid and unreliable (33, 56, 129). Gayle (33) found that the validity of these devices varied significantly at speeds ranging from 54 to 107 $m \cdot min^{-1}$ and that individual calibrations were needed in order for mechanical pedometers to accurately measure distance walked. Likewise, Kemper and Vershuur (56) found two types of mechanical pedometers (one German and one Russian) to be invalid at various walking and running speeds in adolescent boys.

Although the earlier, mechanical pedometers were deemed unacceptable for research purposes, the electronic pedometer developed around 1990, offered some hope for these devices in assessing ambulatory activity. In 1996, Bassett et al. (8) tested five brands of electronic pedometers and found one model (Yamax DW-500) to have a high degree of accuracy and reliability. Pedometers were tested for accuracy over a 4.88 km sidewalk course and at varying treadmill speeds of 54, 67, 80, 94, and 107 $m \cdot min^{-1}$. There were significant differences in distance walked between the five pedometers over the 4.88 km course, with the Yamax DW-500 being one of the three most accurate pedometers at estimating distance. In addition, the Yamax was very consistent in counting steps when comparing the same model worn on both the right and left sides of the body. In comparing steps taken at varying treadmill speeds, it was found that the Yamax DW-500 was significantly more accurate than any of the models for counting steps and estimating distance, particularly at speeds ≤ 80 $m \cdot min^{-1}$. Le Masurier et al. (63) also found the Yamax brand pedometer to be the most accurate of three models assessed under controlled and free-living conditions. In this study, the Yamax SW-200, Omron HJ-105, Sportline 330 and CSA accelerometer were all compared while walking on the treadmill at speeds ranging from 54 to 107 $m \cdot min^{-1}$ and over a 24-hour period. Of the three pedometers tested, the Yamax SW-200 demonstrated the lowest absolute percent error at treadmill speeds ≥ 67 $m \cdot min^{-1}$ and over 24-hours of free-living.

In 2003, Le Masurier and Tudor-Locke (64) compared pedometer and accelerometer accuracy at varying treadmill speeds and while traveling in a motorized vehicle. It was found that the Yamax SW-200 counted significantly fewer steps than the CSA (Computer Science Applications) accelerometer (75% vs. 99% of actual steps taken) at the slowest walking speed (54 $m \cdot min^{-1}$) but the devices were similar at speeds $\geq$67 $m \cdot min^{-1}$. In addition, while the CSA accelerometer counted significantly more steps at the slowest walking speeds, this device also detected more erroneous steps during motorized vehicle travel. Although no actual steps were taken during the motorized vehicle travel, the CSA accelerometer detected 17-fold more erroneous steps than the Yamax pedometer ($p<0.05$). Thus, this study suggests that while the Yamax pedometer has a higher threshold of vertical acceleration required to trigger a step as evidenced by counting fewer steps at the slowest walking speed, this device is also less likely to detect erroneous steps during non-ambulatory motion. In addition, while this study showed that the Yamax pedometer counted just 75% of actual steps taken at 54 $m \cdot min^{-1}$, Hendelman et al. (39) pointed out that this speed is much slower than a normal walking speed and is unlikely to be an important source of error in field studies.

Swartz et al. (119) assessed the effect of body mass index on pedometer accuracy. In this study, subjects were stratified by body mass index (BMI) into one of three tertiles: normal (<25 $kg \cdot m^{-2}$), overweight (25-29.9 $kg \cdot m^{-2}$) and obese ($\geq$30 $kg \cdot m^{-2}$). Each participant walked on a motorized treadmill for 3-minute stages at 54, 67, 80, 94, and 107 $m \cdot min^{-1}$ with a Yamax SW-200 brand pedometer placed in each of three locations (anterior midline of the thigh, mid-axillary line, posterior mid-line of the thigh) on the belt or waistband. It was found that neither BMI category nor pedometer placement affected pedometer accuracy at any of the five walking speeds. It was also noted that pedometers were most accurate at walking speeds $\geq$80 $m \cdot min^{-1}$.

From the aforementioned studies, it can be surmised that electronic pedometers have promise for use in assessing ambulatory physical activity. Some of these devices have been shown to be accurate at a variety of walking speeds and among various populations. In addition, pedometers appear to meet the criteria established by Freedson et al. (32) to denote an ideal objective instrument in that they are low in cost, easy to administer to large groups, unobtrusive to the subject, accurate and reliable. Evidence continues to mount demonstrating that pedometers are practical, accurate and acceptable tools for the measurement of physical activity (124) and may be the method of choice for physical activity assessment in epidemiological studies (7).

ACSM/CDC Physical Activity Recommendation

Previous physical activity guidelines from the American College of Sports Medicine (ACSM) emphasized the importance of vigorous-intensity, continuous aerobic exercise for the attainment of cardiorespiratory fitness (3). By the early 1990's, scientific evidence had suggested that physical activity of lower intensity, duration, and frequency than that required to improve cardiorespiratory fitness could produce significant improvements in health outcomes. As a result of these findings, the focus of physical activity guidelines shifted from vigorous- to moderate-intensity exercise. The current recommendation issued in 1995 by the ACSM and the Centers for Disease Control and Prevention (CDC) encourages American adults to accumulate at least 30 minutes of moderate-intensity physical activity on most, if not all days of the week (87). It should be noted that this recommendation is meant to complement, not supersede the previous recommendation that focused on improving cardiorespiratory fitness.

The current recommendation has several unique aspects that distinguish it from the previous recommendations. First, the current recommendation emphasizes physical activity rather than exercise. Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (15). Conversely, exercise is a subset of physical activity, defined as "planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness" (15). Thus, the new recommendation extends the health benefits more generally to physical activity as opposed to the specific focus on exercise alone. Second, emphasis has been placed on moderate-intensity physical activity, which is considered to be any activity performed at an intensity of 3-6 METs, the equivalent of walking 3-4 mph for most healthy adults. It appears that the majority of the disease prevention benefits can be gained with moderate-intensity physical activities, which may or may not be part of a structured exercise routine. Third, the allowance for the accumulation of activity has been added in the current recommendation. This addition confers the benefits associated with intermittent activity, particularly from an energy expenditure standpoint. As a result, activities such as gardening, lawn work, and dancing can contribute to the 30-minute per day goal as long as the activities are performed at an intensity similar to that of brisk walking.

A clear goal of this current recommendation to accumulate at least 30 minutes of moderate-intensity activity on most if not all days of the week was to get more individuals more active. Thus, an attempt was made to clearly define the minimum amounts and types of physical activities needed to achieve significant health benefits. However, alternative recommendations have surfaced that have focused on more specific health outcomes.

Institute of Medicine Recommendation

In 2002, the Institute of Medicine (IOM) suggested that 60 minutes of exercise per day may be necessary for controlling body weight, a recommendation that is double that of the ACSM/CDC which focused on the attainment of health benefits. The IOM recommendation states, "to prevent weight gain as well as to accrue additional, weight-independent health benefits of physical activity, 60 minutes of daily moderate intensity physical activity is recommended, in addition to the activities required by a sedentary lifestyle." (47). The IOM recommendation acknowledges that some health benefits can be achieved by adhering to the ACSM/CDC recommendation, but suggests that this amount is insufficient to maintain body weight in adults with a BMI ranging from 18.5 to 25 $kg \cdot m^{-2}$ and fully achieve all the identified health benefits. However, the ACSM/CDC recommendation clearly states that 30 minutes per day, most days of the week is the minimum amount of activity needed to obtain some health benefits. The ACSM/CDC recommendation goes on to indicate that the health benefits accrue in approximate proportion to the total amount of activity, and thus, those who are already meeting the recommendation will likely reap some additional health and fitness benefits from becoming more physically active, thereby acknowledging the additional benefits to be obtained by performing more physical activity than the recommended minimum (87).

Although the two recommendations are dissimilar in the amount of activity suggested, it should be emphasized that they were designed with two different goals in mind.

2,000 Steps Per Day Increase

Interestingly, an alternative recommendation that also focuses on the prevention of weight gain encourages American adults to take an additional 2,000 steps per day [illegible] This translates roughly into an extra 15 minutes of daily walking and was developed by Dr. Hill based on the average annual weight gain of American adults. The longitudinal CARDIA study indicated that the average 15-year weight gain was 22.5 to 3[illegible] pounds among adults between the ages of 18 and 30 years at baseline (68). Thus, assuming a linear increase in weight over these 15 years, the average weight gain in this population is about 1.5 to 2.2 pounds per year. Based on this information along with the consideration of the efficiency of energy storage in humans, Dr. Hill believes that weight gain could be eliminated by some combination of increasing energy expenditure and decreasing energy intake by 100 $kcal \cdot d^{-1}$ (43). Hill notes that energy expenditure can be increased by 100 $kcal \cdot d^{-1}$ by walking an extra mile per day. He states that "Walking a mile, whether done all at once or divided up across the day, burns about 100 kcal, which would theoretically completely abolish the energy gap and hence weight gain for most of the population. A mile of walking for most people is only about 2,000 to 2,500 extra steps, and these steps could be accumulated throughout the day as life-style activities, for example, taking the stairs, parking a little farther from a destination, conducting a walking meeting" (43). Based on the above rationale, Hill has prompted the promotion of an activity recommendation called "America on the Move" that uses pedometers to motivate people to walk an additional 2,000 steps per day. However, at this point, there is no evidence to support the effectiveness of this recommendation.

10,000 Steps Per Day

An alternative recommendation using pedometers encourages adults to take at least 10,000 steps per day. Dr. Yoshiro Hatano of Japan, believes that taking 10,000 steps per day is the amount of physical activity needed for cardiovascular disease prevention (37). Hatano has found that increased ambulatory activity is associated with lower levels of blood pressure and subcutaneous fat (36). Hatano also estimated that a 60 kg Japanese male would expend at least 333 kcal/day in walking 10,000 steps/day (37). Previous research by Paffenbarger et al. (85) indicates that this amount of energy expenditure in physical activity (>2000 kcals/wk) appears to protect against heart attacks. In addition, longitudinal studies have demonstrated that walking 10,000 steps/day results in improvements in cardiovascular disease risk factors in sedentary, at-risk populations (77, 121). This particular physical activity recommendation has been rather highly publicized in popular periodicals (38, 96). To show the relative equivalence between the ACSM/CDC recommendation and the 10,000 step/day recommendation, Wilde, et al. (131) showed that by adding a 30-minute walk to their daily routine, subjects increased their mean step counts from 7,220 to 10,030 steps per day. This study indicates that for sedentary women, walking daily for 30 minutes will generally allow them to meet both physical activity recommendations, suggesting that the two are roughly equivalent. However, Wilde et al.i(131) also noted that although the mean step count of the participants in this study was over 10,000 steps per day when they added a 30-minute walk to their routine, only 37.5% took at least 10,000 steps on the first day they walked an extra 30 minutes and just 50% took 10,000 steps or more on the second day that included a 30-minute walk. Therefore, although the recommendation to walk an additional 30 minutes per day in addition to normal daily walking increased the mean steps taken day from 7,220 to just over 10,000, the 30-minute walk was not enough to get the majority of the participants over the 10,000 steps per day mark.

Physical Inactivity

Despite the abundance of literature supporting the benefits of leading a physically active lifestyle, most Americans are not getting a sufficient amount of activity. According to data collected from the CDC's Behavioral Risk Factor Surveillance System (BRFSS), 55% of Americans were not active enough in 2001 to meet the current physical activity recommendation of accumulating at least 30 minutes of any physical activity on five or more days per week or more than 20 minutes of vigorous physical activity on three or more days per week (16). Thus, although a variety of exercise recommendations exist, a clear goal should be to provide a recommendation that will decrease the prevalence of inactivity among American adults. Some factors that may potentially impact physical activity participation include exercise intensity, exercise frequency, group- vs. home-based exercise and an individual's willingness to adopt a physical activity program.

Exercise Intensity and Frequency

Exercise intensity may have a substantial effect on adherence rates to exercise prescriptions. Some studies (21, 88, 100) have provided evidence that moderate-intensity activity programs have greater adoption and adherence rates compared with those of vigorous intensities. One of the suggested reasons for the decreased adherence to vigorous-intensity activities is an increase in injury rates (20, 92).

In 1986, Sallis et al. (100) found that exercise adoption rates were higher for moderate- versus vigorous-intensity activities and that 1-year dropout rates were greater for vigorous-intensity activities. Likewise, a meta-analysis of 127 interventional studies showed a greater increase in physical activity of low-intensity compared with that of moderate- or high-intensity activities (21). Also, a review by Pollock showed that exercise prescriptions of moderate-intensity were associated with greater adherence than those of vigorous-intensity (92). In 2002, Perri et al. (88) compared the adherence to walking based exercise prescriptions in a randomized, factorial design, with two levels of intensity (moderate: 45-55% HR_{res} vs. vigorous: 65-75% HR_{res}) crossed with two levels of frequency (moderate: 3-4 days per week vs. high: 5-7 days per week) for 30 minutes per session over 6 months in a home based setting. The results showed better relative adherence and a lower number of exercise-related injuries in the moderate-intensity than in the high-intensity conditions and equivalent adherence for the moderate and high frequency prescriptions. Likewise, participants in the higher intensity groups walked significantly fewer total minutes than did participants in the moderate-intensity groups. Thus, prescribing a higher frequency of exercise increased accumulation of exercise without a decline in adherence, whereas prescribing a higher intensity decreased adherence and resulted in the completion of less exercise. However, it should be noted that although the vigorous intensity recommendation resulted in lower adherence, when exercise volume, which takes into consideration absolute intensity, duration and frequency of the activity (46), is expressed as $kcal \cdot wk^{-1}$ or $MET\text{-}min \cdot wk^{-1}$, the higher intensity group may not necessarily have done "less exercise" since the increased intensity may offset the decrease in adherence.

Group versus Home-Based Exercise

Several studies have examined the effects of group- vs. home-based exercise in regard to a variety of factors including exercise participation, adherence, fitness, and weight loss. Perri et al. (89) showed that when subjects were given an exercise prescription similar in type, intensity, duration and frequency, those randomly assigned to home-based exercise experienced significantly greater improvements in exercise participation, treatment adherence, and weight loss during the second 6 months of a 12-month intervention than those assigned to group-based exercise. Moreover, although both groups significantly improved their fitness levels in response to the 30 minutes per day, 5 days per week exercise prescription, attrition was significantly lower in the home-based program compared with the group program.

King et al. (58) also compared the effectiveness of group- vs. home-based exercise among healthy older adults. In this study, subjects were randomly assigned to higher-intensity, group-based exercise training; higher-intensity, home-based training; lower-intensity, home-based training; or a control group. Regarding adherence, subjects in both home-based programs reported significantly greater adherence than those in the group-based program. In fact, those assigned to home-based exercise had greater adherence rates at each measurement period throughout the 12-month intervention. Thus, it appears that the flexibility and convenience of a home-based exercise program appears to affect adherence rates over the course of a long-term intervention.

Stages of Change

There is a trend in physical activity research to utilize psychological theories to provide a framework for understanding, predicting, and changing behavior (72). An individual's readiness to become physically active, which can be assessed using the stages of change model, is clearly an important determinant of successful participation in physical activity (72). The stages of change model developed by Prochaska and DiClemente (94) is one of two different trans-theoretical models that have assisted researchers who are interested in understanding and predicting changes in health-related behaviors such as smoking, weight control, and physical activity (73). In developing the stages of change model, Prochaska and DiClemente (94) suggested that individuals engaging in a new behavior, such as physical activity move in an orderly progression through the stages. Marcus et al. (73) describes these stages as they relate to physical activity. The Precontemplation stage describes an individual who is not engaged in the behavior of interest (i.e., exercise) and has no intention of becoming involved in that behavior in the future. The Contemplation stage describes an individual who is not engaged in the behavior of interest but is thinking about becoming involved in the behavior in the near future. The Action stage describes an individual who has initiated some behavior change (i.e., participation in occasional exercise). The Maintenance stage describes an individual who is regularly engaging in the behavior of interest (i.e., participates in the recommended amount of exercise). Exercise researchers have recommended that this model be applied to exercise behavior, as the exercise field shifts from predictive to process models to better understand behavior change as it relates to physical activity (73).

Physical Activity and Cardiovascular Disease

Among the goals of virtually any exercise recommendation should be to maximize adherence while improving cardiovascular disease risk factors. It is well known that cardiovascular disease is the leading cause of death in the United States among both men and women. In addition, it is also well established that physical activity is an important factor involved in the prevention and treatment of cardiovascular disease. Hypertension, hypercholesterolemia, diabetes, and obesity are among the most recognized risk factors for cardiovascular disease and physical activity is known to positively affect each of them. Several cross-sectional and longitudinal studies have documented the impact that leading a physically active lifestyle can have on altering each of these risk factors in addition to decreasing cardiovascular disease mortality.

Hypertension

Hypertension or high blood pressure is among the leading causes of cardiovascular disease, stroke, CVD mortality, heart failure, peripheral arterial disease, and renal insufficiency (90). Commonly defined as a systolic blood pressure (SBP) $\geq$140 mm Hg and/or a diastolic blood pressure (DBP) $\geq$90 mm Hg or reported use of antihypertensive medications, hypertension is estimated affect 29% of American adults (35). The prevalence of hypertension increases with age due to a loss of arterial compliance and is higher among men than women at younger ages, but the reverse appears to be true of older individuals (90). Despite the increased ability to detect and treat hypertension, the prevalence of this condition remains very high (51). In addition, hypertension appears to cluster with hypercholesterolemia, insulin resistance, glucose intolerance and obesity, occurring in isolation less than 20% of the time (51). The aforementioned risk factors further increase the severity of this condition with respect to the development of cardiovascular disease.

Physical inactivity is generally associated with an increased risk for the development of hypertension (85, 97). Reaven et al. (97) documented a dose response inverse relationship between systolic and diastolic blood pressure and increasing levels of physical activity. According to the American College of Sports Medicine Position Stand entitled "Exercise and Hypertension", there is ample evidence to support the use of physical activity as a means to prevent, treat, and manage hypertension (90). This Position Stand recommends at least 30 minutes of continuous or intermittent moderate intensity endurance physical activity (40-<60% of VO_2Reserve) supplemented with resistance training on most, preferably all days of the week (90) for those with hypertension. There are several longitudinal, cross-sectional and interventional studies to support the beneficial effects of physical activity on blood pressure.

Blair et al. (12) conducted a study in which normotensive men and women (SBP $\leq$140 mm Hg and DBP $\leq$90 mm Hg) ranging in age from 20-65 years, were followed for up to 12 years for the development of hypertension. It was found that those with low levels of physical fitness, assessed by a maximal treadmill test, had a relative risk of 1.52 for the development of hypertension compared with those who were highly fit. In this study, physical fitness was significantly associated with hypertension after adjusting for potential confounding factors such as age, BMI, sex, and baseline blood pressure. Similarly, Sawada et al. (103) showed that among Japanese males, the relative risk of developing hypertension was 1.9 times higher in the least fit compared with the most fit group even after adjusting for age, initial blood pressure, body fat, and other potential confounding variables. Although the mechanism responsible for the reduction in blood pressure associated with aerobic exercise is somewhat controversial, it may involve a reduction in sympathetic nervous system activity, thereby lowering resting heart rate, cardiac output and systolic blood pressure (4, 11).

Moreau et al. (77) conducted a study in which 24 postmenopausal women with borderline to stage 1 hypertension (SBP 130-159 mm Hg and/or DBP 85-99 mm Hg) were randomized into either an exercise group or a control group for 24 weeks. Those in the exercise group were given an electronic pedometer and a target number of daily steps that would lead to a 3-km increase in daily walking which is consistent with the previously mentioned ACSM/CDC physical activity recommendation. After 12 weeks, SBP decreased significantly from 142 to 136 mm Hg and was further reduced by 5 mm Hg after 24 weeks in the exercise group who significantly increased daily walking by 4,300 steps while SBP and DBP remained unchanged in the control group who did not significantly change their walking volume. Diastolic blood pressure did not change significantly in either group over the course of the study. The authors did note that the reduction in blood pressure demonstrated in this study was unrelated to changes in body mass, percent body fat, fasting plasma insulin, or dietary intake. Seals et al. (107) also examined the effect of regular aerobic exercise for 12 weeks on blood pressure in high-normal to stage 1 hypertensive, postmenopausal women. The aerobic exercise training consisted of walking at 50% of heart rate reserve (HRR) for 30 $min \cdot d^{-1}$, 3-4 days per week and progressed after about 2 ½ weeks to 40-45 $min \cdot d^{-1}$ at 60-70% of HRR for 4-5 days per week. After 12 weeks of exercise, SBP and DBP at rest decreased significantly by 10/7 and 12/5 mm Hg respectively in the sitting and standing positions. It was also noted that some decrease in blood pressure was observed in every subject and blood pressure changes occurred in the absence of changes in maximal aerobic capacity, body weight, or dietary intake.

Iwane et al. (48) examined the effects of walking 10,000 steps/day or more on blood pressure in 30 mild essential hypertensive adult males. After 12 weeks, participants walked an average of 13,510 steps per day which lowered systolic blood pressure by 10 mm Hg suggesting that recommending 10,000 steps per day or more, without guidance on exercise intensity or duration was effective in lowering blood pressure in patients with mild essential hypertension. Similarly, Higashi et al. (40) assessed the impact of daily walking on blood pressure in Japanese men and women with essential hypertension. In response to 30 minutes per day of brisk walking, 5-7 times per week, participants lowered systolic blood pressure from 155 to 147 mm Hg and diastolic blood pressure from 96 to 92 mm Hg. Both these changes were significant decreases and were also significantly different from the inactive control group whose blood pressure remained essentially unchanged.

Several meta-analyses (53, 54, 106) have been conducted examining the impact of exercise training on blood pressure. Seals and Hagberg (106) conducted a meta-analysis examining the effect of exercise training on hypertension and found most studies report modest reductions in blood pressure (<10 mm Hg) at rest and during submaximal exercise after training. Of the eleven studies reporting resting SBP and DBP values, seven showed a significant reduction in SBP and eight found a significant reduction in DBP. Among the eleven studies, the mean decrease in SBP was 9 mm Hg or 6% while DBP decreased by 7 mm Hg or 7% on average. However, it was noted that studies included in the analysis incorporated numerous methodological shortcomings and inadequate study design suggesting that interpretation of the findings should be done with caution. Kelley et al. (54) conducted a meta-analysis focusing specifically on walking and its effects on resting blood pressure and showed that systolic and diastolic blood pressures decreased significantly in response to walking interventions, independent of changes in body mass. Sixteen studies were included in this meta-analysis and training programs ranged in length from 4 to 52 weeks, frequency from 2 to 5 times per week, intensity from 45 to 86% of VO_{2max}, and duration from 28 to 60 minutes. Interestingly, both systolic and diastolic blood pressure decreased about 2% in response to the intervention. However, some of the potential effects of walking on blood pressure may have been masked by the fact that several of the studies included in the meta-analysis examined the blood pressure response of normotensive individuals in response to exercise training. It is generally accepted that blood pressure changes following physical activity interventions are greatest in hypertensives and may be minimal in normotensive individuals (24, 52, 53, 79, 93).

Despite the fact that variations exist in regard to the degree that blood pressure changes in response to exercise training, it has been noted that even relatively small decreases in blood pressure can result in significant health improvements. Stamler et al. (114) estimated that a decrease of as little as 2 mm Hg in the average population SBP can reduce mortality from coronary heart disease, stroke, and all causes by 4, 6, and 3% respectively. Although differences exist in regard to the magnitude of blood pressure change in response to regular aerobic exercise, it is thought that the effects of exercise on blood pressure may be due differences in baseline blood pressures, demographic characteristics, characteristics of the training program, inadequate controls, and blood pressure assessment limitations (90). In regard to a gender comparison, meta-analytic studies limited to randomized controlled trials found no significant differences between resting blood pressure responses of normotensive and hypertensive men and women to endurance training (52, 53).

Hyperlipidemia

Elevated lipid and lipoprotein levels are known to be among the most significant risk factors for the development of cardiovascular disease. In addition, most efforts to improve lipid and lipoprotein profiles begin with a multifaceted approach that includes increased levels of physical activity (28). Among the postulated benefits of physical activity in preventing heart disease is a favorable effect on blood lipids, particularly an increase in high-density lipoprotein cholesterol (HDL-C) (25, 26, 80, 82, 95, 105, 113).

A review by Leon and Sanchez (67) presented evidence showing the relationship between physical activity and blood cholesterol levels from cross-sectional, longitudinal epidemiologic observational, and experimental exercise training studies. Cross-sectional observational studies including both genders and all ages performing various aerobic activities have consistently shown what appears to be a positive dose-response association between the volume and intensity of aerobic activities and plasma HDL-C and an inverse relationship with triglyceride (TG) levels (67). Among endurance exercise training studies, the most commonly observed lipid change was an increase in HDL-C. It was also noted that aerobic exercise training helped to negate or attenuate the dietary-induced reduction in HDL-C, particularly in cases where substantial weight loss has occurred. Although significant reductions in total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and TG occurred less frequently with exercise training than an increase in HDL-C, it was noted that men typically experienced greater reductions in TG than women in response to endurance exercise.

To assess the impact of exercise intensity on lipid/lipoprotein changes, Duncan et al. (24) analyzed the effect of walking speed on cholesterol levels in 59 sedentary postmenopausal women. Participants were randomized into one of four treatment groups: aerobic walkers (8 $km \cdot h^{-1}$), brisk walkers (6.4 $km \cdot h^{-1}$), strollers (4.8 $km \cdot h^{-1}$), or sedentary controls. After 24 weeks of training, HDL-C increased significantly among the aerobic walkers and the strollers (6% increase in both groups), but not in the brisk walkers (4% increase) or controls (1% increase). It was also noted that the TC:HDL ratio decreased significantly within the strollers (7% decrease) but not in any other group. Thus, this data suggests that vigorous exercise is not necessary for women to obtain significant improvements in blood lipid profile. Crouse et al. (18) also conducted a study examining the effect of exercise intensity on blood lipids. This study consisted of 26 hypercholesterolemic men who trained at either a high (80% VO_{2max}) or moderate (50% VO_{2max}) intensity, 3 days per week for durations calculated to result in 350 kcal of energy expenditure per session. After 24 weeks, training intensity did not significantly affect blood lipid profile when caloric expenditure was held constant. Suter et al. (118) compared the changes in lipid/lipoprotein levels in sedentary men in response to jogging or walking. Participants were randomized to one of two groups: jogging at 75% VO_{2max}, 4 times per week for 30 minutes per session or walking at 50% VO_{2max}, 6 times per week for 30 minutes per session. After 6 months of exercise training, there were no significant differences in lipid/lipoprotein levels between the two groups. Although it is difficult to draw conclusions about the effect of exercise intensity on lipid/lipoproteins when other components of the exercise prescription vary, from the abovementioned studies, exercise intensity does not seem to affect lipid profile changes in men or women in response to aerobic exercise training.

One question concerning the increase in HDL-C that may occur in response to exercise training is whether the increase is dependent upon changes in body weight. Higashi et al. (40) assessed the impact of daily aerobic exercise on lipoprotein levels in men and women. The aerobic exercise consisted of 30 minutes of brisk walking, 5-7 times per week for 12 weeks. In this study, the exercise group noted significant improvements in both HDL-C and LDL-C, despite no change in body weight. However, there were no significant changes in TC or TG in response to the exercise intervention. No significant changes occurred in any of the lipoprotein values in the control group. Schwartz (105) determined the effect of dietary weight loss and aerobic training on HDL-C in obese men. In this study, 26 participants were randomized to either a diet or aerobic exercise group. The exercise consisted of a walk/jog program 3-5 days per week for 40 minutes per day at 70-85% HRR. After 3 months, those in the diet group lost significantly more weight than those in the exercise group. In addition, TC, TG, and HDL-C improved significantly within the diet group while only the HDL-C improved significantly within the exercise group. However, in regard to the HDL-C subfractions, the more anti-atherogenic HDL_2 subfraction increased significantly in the exercise group but not in the diet group. Thus, while diet and exercise can both impact HDL-C independent of body weight change, exercise appears to be more effective at increasing the more anti-atherogenic subfraction of HDL-C.

Sopko et al. (113) designed a study to analyze the independent effects of exercise training and weight loss on blood lipids. Sedentary, obese men were stratified into one of four treatment groups: 1) inactive and constant weight (controls), 2) exercise training and constant weight, 3) inactive and weight loss, and 4) exercise training and weight loss. The exercise training consisted primarily of walking 5 days per week at a 5-10% grade with a total energy expenditure goal of 3500 kcal/week. After 12 weeks, TC decreased in the exercise and weight loss group alone, LDL-C decreased only in the exercise and weight loss group while increasing in all other groups, and HDL-C increased significantly in all groups with the exception of the inactive and constant weight control group. Thus, both exercise training alone and dietary induced weight loss in obese men independently increased HDL-C similarly and the increase occurred independent of changes in body weight.

Several studies that have examined the impact of walking alone on lipid and lipoprotein levels have reported conflicting results (24, 44, 62, 76, 81, 102, 117, 132).

Hinkelman and Nieman (44) examined the effects of walking five days per week for 45 minutes per day at 62% VO_{2max} for 15 weeks in overweight women. Although the pattern of change in TG, TC, and LDL-C was not statistically different between the exercise and control groups, the interaction for HDL-C was significant with HDL-C actually increasing in the control group and decreasing slightly in the exercise group. The authors suggested that the surprising increase in HDL-C noted in the control group may have resulted from an increase in body weight.

Santiago et al. (102) assessed the impact of 3 miles of brisk treadmill walking up a slight incline (5-7%) four times a week on blood lipid levels of sedentary women with a high baseline HDL-C. After 40 weeks, no significant change was noted in blood lipid variables despite a 22% increase in aerobic power. The authors concluded that the unchanged HDL-C following the walking intervention may be attributed to either a lack of change in body weight/percent body fat or to the favorable baseline blood lipoprotein values of the women in this study.

Miyatake et al. (76) showed that daily walking can result in significant improvements in lipoprotein levels in obese Japanese males. Although subjects were instructed to walk 1000 steps more than their baseline steps per day value, the average increase in daily walking was over 1,800 steps per day more than their baseline value, which is roughly equivalent to an additional 1 mile of walking per day. After 12 months, in addition to a significant reduction in body weight, TC remained unchanged, TGa decreased significantly and HDL-C increased significantly. Interestingly, both the average TG and HDL-C at baseline were within normal limits suggesting that lipoprotein levels do not have to be abnormal initially to improve significantly in response to a regular exercise program.

Woolf-May et al. (132) examined the efficacy of accumulated short vs. long bouts of brisk walking on blood lipid levels in men and women. Participants were allocated to one of four groups: long walkers (20-40 minutes/bout), intermediate walkers (10-15 minutes/bout), short walkers (5-10 minutes/bouts), and a control group. All three walking groups were instructed to walk at an intensity equivalent to 70-75% VO_{2max} and all three groups performed the same total amount of walking for the duration of the study. After 18 weeks, all three walking groups showed similar improvements in fitness. However, only the long and intermediate walkers statistically decreased their LDL-C compared to the control group. No other significant changes in lipid/lipoprotein levels were noted.

Nieman et al. (81) measured the impact of diet, exercise, and diet plus exercise on lipid and lipoprotein risk factors in moderately obese women. The exercise consisted of brisk walking for 45 minutes per day, 5 days per week at about 78% of maximal heart rate. Relative to the control group, TC and TG decreased significantly in both the diet and diet plus exercise groups, while LDL decreased significantly in the diet plus exercise group alone following the 12-week intervention. Although HDL changes were insignificant, HDL levels increased in the exercise group, decreased in the diet group and remained unchanged in the diet plus exercise group. The authors of this study noted that significant cholesterol improvements were most strongly related to weight loss.

Kraus et al. (62) examined the impact of exercise intensity and frequency on changes in lipid/lipoprotein levels in sedentary overweight men and women. In this study, participants were randomized into a high-amount, high intensity group; low-amount, high-intensity group; low-amount, moderate intensity group; or a control group. Interestingly, subjects were encouraged to maintain their baseline body weight. After eight months, exercise training had no effect on the TC or LDL-C concentrations. However, HDL-C increased significantly in the high-amount, high-intensity group while increasing slightly in the low-amount, high intensity and low-amount, moderate intensity groups. Thus, it was concluded from this study that improvements in lipoproteins were related to the amount of activity and not to exercise intensity or the improvement in fitness.

Sugiura et al. (117) also showed that daily walking can significantly improve lipoprotein levels in sedentary, middle-aged women. The women in the exercise group were asked to participate in a 90-minute physical education class consisting of walking, jogging, or rhythm dance at 40-60% of VO_{2max} once a week for 24 months in addition to increasing their steps per day by 2,000 to 3,000 more than their baseline average daily step count. Participants in the exercise group increased their daily steps from 6,800 to over 8,500 steps while the control group increased their daily step count from 5,700 to 6,800 steps. In response to the intervention, TC, HDL-C, and the TC:HDL ratio improved significantly while all lipid/lipoprotein values remained unchanged in the control group. In addition, LDL-C also decreased nearly 20 mg/dL in the exercise group although this change was not significant. A multiple regression analysis showed that TC, HDL-C, and TC:HDL were significantly associated with daily steps, but were not associated with the modest change in BMI. Thus, the improvements in lipid profile in this study were attributed to the walking intervention and not the slight reduction in BMI.

Kelley et al. (55) conducted a meta-analysis involving 25 randomized controlled studies that assessed the relationship between walking and lipid/lipoprotein levels. The studies assessed in this meta-analysis ranged in length from 10-104 weeks, frequency from 3-15 times per week, intensity from 50-86% VO_{2max}, duration from 10-75 minutes per session and compliance (defined as the percentage of walking sessions attended) from 50-100%. While all the changes in lipoproteins were in the direction favoring improvement, statistically significant changes were limited to LDL-C and TC:HDL. The average change for each lipid or lipoprotein level was as follows: TC (-3.4 mg/dL), HDL-C (1.2 mg/dL), LDL-C (-5-5 mg/dL) and TG (.2 mg/dL). It was concluded that the lack of statistically significant improvements in TC, HDL-C, and TG may have to do with an actual lack of effect of walking on these factors and/or the generally acceptable mean baseline values of the subjects for these variables.

In regard to a gender comparison, it has been suggested that women may be more resistant to physical activity induced changes in HDL-C and TG (44, 67). The most likely explanation for this is that women have higher initial HDL-C concentrations than men, thereby limiting the possibility of change (69). As with changes in blood pressure in response to an exercise regimen, differences in the extent of blood lipid changes in response to regular aerobic exercise and the differences in the magnitude of change between genders may be due to differences in baseline blood lipid/lipoprotein values and characteristics of the training program.

Obesity Epidemic

In recent years, obesity has developed into a global epidemic. In 1998, the American Heart Association issued a Call to Action that reclassified obesity as a major, modifiable risk factor for coronary heart disease (27). In fact, the obesity epidemic may be progressing much faster than our understanding of the etiology and our ability to prevent and treat the disease (41). Recent evidence from the National Health and Nutrition Examination Survey (NHANES) indicates that the prevalence of overweight and obesity among adults in the United States is 64.5 and 30.5%, respectively (30). Compared with data from NHANES III (1988-1994), current NHANES data (1999-2000) showed that increases in the prevalence of overweight and obesity have been observed among males and females and across all ages and racial/ethnic groups (30). It has been estimated that by the year 2008, nearly 39% of the population will be considered obese (43). In regard to the risk associated with obesity, the Rand Institute recently reported that obese individuals have more overall health problems than smokers or drinkers (116).

Overweight and Obesity

In order to clarify the cause of weight change, it is necessary to understand the various energy balance equations. When energy intake is equal to energy expenditure, weight is maintained. In contrast when there is an imbalance between energy intake and energy expenditure, weight changes will likely occur. In consideration of the dynamic energy balance equation (122), if the rate of energy intake exceeds the rate of energy expenditure, a positive caloric balance results and consequently, weight gain occurs. In contrast, if the rate of energy expenditure exceeds the rate of energy intake, a negative caloric balance results and therefore, weight loss occurs. Thus, from this information, it can be gathered that the two alternatives for promoting weight loss are to decrease the rate of energy intake and/or increase the rate of energy expenditure.

A meta-analysis by Miller et al. (75) examined the effectiveness of diet, exercise or diet plus exercise on weight loss and found diet and diet plus exercise to be more effective than exercise alone over the short-term. However, after one-year, diet plus exercise tended to be the superior program, although the weight lost maintained at one year did not significantly differ between the three conditions. Thus, it was concluded that while diet alone and diet plus exercise may be most beneficial over the short-term, an exercise component should be considered as part of the long-term intervention and/or follow-up. Similarly, Skender et al. (110) compared the effects of diet-only, exercise-only and diet-plus-exercise on weight loss in 127 overweight men and women. The dietary intervention was adjusted to produce a weight loss of 1 kg/wk while the exercise component consisted of a home-based walking program, 3-5 days per week for up to 45 minutes per session. In regard to intensity, subjects were instructed to walk at a level that felt "vigorous" but never "strenuous." Each of the three treatment conditions, which lasted 1 year, were accompanied by a total of 18 group instructional sessions that were conducted weekly for the first 12 weeks, followed by 3 biweekly sessions, followed by 3 monthly sessions. After 1 year, there were no significant differences (p=.09) among the three groups. The diet-only group lost 6.8 kg, the exercise-only group lost 2.9 kg, and the diet plus-exercise-group lost 8.9 kg. One year after completing the treatment, the subjects were invited back for a follow-up examination. Interestingly, in the year following the intervention, only 6.7% of the diet-only group and 14.3% of the diet-plus-exercise group reported adhering "often" to dietary recommendations. In contrast, 44% of the exercise-only group reported exercising often during the year after treatment and 74.3% of the exercise-only group considered exercise to be enjoyable. In regard to weight change after 2 years (1 year of intervention and 1 year of follow-up), the diet-only group was .9 kg above their baseline weight while the exercise-only and the diet-plus-exercise groups were 2.7 and 2.2 kg below their baseline weights, respectively.

Despite the fact that diet often produces more substantial weight loss than exercise over the short term, Ross et al. (99) demonstrated that diet-induced and exercise-induced weight loss can be equivalent as long as the energy deficit is equal. In this study, obese men were randomly assigned to one of four groups: diet-induced weight loss, exercise-induced weight loss, exercise without weight loss or an inactive control group. Those in the diet-induced weight loss group were asked to reduce their isocaloric diet by 700 kcal/day to achieve a weekly weight loss of 0.6 kg. To lose the same amount of weight, those in the exercise-induced weight loss group were asked to maintain their isocaloric diet while performing exercise that expended 700 kcal/day. Participants in the exercise without weight loss did the same amount of exercise each day as the exercise-induced weight loss group but were told to consume enough calories to compensate for the energy expended during exercise (700 kcal/day). After 3 months, body weight decreased by 7.5 kg in both weight loss groups while remaining unchanged in the exercise without weight loss and control groups. Thus, from this study it can be concluded that as long as the caloric deficit is equal, exercise and diet can result in an equally significant amount of weight loss.

The observation that dieting often produces greater weight loss than exercise over the short-term, and that exercise in combination with dieting often adds little to weight loss by dieting alone is not surprising (74). It is unrealistic to expect a sedentary person initiating an exercise program to achieve the same magnitude of energy deficit through exercise that could be achieved through an energy restricting diet (74). However, as a person trains, his/her ability to exercise for longer durations increases resulting in an increase in energy expenditure. An additional benefit of training is the ensuing increase in fat oxidation that may occur if training is of sufficient intensity and duration (74).

The origin of obesity can be traced to a variety of causes including metabolic, genetic, behavioral, environmental, cultural and socioeconomic (128). Of these potential causes, behavioral and environmental factors appear to be the most impressionable. The current environment in the United States encourages consumption of energy and discourages energy expenditure (6, 42, 43). Thus, the solution to the obesity problem appears to lie in the identification of feasible ways or behaviors to cope with and to change the current environment (43).

Walking

Walking is the most common type of physical activity in the United States (127). It is the most natural form of activity and is the only sustained dynamic aerobic exercise common to everyone with the exception of the seriously disabled or very frail (78). Walking has the benefit of convenience, it may be accommodated in occupational and domestic routines and it is self-regulated in intensity, duration and frequency and, having a low ground impact, it is inherently safe (37, 78).

A recent study reported that approximately 34% of adults ages 18 and older participated in regular walking, defined as walking at least five times per week for at least 30 minutes per session while an additional 46% reported walking occasionally, defined as walking for at least 10 minutes per time but did not meet the criteria for a regular walker (29). Walking is an activity that can be done independently as most adults prefer to walk on their own as opposed to in a supervised group setting (57). From a caloric expenditure standpoint, walking at any pace expends energy; about 4 kJ/kg of body weight for every kilometer walked (78). Thus, the cumulative effect of walking (like many other types of physical activity) has the potential to impact energy balance in a manner that may promote weight loss or weight maintenance.

Walking is one of the few feasible exercise regimens in the treatment of overweight individuals because cardiovascular functional capacities are likely to be poor, and other exercise such as jogging and aerobics may be hazardous (78). Gwinup (34) suggested that walking would have to be recommended as the most practical form of exercise for obese subjects who wish to lose weight. The physiological response during walking is determined by the intensity of the exercise in relation to the individual's cardiovascular functional capacity (78). When walking at 4.8 km/hr (3.0 mph) on level ground, oxygen uptake is about 3.7 METs regardless of age, sex, or level of fitness. One MET is the energy requirement for resting. Therefore, the physiological stress of walking at this intensity is far less for an individual with a VO_{2max} of 14.0 METs compared with an individual with a VO_{2max} of 7.0 METs.

Walking is familiar, convenient, safe, readily habit forming and it requires no special skills or equipment (45, 78). The benefits of walking extend to improvements in physical, cognitive, and social function, all of which enhance the 'health-related quality of life' (98). While walking is generally considered to be a moderate intensity activity (93), physical activity on a high-intensity level is not always feasible for certain populations including the elderly, overweight, untrained, and individuals with cardiovascular disease (118). Thus, walking may be the ideal activity for such populations. Walking is a rhythmic, dynamic, aerobic activity of large skeletal muscles that confers the various benefits with minimal adverse effects.

Walking and Weight Status

Studies that have assessed the relationship between physical activity and body weight have generally reported that overweight people perform less physical activity. Chirico and Stunkard (17) showed that obese men and women walked significantly fewer miles per day than non-obese men and women. Similarly, Tyron et al. (126) reported a significant negative correlation between percentage overweight and physical activity. It was noted that as percentage overweight increased, physical activity reported as miles walked per hour decreased. Likewise, the prevalence of obesity has been shown to be lower in more active individuals. Tudor-Locke et al. (125) noted that the prevalence of obesity was only 10% among those taking more than 9,400 steps/day, compared to 40% among those taking less than 5,300 steps/day. Similarly, Thompson et al. (123) assessed the relationship between accumulated walking and body composition specifically in middle-aged women and noted significant negative correlations between steps per day and percent body fat (-.71), BMI (-.42), waist circumference (-.62), hip circumference

(-.28), and waist:hip ratio (-.65). In addition, when participants were stratified into activity tertiles, significant differences in body composition variables were noted among the activity groups. Although these studies demonstrate an association between physical activity and weight status/body composition, they are unable to establish a cause and effect relationship. However, whether a decrease in physical activity is a cause or an effect of obesity, inactivity contributes to a positive energy imbalance and thereby exacerbates the problem (126).

Walking and Fitness

Several studies have examined the relationship between walking and fitness (14, 93, 102, 118). In 1994, Suter et al. (118) compared the effects of walking (50% VO_{2max}) and jogging (75% VO_{2max}) programs that elicited similar values for weekly energy expenditure in sedentary men. After 6 months of training, the walking and jogging groups increased VO_{2max} significantly by 2.5 and 2.9 ml/kg/min, respectively while the control group experienced a decrease in VO_{2max} by 1.2 ml/kg/min. The results of this study showed that the amount of training in terms of energy expenditure, which was about the same for both groups, rather than the intensity was the important criterion for improvement in cardiovascular fitness.

Pollock et al. (93) assessed the effect of walking 4 times/week for approximately 40 minutes for each training session for a total of 20 weeks on middle-aged men. Subjects in this study were encouraged to walk as far as possible in each 40-minute session. Walking distance increased from 2.5 miles during week 1 to 3.25 miles for the final 4 weeks of the study. As a result of training, VO_{2max} increased from 2.30 to 2.94

L/min (28% increase), one-mile walk time decreased by over 1 ½ minutes (17% decrease), and heart rate response decreased significantly at each of the three stages of a standard treadmill walk and remained decreased up to 5 minutes into recovery, all factors indicating improved cardiovascular fitness.

Lynch et al. (70) determined that visceral fat reduction following a weight loss intervention which included a reduced calorie diet and a walking program, was significantly related to improvements in VO_{2max}. The walking program in this intervention consisted 30-40 minutes of exercise, 3 days per week at a target heart rate of 50-60% HRR. In comparing those that increased their aerobic fitness by an average of 10% with those that showed no increase, those that increased their VO_{2max} experienced significant reductions in visceral adipose tissue area.

In 1989, Blair et al. showed that significantly lower death rates may be related to moderate levels of physical fitness (14). In a prospective study involving over 3,000 women and 10,000 men, there were significant differences in mortality between individuals in the least fit quintile and those in the next "moderately fit" quintile. The encouragement in this study lies in the fact that these differences in fitness represent a degree of improvement that should be achievable by brisk walking (13, 78). With an emphasis on the personal and public health gain associated with the shift from the inactive/unfit to the next higher level, walking is the ideal mode to serve the transition (87).

Physical Activity and Weight Management

In 1999, Serdula et al. (108) reported that the prevalence those attempting to lose and maintain weight was 28.8% and 35.1% among men and 43.6% and 34.4% among women, respectively. Several studies have examined the impact of regular walking on body composition variables. However, differences in exercise prescription, baseline characteristics, and measurement methods make direct comparisons among studies difficult. Nonetheless, it is possible to look at the effect of different components of the exercise prescription on changes in body composition.

Continuous versus Intermittent Exercise

The current ACSM/CDC physical activity recommendation suggests that accumulated physical activity (intermittent bouts of physical activity, as short as 8-10 minutes each, totaling 30 minutes or more) can provide equivalent health and fitness benefits as can continuous physical activity as long as the total amount of activity performed, expressed either in terms of caloric expenditure or minutes of activity, is the same (87). Several studies have examined the impact of continuous versus intermittent exercise on body weight change and have reported conflicting results.

Donnelly et al. (23) investigated the effects of continuous vs. intermittent exercise on body composition in moderately obese females. Those randomized to the continuous group exercised for 30 minutes at 60-75% VO_{2max}, 3 times per week under direct supervision while those in the intermittent group were instructed to walk briskly, yet comfortably at approximately 50-65% HRR, 2 times per day, 15 minutes per session, 5 days per week at their home or worksite. Although the volume of exercise differed between the two groups with the continuous group expending 2235 kJ per week compared to 3235 kJ per week in the intermittent group, only those in the continuous group noted significant reduction in body weight and percent body fat after 18 months. However, the fact that only the continuous group exercised under direct supervision may have influenced these results.

Jakicic et al. (50) also examined the effects of continuous vs. intermittent exercise. In this study, the duration of exercise was set at 20 minutes per day for weeks 1-4, 30 minutes per day for weeks 5-8, and 40 minutes per day for weeks 9-20. Participants in the continuous group were told to walk the specified duration in one continuous bout while those in the intermittent group were told to perform the specified duration in multiple 10-minute bouts per day. Both groups were instructed to walk 5 days per week at 70% of HRR. After 20 weeks, both body weight and BMI decreased significantly in both groups although the group by time interaction suggested that there was a trend for the intermittent group to have a greater magnitude of weight loss compared to the continuous group. This may be due to improved adherence as the intermittent group reported exercising significantly more days and for a greater total duration.

Schmidt et al. (104) compared the effects of continuous versus intermittent exercise in overweight college aged females. Participants were assigned to one of four groups: a nonexercising control group, 30 minutes of continuous exercise group, 30 minutes of accumulated exercise group (2, 15 minute bouts per day) and a second 30 minutes of accumulated exercise group (3, 10 minute bouts per day). The exercising subjects participated in aerobic exercise training at 75% HRR, 3-5 days per week. In addition, subjects were also asked to follow a self-monitored calorie restricted diet (80% of resting energy expenditure) for the duration of the study. After 12 weeks, body weight, BMI, the sum of 7 skinfold sites, and the sum of 4 circumference measurements all decreased significantly in the three exercise groups while remaining unchanged in the control group. Unlike the findings of Jakicic et al. (50), exercise participation did not differ among the exercising groups with regard to the average number of days spent exercising per week.

Murphy and Hardman (79) examined the effects of short and long bouts of physical activity in sedentary, middle-aged women. Participants in the short bouts group performed three 10-minute bouts of walking while those in the long bout group performed one 30-minute bout of walking. Both groups were instructed to walk briskly at 70-80% of their maximal heart rate, 5 days per week. In addition, subjects also agreed not to make any changes in their diet. After 10 weeks, body mass and waist circumference decreased significantly in the short bout group alone, while the sum of 4 skinfolds decreased significantly in both exercise groups in comparison with the inactive control group. In this study, total time spent in brisk walking did not differ significantly between the two walking groups.

Thus, although the data comparing continuous and intermittent exercise appear conflicting, three of the four studies mentioned suggest that exercise accumulated in bouts of at least 10 minutes each are at least as beneficial in reducing body weight as one continuous bout as long as the total amount of activity performed is equal. However, it should be mentioned that although changes in body mass are noted in each study, changes in fat mass, which are more desirable, are not consistently reported.

Exercise Intensity and Weight Management

Several studies have examined the effect of varying exercise intensities on body weight changes. Slenz et al. (111) compared eight months of varying amounts of exercise on body weight and body composition. In this study, sedentary, overweight men and women were randomized into one of four groups: a high amount/vigorous intensity group, a low amount/vigorous intensity group, a low amount/moderate intensity group, or an inactive control group. Despite being counseled to maintain baseline body weight, all three exercise groups lost a significant amount of body weight and fat mass compared with the inactive control group. In comparing those that did the same amount of exercise but at different intensities (low amount/moderate intensity vs. low amount/vigorous intensity), there was no significant difference in the decrease in body weight or fat mass. In fact, the authors noted that there were no variables for which the low-amount/vigorous intensity group was significantly better than the low-amount/moderate intensity group. Based on the fact that none of the four groups made any significant changes in mean caloric intake or in carbohydrate, fat, or protein intake, the changes noted are likely due to the increase in physical activity among these previously sedentary individuals.

Suter et al. (118) compared the effects of walking vs. jogging on several body composition variables. In this study, sedentary, nonsmoking men were randomized into either a home-based unsupervised exercise program consisting of jogging at 75% VO_{2max} for 4 days per week for 30 minutes per day, walking at 50% VO_{2max} for 6 days per week for 30 minutes per day, or an inactive control group. After 6 months, there were no significant changes between either the joggers or walkers in body fat determined by skinfold measurements or fat distribution as determined by waist:hip ratio. One likely explanation for a lack of change in body composition variables is that all three groups had a mean BMI of 24.9 $kg \cdot m^{-2}$ suggesting that the groups were not overweight at the onset of the study. Interestingly, although there was no change in body fat on average in either exercising group, a significant association between the amount of training and a decrease in the sum of skinfolds and waist:hip ratio was observed only in the walkers. Similarly, Santiago et al. (101) compared the physiological responses of sedentary women to a conditioning program of walking or jogging. Participants consisted of 40 slightly overweight, sedentary women randomized into either a walking group, jogging group or an inactive control group. The exercise prescription was standardized with respect to distance (4.8 km/session) and frequency (4 days/week). After 20 weeks, there were no significant changes in body weight, percentage of body fat, or the sum of five skinfolds for any of the three groups. As is the case in the Suter et al. study, there was no mention of a dietary analysis and thus, it is possible that in both studies, the walking and jogging groups had a compensatory increase in caloric intake that could have masked any potential changes in body weight that may have resulted from the increase in physical activity.

A study by Duncan et al. (24) assessed the impact of the intensity of walking alone on body composition variables. Sedentary middle-aged women were randomized into one of four treatment groups: aerobic walkers (8 km/hr), brisk walkers (6.4 km/hr), strollers (4.8 km/hr) or sedentary controls. Each group was instructed to walk 4.8 km/day (3 miles), 5 days per week. Caloric intake, dietary fat, carbohydrate, and protein intake remained unchanged in all four groups over the course of the study. After 24 weeks, all groups gained weight with the exception of the brisk walkers. The brisk walkers were the only group in which their change in body weight was significantly different from that of the control group. In regard to percent body fat, only the change among the strollers was significantly different from the controls. However, it is interesting to note that while none of the exercising groups lost body weight in response to the intervention, all three exercise groups decreased their body fat percentage on average while the control group increased their percent body fat.

Likewise, Asikainen et al. (5) also looked at the effect of varying intensities of walking on body weight and body composition. In this study, sedentary, non-obese, postmenopausal women were randomized to one of five groups: walking at 55% VO_{2max} with a caloric goal of 1500 calories per week, walking at 45% VO_{2max} with a caloric goal of 1500 calories per week, walking at 55% VO_{2max} with a caloric goal of 1000 calories per week, walking at 45% VO_{2max} with a caloric goal of 1000 calories per week, or an inactive control group. Each walking group was instructed to walk 5 days per week for 24 weeks. In addition, while no significant differences were noted between body weight change in the walkers vs. the controls, there were significant differences between the walkers and the controls in respect to change in body fat percentage. Although there was no clear dose-response relation between exercise intensity, changes in body weight or fat weight, percent fat did decrease in each of the walking groups while increasing slightly in the control group, a finding similar to that of Duncan et al. (24). Thus, while walking did not produce a significant amount of weight loss in all three groups, it did limit the increase in percent fat that occurred in the control group.

Although studies have made comparisons between the effects of walking at various intensities, it is difficult to weigh the impact of intensity alone when other variables of the exercise prescription such as frequency and duration vary. However, from the aforementioned studies that focused on walking alone, it appears that walking intensity does not significantly affect body weight or body composition changes. This is in agreement with Ballor and Keesey who have suggested that if weight regulation is the goal, it appears that walking pace is not as important as regularity and duration (6). In addition, Jakicic and Gallagher (49) noted that exercise prescribed at a relatively high intensity may increase the risk associated with exercise participation in sedentary, overweight adults, particularly when other cardiovascular disease risk factors are present.

Walking and Weight Management

In addition to the abovementioned studies that have looked at exercise of varying intensities in addition to continuous vs. intermittent exercise, other studies have examined the effect of walking for various durations and frequencies on body weight and body composition. However, the results from these studies are equivocal. Possible reasons for the lack of agreement may be due to the differences in subject characteristics, training protocols, and the durations of the interventions, which make it difficult to directly compare results between individual studies.

In 1975, Gwinup (34) reported on the effect of exercise alone on the weight of obese women. In this study, eleven obese women progressively increased their amount of walking for one year or longer while on an ad libidum diet. Exercise time was divided into one, two, or occasionally three periods daily and subjects were advised to walk as rapidly as could comfortably be tolerated. Weight loss over the 1-year intervention averaged 10 kg and ranged from 4.5 to 17.3 kg. In general, the amount of weight loss paralleled the amount of exercise with the most active individuals losing the greatest amount of weight. Interestingly, it was noted that weight loss did not begin until walking exceeded 30 minutes daily, with the exception of two subjects who were somewhat active when they began the study. Thus, it was concluded that exercise alone can produce substantial and sustained weight loss in women who exercise for long durations on a daily basis.

Moreau et al. (77) determined the impact of an increase in daily walking on body weight and body composition in postmenopausal women with borderline to stage 1 hypertension. In being instructed to walk an additional 3 km per day, the women increased their daily walking from 5,400 steps/day to 9,700 steps/day. As a result, the women engaged in the walking intervention lost a statistically significant 1.3 kg of body mass after 24 weeks, despite the fact that body fat percentage remained essentially unchanged.

Miyatake et al. (76) assessed the effect of daily walking on body composition in obese, Japanese men. In this study, participants were instructed to walk an additional 1,000 steps per day above their baseline level. After 1 year, participants increased their daily walking significantly from 7,013 to 8,840 steps per day while reducing their caloric intake by a statistically insignificant 95 calories per day, which resulted in a significant reduction in body weight (-3.7 kg), body fat mass (-2.8 kg), waist circumference (-4.6 cm), hip circumference (-1.6 cm), and body fat percentage (-2.5%).

Pollock et al. (93) determined the effect of a 20-week walking program of moderate- to high-intensity in sedentary middle-aged men. The training program consisted of walking 4 days/week for approximately 40 minutes per day. After the 20-week intervention, body weight (-1.3 kg), percent body fat (-1.1%), abdominal (-0.7 in) and gluteal (-0.3 in) circumferences all decreased significantly. Percent body fat increased significantly in the control group while all other body composition and girth measurements remained unchanged.

Leon et al. (66) examined the effects of a vigorous walking program on body composition of young, obese men. The walking program increased from one, 15-minute walk at 1.5 mph walk up a 10% grade each session for 5 days per week to three, 30-minute walks at 3.2 mph up a 10% grade each session for 5 days per week. After 16 weeks, significant decreases were shown in body weight (-5.7 kg), BMI (-1.8 $kg \cdot m^{-2}$), and fat weight (-5.9 kg). In addition, significant decreases in 5 of the 7 skinfold measurements also occurred in response to 16 weeks of vigorous walking.

A study by Parkkari et al. (86) assessed the impact of golfing 2-3 times per week on health outcomes in previously sedentary overweight, middle-aged men. It was found that low intensity walking equivalent to 15-20 km per week resulted in significant improvements in aerobic performance, body weight (-1.4 kg), waist circumference (-2.2 cm), and abdominal skinfold thickness (-2.2 cm).

Yamanouchi et al. (133) compared the effects of diet and diet plus exercise on insulin sensitivity and body weight in obese patients with non-insulin dependent diabetes mellitus. The diet consisted of a daily caloric intake equivalent to 1,000 kilocalories (54-58% carbohydrates, 17-20% protein, and 25-26% fat) below their usual self-reported intake. The diet plus exercise group was instructed to walk at least 10,000 steps/day. Over the course of the intervention the diet only group walked an average of 4,500 steps per day while the diet plus exercise group walked 19,200 steps/day. As a result, the diet plus exercise group lost significantly more body weight than the diet only group (7.8 vs. 4.2 kg).

Hinkleman and Nieman (44) assessed the benefits of a walking program on body composition of overweight, sedentary women. The training program consisted of walking five days per week, for 45 minutes per day at an intensity equivalent to 62% VO_{2max}. After 15 weeks, there were no significant changes in body weight, body fat percentage, fat weight or lean weight in the walking group while body weight, fat weight, and lean weight all increased significantly in the inactive control group. Thus, while the walking intervention did not produce weight loss, it did help to prevent the weight gain (1.7 kg) that occurred in the control group.

Similarly, Snyder et al. (112) found that a long-term, moderate intensity intermittent exercise program failed to improve body weight or body composition in overweight females. The intervention consisted of moderate intensity exercise 5 days per week for 30 minutes per day (3, 10 minute bouts). After 32 weeks, body weight, percent body fat, and waist:hip ratio remained unchanged. Surprisingly, energy intake and nutrient composition estimated by 24-hour recall remained unchanged. Although body weight and body composition remained unchanged in the group as a whole, 7 of the 13 participants experienced significant decreases in fat weight and waist:hip ratio while the remaining 6 subjects significantly increase fat weight over the course of the intervention.

Thus, it was suggested that among overweight, middle-aged females, there may be responders and non-responders to the same intervention.

Swartz et al. (121) examined the impact of a 10,000 step/day recommendation on glucose and insulin dynamics in overweight women. Subjects in this study increased their daily walking from 4,972 to 9,213 steps/day. Despite improvements in 2-hour plasma glucose levels and the area under the curve for glucose, body weight essentially remained unchanged, which is likely due to the relatively short duration of the study (8 weeks).

Gender Comparison

Although several studies have assessed the impact of walking on body composition in men and women, very few have compared the gender effect in response to the same intervention. Although exercise has been shown to be an effective tool for weight management, its effects may be influenced by gender. A meta-analysis of 40 studies by Ballor and Keesey provided evidence that males lost more body mass than females in response to run/walk exercise interventions (6). It was suggested that males participating in the studies were heavier and relatively more fat than the females resulting in increased energy expenditure per session which may have contributed to the greater body mass reduction observed in males.

Kirk et al. (59) showed that both males and females significantly improved aerobic capacity in response to an exercise program of equal intensity and duration, but only the males lost a significant amount of body weight after the 16-month intervention. The exercise regimen progressed from 3 days per week for 30 minutes per session at 60%

HRR for the first 4 months and was increased to 5 days per week for 45 minutes per session at 75% HRR and was maintained for the duration of the study. It was noted that energy intake was not restricted and remained unchanged throughout the duration of the study. After 9 months, males significantly decreased body weight (-5.3 kg) and fat weight (-5.0 kg) and maintained the weight loss throughout the remainder of the study. However, females did not significantly decrease their body weight or fat weight over the 16-month intervention. Similarly, Snyder-Heelan et al. (112) found that only the males lost a significant amount of body weight in response to an exercise program with a goal energy expenditure of 420 kcal/session. In this study, moderately obese males and females were randomized to an exercise group (5 days per week for 45 minutes per session at 70-85% HRR) or an inactive control group. After 66 weeks, the males in the exercise group lost a significant amount of body weight (-5.1 kg) while the females in the exercise group increased body weight slightly (0.8 kg). Although this amount of exercise was not effective for weight loss in females, it did serve to limit weight gain that occurred in the female control group (4.1 kg) over 66-week intervention.

In 2003, Donnelly et al. (22) compared the long-term effects of supervised, moderate-intensity exercise on body weight and body composition in previously sedentary, overweight and moderately obese men and women. The training protocol consisted primarily of walking on a motor-driven treadmill 5 days per week and progressed in intensity from 60% of the HRR at baseline to 75% HRR at 6 months and duration from 20 minutes per session at baseline to 45 minutes per session at 6 months. The targeted minimum energy equivalent for exercise was approximately 400 kcal per session. After 16 months, the men averaged 668 kcal per exercise session and the women averaged 439 kcal. In addition, the men experienced significant decreases in body weight (-5.2 kg), BMI (-1.6 kg/m^{-2}), and fat mass (-4.9 kg) compared with men in the control group. Women who exercised maintained body weight, BMI, and fat mass while the women in the control group experienced significant increases in these three variables after 16 months. Although the women in this study did not lose weight, the exercise regimen did attenuate weight gain in the women who exercised compared with women in the control group. At 16 months, the women who exercised had significantly lower body weight, BMI, and fat mass compared with the controls. Interestingly, no significant differences were found either between or within groups across the 16-month intervention in total energy intake or macronutrient intake for men and women at any point in the study. It was concluded that 16 months of moderate-intensity exercise prevented weight gain in women and produced weight loss in men. Thus, it was suggested that 225 minutes of moderate-intensity exercise per week may be a guideline for the amount of exercise necessary to prevent weight gain in young women and produce weight loss in young men.

From studies directly comparing the male and female response to exercise training, it can be surmised that males are more likely to lose weight while females are more likely to maintain their weight following an exercise intervention. Interestingly, animal research supports these findings in that a gender specific response in regard to body mass and exercise training has consistently been noted with females conserving and males reducing body mass in response to exercise training (19, 83).

Summary

Although the results regarding the effect that regular walking has on body composition are not in complete agreement, there is substantial evidence suggesting that that walking can positively influence body composition variables. As is the case with changes in blood pressure and lipid/lipoprotein levels in response to a walking intervention, differences in baseline subject characteristics and training protocol likely contribute to some of the noted discrepancies. In addition, considering the impact that energy intake can have on body composition changes, the fact that several studies failed to account for this important factor makes it difficult to focus on physical activity alone as the factor influencing body composition changes. Nevertheless, there are plenty of reasons to believe that exercise can favorably alter body composition. Along with the increase in energy expenditure that accompanies physical activity, time spent exercising is also time spent away from food, which positively affects both sides of the energy balance equation. In addition to being a tool for promoting weight loss, walking can also be used as an activity to prevent weight regain following a physical activity intervention (31). In fact, data from the National Weight Control Registry has shown that the maintenance of exercise is one of the major factors associated with the maintenance of weight loss (60).

It also well known that physical activity can affect variables other than body composition, blood pressure and blood cholesterol. It is generally agreed that increased physical activity can result in significant psychological benefits. Gwinup noted that although many of the subjects indicated that they did not enjoy the exercise periods, most were quite pleased about the results achieved and particularly about the general feeling of wellbeing they experienced. They commented that weight loss through exercise, unlike that previously achieved through dieting, was not accompanied by feelings of weakness and increased nervousness, but rather by feelings of increased strength and relaxation (34).

Given the vast potential for physical activity to alter a wide range of health related variables, it is essential to not only encourage the inactive to become more physically active but also to encourage those who are physically active to maintain it. It is important to note that regular exercise may elicit health benefits such as improved cardiorespiratory fitness (82), blood lipid profile (40), blood pressure (107), and blood sugar control (121), even in the absence of a weight reduction (130). As noted by Donnelly et al. (22) our challenge now is to develop means of achieving sustained increases in exercise (or physical activity) in young men and women.

References

1. Ainsworth, B. E., M. T. Richardson, D. R. Jacobs, A. S. Leon, and B. Sternfeld. Accuracy of recall of occupational physical activity by questionnaire. *J. Clin. Epidemiol.* 52:219-227, 1999.

2. American College of Sports Medicine. Benefits and risks associated with exercsie. In: *ACSM's Guidelines for Exercise Testing and Prescription.* B. A. Franklin (Ed.) Baltimore, MD: Lippincott Williams & Wilkins, 2000, pp. 5-7.

3. American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Med. Sci. Sports Exerc.* 10: 7-10, 1978.

4. Arakawa, R. Hypertension and exercise. *Clin. Exp. Hypertens.* 15:1171-1179, 1993.

5. Asikainen, T.-M., S. Miilunpalo, P. Oja, et al. Randomised, controlled walking trials in postmenopausal women: the minimum dose to improve aerobic fitness. *Br. J. Sports Med.* 36:189-194, 2002.

6. Ballor, D. L. and R. E. Keesey. A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass and fat-free mass in males and females. *Int. J. Obes.* 15:717-726, 1991.

7. Bassett, D. R. Validity and reliability issues in objective monitoring of physical activity. *Res. Q. Exerc. Sport* 71:30-36, 2000.

8. Bassett, D. R., B. E. Ainsworth, S. R. Leggett, et al. Accuracy of five electronic pedometers for measuring distance walked. *Med. Sci. Sports Exerc.* 28:1071-1077, 1996.

9. Bassett, D. R., B. E. Ainsworth, A. M. Swartz, S. J. Strath, W. L. O'Brien, and G. A. King. Validity of four motion sensors in measuring moderate intensity physical activity. *Med. Sci. Sports Exerc.* 32:S471-S480, 2000.

10. Bassett, D. R. and S. J. Strath. Use of pedometers to assess physical activity. In: *Physical activity assessments for health-related research.* G. J. Welk (Ed.) Champaign, IL: Human Kinetics, 2002, pp. 163-177.

11. Bjorntorp, P. Hypertension and exercise. *Hypertension* 4(suppl 3):III56-59, 1982.

12. Blair, S. N., N. N. Goodyear, L. W. Gibbons, and K. H. Cooper. Physical fitness and incidence of hypertension in healthy normotensive men and women. *JAMA.* 252:487-490, 1984.

13. Blair, S. N., J. B. Kampert, H. W. Kohl, et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA*. 276:205-210, 1996.

14. Blair, S. N., H. W. Kohl, R. S. Paffenbarger, D. G. Clark, K. H. Cooper, and G. L. W. Physical fitness and all-cause mortality: a prospective study of healthy men and women. *JAMA*. 262:2395-2401, 1989.

15. Casperson, C. J., K. E. Powell, and G. M. Christenson. Physical activity, exercise, and physical fitness. *Public Health Report*. 100:125-1341, 1985.

16. Centers for Disease Control and Prevention. *Prevalence of Physical Activity, Including Lifestyle Activities Among Adults - United States, 2000-2001*: Morbidity and Mortality Weekly Report, 2003, pp. 764-769.

17. Chirico, A., M. and A. J. Stunkard. Physical activity and human obesity. *New Engl. J. Med.* 263:935-940, 1960.

18. Crouse, S. R., B. C. O'Brien, P. W. Grandjean, et al. Training intensity, blood lipids, and apolipoproteins in men with high cholesterol. *J. Appl. Physiol.* 82:270-277, 1997.

19. Dance, D. M., B. Bromley, R. J. Barnard, and R. A. Gorski. Sexually dimorphic effects of forced exercise on food intake and body weight in the rat. *Physiol. Behav.* 19:155-158, 1977.

20. Dishman, R. K. and J. Buckworth. Adherence to physical activity. In: *Physical Activity and Mental Health.* W. P. Morgan (Ed.) Philadelphia: Taylor & Francis, 1997, pp. 63-80.

21. Dishman, R. K. and J. Buckworth. Increasing physical activity: A quantitiative sytnthesis. *Med. Sci. Sports Exerc.* 28, 1996.

22. Donnelly, J.æE., J. O. Hill, D. J. Jacobsen, et al. Effects of a 16-month randomized controlled exercise trial on body weight and composition in young, overweight men and women. *Arch. Intern. Med.* 163:1343-1350, 2003.

23. Donnelly, J. E., D. J. Jacobsen, K. Snyder-Heelan, R. Seip, and S. Smith. The effects of 18 months of intermittent vs continuous exercise on aerobic capacity, body weight and composition, and metabolic fitness in previously sedentary, moderately obese females. *Int. J. Obes.* 24:566-572, 2000.

24. Duncan, J. J., N. F. Gordon, and C. B. Scott. Women walking for health and fitness. *JAMA*. 266:3295-3299, 1991.

25. Durstine, L. J., P. W. Grandjean, P. G. Davis, M. A. Ferguson, N. L. Alderson, and K. D. DuBose. Blood lipid and lipoprotein adaptations to exercise. *Sports Med.* 31:1033-1062, 2001.

26. Durstine, L. J. and W. L. Haskell. Effects of exercise training on plasma lipids and lipoproteins. *Exerc. Sports Sci. Rev.* 22:477-521, 1994.

27. Eckel, R. H. and R. M. Krauss. American Heart Association Call to Action: Obesity as a Major Risk Factor for Coronary Heart Disease. *Circulation* 97:2099-2100, 1998.

28. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. *JAMA*. 285:2486-2497, 2001.

29. Eyler, A. A., R. C. Brownson, S. J. Bacak, and R. A. Housemann. The epidemiology of walking for physical activity in the United States. *Med. Sci. Sports Exerc.* 35:1529-1536, 2003.

30. Flegal, K. M., M. D. Carroll, C. L. Ogden, and C. L. Johnson. Prevalence and Trends in Obesity Among U.S. Adults, 1999-2000. *JAMA*. 288:1723-1727, 2002.

31. Fogelholm, M., K. Kukkonen-Harjula, A. Nenonen, and M. Pasanen. Effects of walking training on weight mantenance after a very low-energy diet in premenopausal women. *Arch. Intern. Med.* 160:2177-2184, 2000.

32. Freedson, P. S. and K. Miller. Objective monitoring of physical activity using motion sensors. *Res. Q. Exerc. Sport* 71:21-29, 2000.

33. Gayle, R., H. J. Montoye, and J. Philpot. Accuracy of pedometers for measuring distance walked. *Res. Q.* 48:632-636, 1977.

34. Gwinup, G. Effect of exercise alone on the weight of obese women. *Arch. Intern. Med.* 135:676-680, 1975.

35. Hajjar, I. and T. A. Kotchen. Trends in prevalence, awareness, treatment, and control of hypertension in the United States. *JAMA*. 290:199-206, 2003.

36. Hatano, Y. Prevalence and use of pedometer. *Res. J. Walking*. 1:45-54, 1997.

37. Hatano, Y. Use of the pedometer for promoting daily walking exercise. *ICHPER J.* 29:4-8, 1993.

38. Helmrich, N. Journey to better fitness starts with 10,000 steps. *USA Today*. June 29, 1999:1.

39. Hendleman, D., K. Miller, C. Baggett, E. Debold, and P. Freedson. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Med. Sci. Sports Exerc.* 32:S442-S449, 2000.

40. Higashi, Y., S. Sasaki, N. Sasaki, et al. Daily aerobic exercise improves reactive hyperemia in patients with essential hypertension. *Hypertension* 33(part II):591-597, 1999.

41. Hill, J. O. A new way of looking at obesity. *Nutrition* 17:975-976, 2001.

42. Hill, J. O. and J.eC. Peters. Environmental contributions to the obesity epidemic. *Science* 280:1371-1374, 1998.

43. Hill, J. O., H. R. Wyatt, G. W. Reed, and J. C. Peters. Obesity and the environment: Where do we go from here? *Science* 299:853-855, 2003.

44. Hinkleman, L. L. and D. C. Nieman. The effects of a walking program on body composition and serum lipids and lipoproteins in overweight women. *J. Sports Med. Phys. Fitness.* 33:49-58, 1993.

45. Hootman, J. M., C. A. Macera, B. E. Ainsworth, M. Martin, C. L. Addy, and S. N. Blair. Association among physical activity level, cardiorespiratory fitness, and risk of musculoskeletal injury. *Am. J. Epidemiol.* 154:251-258, 2001.

46. Howley, E. T. Type of activity: resistance, aerobic and leisure versus occupational physical activity. *Med. Sci. Sports Exerc.* 33:S364-S369, 2001.

47. Institute of Medicine for the National Academies. *Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Protein and Amino Acids (Macronutrients).* Washington, DC: The National Academies Press, 2002.

48. Iwane, M., M. Arita, S. Tomimoto, et al. Walking 10,000 steps/day or more reduces blood pressure and sympathetic nerve activity in mild hypertension. *Hypertens. Res.* 23:573-580, 2000.

49. Jakicic, J. M. and K. I. Gallagher. Exercise considerations for the sedentary, overweight adult. *Exerc. Sports Sci. Rev.* 31:91-95, 2003.

50. Jakicic, J. M., R. R. Wing, B. A. Butler, and R. J. Robertson. Prescribing exercise in multiple short bouts versus one continuous bout: effects on adherence, cardiorespiratory fitness, and weight loss in overweight men. *Int. J. Obes.* 19:893-901, 1995.

51. Kannel, W. B. Blood pressure as a cardiovascular risk factor. *JAMA*. 275:1571-1576, 1996.

52. Kelley, D. A., K. A. Kelley, and Z. V. Tran. Aerobic exercise and resting blood pressure: A meta-analytic review of randomized, controlled trials. *Prev. Cardiol.* 4:73-80, 2001.

53. Kelley, G. A. Effects of aerobic exercise in normotensive adults: a brief meta-analytic review of controlled clinical trials. *South Med. J.* 88:42-46, 1995.

54. Kelley, G. A., K. S. Kelley, and Z. V. Tran. Walking and resting blood pressure in adults: A meta-analysis. *Prev. Med.* 33:120-127, 2001.

55. Kelley, G. A., K. S. Kelley, and Z. V. Tran. Walking, lipids, and lipoproteins: a meta-analysis of randomized controlled trials. *Prev. Med.* 38:651-661, 2004.

56. Kemper, H. C. G. and R. Verschuur. Validity and reliability of pedometers in habitual physical activity research. *Eur. J. Appl. Physiol.*e. 37:71-82, 1977.

57. King, A. C., C. Castro, S. Wilcox, A. A. Eyler, J. F. Sallis, and R. C. Bronson. Personal and environmental factors associated with physical inactivity among different racial-ethnic groups of middle-aged and older-aged women. *Health Psychol.* 19:354-364, 2000.

58. King, A. C., W. L. Haskell, C. Barr Taylor, H. C. Kraemer, and R. F. DeBusk. Group- vs. home-based exercise training in healthy older men and women. *JAMA*. 266:1535-1542, 1991.

59. Kirk, E. P., J. E. Donnelly, D. J. Jacobsen, and C. Gibson. Time-course and gender effects in aerobic capacity and body composition for overweight individuals: Midwest exercise trial (MET). *Med. Sci. Sports Exerc.* 34:S120 [abstract], 2002.

60. Klem, M. L., R. R. Wing, M. T. McGuire, H. M. Seagle, and J. O. Hill. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. *Am. J. Clin. Nutr.* 66:239-246, 1997.

61. Kohl, H. W. Physical activity and cardiovascular disease: Evidence for a dose response. *Med. Sci. Sports Exerc.* 33:S472-S483, 2001.

62. Kraus, W. E., J. A. Houmard, B. D. Duscha, et al. Effects of the amount and intensity of exercise on plasma lipoproteins. *New Engl. J. Med.* 347:1483-1492, 2002.

63. Le Masurier, G. C., S. M. Lee, and C. Tudor-Locke. Motion sensor accuracy under controlled and free-living conditions. *Med. Sci. Sports Exerc.* 36:905-910, 2004.

64. Le Masurier, G. C. and C. Tudor-Locke. Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med. Sci. Sports Exerc.* 35:867-871, 2003.

65. Lee, I. M. and P. J. Skerrett. Physical activity and all-cause mortality: what is the dose-response relation? *Med. Sci. Sports Exerc.* 33:S459-S471, 2001.

66. Leon, A. S., J. Conrad, D. B. Hunninghake, and R. Serfass. Effects of a vigorous walking program on body composition, and carbohydrate and lipid metabolism of obese young men. *Am. J. Clin. Nutr.* 33:1776-1787, 1979.

67. Leon, A. S. and O. A. Sanchez. Response of blood lipids to exercise training alone or in combination with dietary intervention. *Med. Sci. Sports Exerc.* 33:S502-S515, 2001.

68. Lewis, C. E., H. E. McCreath, D. E. West, C. Loria, C. I. Kiefe, and A. B. Huylley. The obesity epidemic rolls on: 15 years in CARDIA. *Circulation* 104 (supple II):787, 2001.

69. Lokey, E. A. and Z. V. Tran. Effects of exercsie training on serum lipid and lipoprotein concentrations in women: A meta-analysis. *Int. J. Sports Med.* 10:424-429, 1989.

70. Lynch, N. A., B. J. Nicklas, D. M. Berman, K. E. Dennis, and A. P. Goldberg. Reductions in visceral fat during weight loss and walking are associated with improvements in VO2max. *J. Appl. Physiol.* 90:99-104, 2001.

71. Manson, J.Æ., F. B. Hu, J. W. Rich-Edwards, et al. A prospective study of walking as compared with vigorous exercise in the prevention of coronary heart disease in women. *New Engl. J. Med.* 341:650-658, 1999.

72. Marcus, B. H. Exercise Behavior and Strategies for Intervention. *Res. Q. Exerc. Sport* 66:319-323, 1995.

73. Marcus, B. H., V. C. Selby, R. S. Niaura, and J. S. Rossi. Self-Efficacy and the Stages of Exercise Behavior Change. *Res. Q. Exerc. Sport* 63:60-66, 1992.

74. Melby, C. L. and J. O. Hill. Exercise, Macronutrient Balance, and Body Weight Regulation. *GSSI.* 12:1-6, 1999.

75. Miller, W. C., D. M. Koceja, and E. J. Hamilton. A meta-analysis of the past 25 years of weight loss research using diet, exercise, or diet plus exercise intervention. *Int. J. Obes.* 21:941-947, 1997.

76. Miyatake, N., H. Nishidawa, A. Morishita, et al. Daily walking reduces visceral adiposte tissue areas and improves insulin resistance in Japanese obese adults. *Diabetes Res. Clin. Pract.* 58:101-107, 2002.

77. Moreau, K. L., R. Degarmo, J. Langley, et al. Increasing daily walking lowers blood pressure in postmenopausal women. *Med. Sci. Sports Exerc.* 33:1825-1831, 2001.

78. Morris, J. N. and A. E. Hardman. Walking to Health. *Sports Med.* 23:307-332, 1997.

79. Murphy, M. H. and A. E. Hardman. . Training effects of short and long bouts of brisk walking in sedentary women. *Med. Sci. Sports Exerc.* 30:152-157, 1998.

80. National Institutes of Health Consensus Development Panel. Triglyceride, HDL, and CHD. *JAMA*. 269:505-510, 1993.

81. Nieman, D. C., D. W. Brock, D. Butterworth, A. C. Utter, and C. C. Nieman. Reducing diet and/or exercise training decreases the lipid and lipoprotein risk factors of moderately obese women. *J. Am. Coll. Nutr.* 21:344-350, 2002.

82. Nieman, D. C., J. L. Haig, K. S. Fairchild, E. D. DeGuia, G. P. Dizon, and U. D. Register. Reducing-diet and exercise-training effects on serum lipids and lipoproteins in mildly obese women. *Am. J. Clin. Nutr.* 52:640-645, 1989.

83. Oscai, L. B. The role of exercise in weight control. *Exerc. Sports Sci. Rev.* 1:103-123, 1973.

84. Paffenbarger, R. S., R. T. Hyde, S. L. Wing, and C. C. Hseih. Physical activity, all-cause mortality, and longevity of college alumni. *New Engl. J. Med.* 314:605-613, 1986.

85. Paffenbarger, R. S., A. L. Wing, and R. T. Hyde. Physical activity as an index of heart attack risk in college alumni. *Am. J. Epidemiol.* 108:161-175, 1978.

86. Parkkari, J., A. Natri, P. Kannus, et al. A controlled trial of the health benefits of regular walking on a golf course. *Am. J. Med.* 109:102-108, 2000.

87. Pate, R.aR., M. Pratt, S. N. Blair, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 273:402-407, 1995.

88. Perri, M. G., S. D. Anton, P. E. Durning, et al. Adherence to exercise prescriptions: Effects of prescribing moderate versus higher levels of intensity and frequency. *Health Psychol.* 21:452-458, 2002.

89. Perri, M. G., D. Martin, E. A. Leermakers, S. F. Sears, and M. Notelovitz. Effects of group- versus home-based exercise in the treatment of obesity. *J. Consult. Clin. Psychol.* 65:278-285, 1997.

90. Pescatello, L. S., B. A. Franklin, R. Fagard, W. B. Farquhar, G. A. Kelley, and C. A. Ray. American College of Sports Medicine position stand: Exercise and hypertension. *Med. Sci. Sports Exerc.* 36:533-553, 2004.

91. Philippaerts, R. M., K. P. Westerterp, and J. Lefevre. Doubly labeled water validation of three physical activity questionnaires. *Int. J. Sports Med.* 20:284-289, 1999.

92. Pollock, M. L. Prescribing exercise for fitness and adherence. In: *Exercsie adherence: It's impact on public health.* R. K. Dishman (Ed.) Champaign, IL: Human Kinetics, 1988, pp. 259-277.

93. Pollock, M. L., H. S. Miller, R. Janeway, A. C. Linnerud, B. Robertson, and V. R. Effects of walking on body composition and cardiovascular function of middle-aged men. *J. Appl. Physiol.* 30:126-130, 1971.

94. Prochaska, J. O. and C. C. DiClemente. Stages and processes of self-change in smoking: Towards an integrative model of change. *J. Consult. Clin. Psychol.* 52:390-395, 1983.

95. Prong, N. P. Short term effects of exercise on plasma lipids and lipoptrotien in humans. *Sports Med.* 16:431-448, 1993.

96. Quittner, J. High-Tech Walking. *Time*. 156:77, 2000.

97. Reavan, P. D., E. Barrett-Connor, and S. Edelstein. Relation between leisure-time physical activity and blood pressure in older women. *Circulation* 83:559-565, 1991.

98. Rejeske, W. J., L. R. Brawley, and S. A. Schumaker. Physical activity and health-related quality of life. *Exerc. Sports Sci. Rev.* 24:71-108, 1996.

99. Ross, R., D. Dagnone, P. J. H. Jones, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. *Ann. Epidemiol.* 133:92-103, 2000.

100. Sallis, J. F., W. L. Haskell, S. P. Fortmann, K. M. Vranizan, C. B. Taylor, and D. S. Solomon. Predictors of Adoption and Maintenance of Physical Activity in a Community Sample. *Prev. Med.* 15:331-341, 1986.

101. Santiago, M. C., J. F. Alexander, G. A. Stull, R. C. Serfass, A. M. Hayday, and A. S. Leon. Physiological responses of sedentary women to a 20-week conditioning program of walking or jogging. *Scand. J. Sports Sci.* 9:33-39, 1987.

102. Santiago, M. C., A. S. Leon, and R. C. Serfass. Failure of 40 weeks of brisk walking to alter blood lipids in normolipemic women. *Can. J. Appl. Physiol.* 20:417-428, 1995.

103. Sawada, S., H. Tanaka, M. Funakoshi, M. Shindo, S. Kono, and T. Ishiko. Five-year prospective study on blood pressure and maximal oxygen uptake. *Clin. Exp. Parmacol. Physiol.* 20:483-487, 1993.

104. Schmidt, W. D., C. J. Biwer, and L. K. Kalscheuer. Effects of long versus short bout of exercise on fitness and weight loss in overweight females. *J. Am. Coll. Nutr.* 20:494-501, 2001.

105. Schwartz, R. S. The independent effects of dietary weight loss and aerobic training on high density lipoproteins and apolipoprotein A-I concentrations in obese men. *Metabolism*. 36:165-171, 1987.

106. Seals, D. R. and J. M. Hagberg. The effect of exercise training on human hypertension: A review. *Med. Sci. Sports Exerc.* 16:207-215, 1984.

107. Seals, D.dR., H. G. Silverman, M. J. Reiling, and K. P. Davy. Effect of regular aerobic exercise on elevated blood pressure in postmenopausal women. *Am. J. Cardiol.* 80:49-55, 1997.

108. Serdula, M. K., A.dH. Mokdad, D. F. Williamson, D. A. Galuska, J.dM. Mendlein, and G. W. Heath. Prevalence of attempting weight loss and strategies for controlling weight. *JAMA*. 282:1353-1358, 1999.

109. Sesso, H. D., R. S. Paffenbarger, and I. M. Lee. Physical activity and coronary heart disease in men: The Harvard Alumni Health Study. *Circulation* 102:975-980, 2000.

110. Skender, M. L., G. K. Goodrick, D. J. DelJunco, et al. Comparison of 2-year weight loss trends in behavioral treatments of obesity: Diet, exercise and combination interventions. *J. Am. Diet. Assoc.* 96:342-346, 1996.

111. Slenz, C. A., B. D. Duscha, J. L. Johnson, et al. Effects of the amount of exrecise on body weight, body composition, and measures of central obesity. *Arch. Intern. Med.* 164:31-39, 2004.

112. Snyder, K. A., J. E. Donnelly, D. J. Jacobsen, G. Hertner, and J. M. Jakicic. The effects of long-term, moderate intensity, intermittent exercise on aerobic capacity, body composition, blood lipids, insulin and glucose in overweight females. *Int. J. Obes.* 21:1180-1189, 1997.

113. Sopko, G., A. S. Leon, D. R. Jacobs, et al. The effects of exercise and weight loss on plasma lipids in young obese men. *Metabolism* 34:227-236, 1985.

114. Stamler, J., G. Rose, R. Stamler, P. Elliot, A. Dyer, and M. Marmot. INTERSALT study findings: public health and medical care implications. *Hypertension* 14:570-577, 1989.

115. Stunkard, A. A method of studying physical activity in man. *Am. J. Clin. Nutr.* 8:595-601, 1960.

116. Sturm, R. and K. B. Wells. Does obesity contribute as much to mortality as poverty or smoking? *Public Health.* 115:229-235, 2001.

117. Sugiura, H., H. Sugiura, K. Kajima, S. Mohammad Mirbod, H. Iwata, and T. Matsuoka. Effects of long-term moderate exercise and increase in number of daily steps on serum lipids in women: randomised controlled trial. *BMC Women's Health*. 2:3-10, 2002.

118. Suter, E., B. Marti, and F. Gutzwiller. Jogging or Walkingi- Comparison of Health Effects. *Ann Epidemiol*. 4:375-381, 1994.

119. Swartz, A. M., D.iR. Bassett, J.iB. Moore, D. L. Thompson, and S. J. Strath. Effects of body mass index on the accuracy of an electronic pedometer. *Int. J. Sports Med.* 24:588-592, 2003.

120. Swartz, A. M., S. J. Strath, D.iR. Bassett, W. L. O'Brien, G. A. King, and B. E. Ainsworth. Estimation of energy expenditure using CSA accelerometers at the hip and wrist sites. *Med. Sci. Sports Exerc.* 32:S450-S456, 2000.

121. Swartz, A. M. and D. L. Thompson. Increasing daily walking improves glucose tolerance in overweight women. *Prev. Med.* 37:356-362, 2003.

122. Swinburn, B. and E. Ravussin. Energy balance or fat balance? *Am. J. Clin. Nutr.* 57(suppl):766S-771S, 1993.

123. Thompson, D. L., J. Rakow, and S. M. Perdue. Relationship between accumulated walking and body composition in middle-aged women. *Med. Sci. Sports Exerc.* 36:911-914, 2004.

124. Tudor-Locke, C. Taking steps toward increased physical activity: Using pedometers to measure and motivate. *Research Digest*. 3:1-8, 2002.

125. Tudor-Locke, C. E., B. E. Ainsworth, M. C. Whitt, R. W. Thompson, C. L. Addy, and D. Jones. The relationship between pedometer-determined ambulatory activity and body composition variables. *Int. J. Obes.* 25:1571-1578, 2001.

126. Tyron, W. W., J. L. Goldberg, and D. R. Morrison. Activity decreases as percentage overweight increases. *The International Journal of Obesity.* 16:591-595, 1992.

127. U.S. Department of Health and Human Services. *Physical activity and health: a report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.

128. U.S. Department of Health and Human Services. *The Surgeon General's call to action to prevent and decrease overweight and obesity.* Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Office of the Surgeon General, 2001, pp. 1-60.

129. Washburn, R. A., M. K. Chin, and H. J. Montoye. Accuracy of pedometer in walking and running. *Res. Q.* 51:695-701, 1980.

130. Wei, M., J. Kampert, C. E. Barlow, et al. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. *JAMA.* 282:1547-1553, 1999.

131. Wilde, B. E., C. L. Sidman, and C. B. Corbin. A 10,000-Step Count as a Physical Activity Target for Sedentary Women. *Res. Q. Exerc. Sport* 72:411-414, 2001.

132. Woolf-May, K., E. M. Kearney, A. Owen, D. W. Jones, r. C. Davison, and S. R. Bird. The efficacy of accumulated short bouts versus single daily bouts of brisk walking in improving aerobic fitness and blood lipid profiles. *Health Educ. Res.* 14:803-815, 1999.

133. Yamanouchi, K., T. Shinozaki, K. Chikada, et al. Daily walking combined with diet therapy is a useful means for obese NIDDM patients not only to reduce body weight but also to improve insulin sensitivity. *Diabetes Care* 18:775-778, 1995.

PART III

ACCURACY AND RELIABILITY OF TEN PEDOMETERS FOR MEASURING STEPS OVER A 400-M WALK

Abstract

Purpose: The purpose of this study was to determine the accuracy and reliability of the following electronic pedometers for measuring steps: Freestyle Pacer Pro (FR), Kenz Lifecorder (KZ), New Lifestyles NL-2000 (NL), Omron HJ-105 (OM), Oregon Scientific PE316CA (OR), Sportline 330 (SL330) and 345 (SL345), Walk4Life LS 2525 (WL), Yamax Skeletone EM-180 (SK), and the Yamax Digi-Walker SW-701 (DW).

Methods: Ten males (34.7 ± 12.6 yrs), (mean± SD), and ten females (43.1 ± 19.9 yrs) ranging in BMI from 19.8 to 33.6 $kg \cdot m^{-2}$ walked 400-m around an outdoor track while wearing two pedometers of the same model (one on the right and left sides of the body) for each of ten models. Four pedometers of each model were assessed in this fashion. The actual steps taken were tallied by a researcher. **Results:** The KZ, NL, and DW were the most accurate in counting steps, displaying values that were within ± 3% of the actual steps taken, 95% of the time. The SL330 and OM were the least accurate, displaying values that were within± 37% of the actual steps, 95% of the time. The reliability within a single model (Chronbach's alpha) was >0.80 for all pedometers with the exception of the SL330. The intra-model reliability was exceptionally high (>0.99) in the KZ, OM, NL, and the DW. **Conclusion:** Due to the variation that exists among models in regard to the internal mechanism and sensitivity, not all pedometers count steps accurately. Thus, it is important for researchers who use pedometers to assess physical activity to be aware of their accuracy and reliability.

Key Words: steps, step counter, physical activity, motion sensor, walking

Introduction

Prospective epidemiological studies support the belief that a physically active lifestyle can lower the risk of developing various chronic diseases such as coronary artery disease, Type 2 diabetes mellitus, hypertension, and obesity (1). With an emphasis on promoting a physically active lifestyle, numerous studies have examined the practicality and feasibility of using the pedometer as a tool for measuring physical activity levels (10,11,17,22,23,28,29). Pedometers are devices that are typically worn at the waist and are capable of counting steps. Some models also calculate distance and estimate energy expenditure. Pedometers are a means of objectively measuring ubiquitous, ambulatory activity as well as many types of structured physical activities (24).

The three main areas in which pedometer models may differ are cost, mechanism, and sensitivity of the device. There is considerable variation in the cost of a pedometer which can range anywhere from $10 to $200. Given the wide range of costs of various pedometers, a less expensive pedometer becomes an attractive option for those wanting to do large-scale studies. Thus, it would be of interest to determine if some of the less expensive pedometers are as accurate as some of the more costly versions. The internal mechanism is also a distinguishing point among the various brands and models of pedometers. There are three primary mechanisms by which pedometers function. The first type uses a spring-suspended horizontal lever arm that moves up and down in response to the hip's vertical accelerations. This movement opens and closes an electrical circuit; the lever arm makes an electrical contact (metal-on-metal contact) and a step is registered. The second type of mechanism is a magnetic reed proximity switch. With this mechanism, a magnet connected to a spring-suspended horizontal lever arm within the pedometer moves up and down with each vertical acceleration of the hip. The magnetic field triggers a proximity switch encased in a glass cylinder and a step is counted. The third type uses an accelerometer-type mechanism consisting of a horizontal beam and a piezo-electric crystal. Pedometers using this particular mechanism can distinguish between differing intensities of exercise when estimating caloric expenditure. Finally, pedometers may also differ in their sensitivity, which is a function of the vertical acceleration "threshold" needed to trigger a step. Although this issue is related to the mechanism, the sensitivity of the internal mechanisms of different pedometers can vary as can the quality of the mechanism itself.

In general, pedometers are most accurate in counting steps, less accurate in calculating distance, and even less accurate at estimating energy expenditure (2,4). Since steps are the most direct expression of what the pedometer actually measures (25), most researchers recommend reporting pedometer data as steps (4,25). A previous study conducted by Bassett et al. (2) assessed the accuracy of five electronic pedometers in measuring distance walked and steps taken on a sidewalk course and found that pedometers varied significantly in the pedometer-calculated distance over 4.88 km. Due to the potential for such inaccuracies between pedometer models, it is essential that pedometers be tested for accuracy.

In addition to the variation that exists between models, it is possible for discrepancies to exist within a particular pedometer model (intra-model reliability). Given the potential for differences in manufacturing tolerances and design specifications, it is conceivable for devices of the same model to differ significantly in steps counted.

Thus, it is evident that the reliability of pedometers within a particular model should be assessed.

Considering the fact that a great number of pedometer models have been introduced in recent years and that variability exists not only in the cost but also in the mechanism and sensitivity among pedometers, it would be beneficial to determine the accuracy of a variety of pedometers. In addition, the only multi-brand comparison was carried out in 1996 (2), and none of the pedometers that were assessed at that time are currently available. Therefore, the purpose of this study was to determine the accuracy and reliability of ten electronic pedometers for counting steps.

Methods

Pedometers

Ten models of commercially available electronic pedometers were assessed in this study: Freestyle Pacer Pro (FR), Kenz Lifecorder (KZ), New Lifestyles NL-2000 (NL), Omron HJ-105 (OM), Oregon Scientific PE316CA (OR), Sportline 330 (SL330) and 345 (SL345), Walk4Life LS 2525 (WL), Yamax Skeletone EM-180 (SK), and the Yamax Digi-Walker SW-701 (DW). Pedometer characteristics are presented in Table 1.

Subjects

Ten male and ten female adults (22-69 yrs of age) volunteered to participate in the study. The procedures were reviewed and approved by the Institutional Review Board at the University of Tennessee. Each subject completed a Physical Activity Readiness

Table 1. Pedometer characteristics

Model	Model	Country of Manufact.	Mechanism	Features	Approx. Cost
Freestyle	Pacer Pro	China	M-M	S, D, C	$20
Kenz	Lifecorder	Japan	Accelerom.	S, C*	$200
New Lifestyles	NL-2000	Japan	Accelerom.	S, C*	$50
Omron	HJ-105	China	Reed	S, D, C	$27
Oregon Scientific	PE316CA	China	Reed	S, D, C	$20
Sportline	330	Taiwan	M-M	S	$13
Sportline	345	Taiwan	M-M	S, D, C	$30
Walk4Life	LS 2525	Taiwan	M-M	S, D, C	$29
Yamax	Skeletone	Japan	Reed	S	$15
Yamax	SW-701	Japan	M-M	S, D, C	$30

Mechanism: Metal-on-metal (M-M), Accelerometer (Accelerom.), Magnetic Reed Proximity Switch (MRPS)
Features: Steps (S), Distance (D), Calories (C)
* Indicates pedometers that estimate both gross and net caloric expenditure
Approx. cost represents suggested retail cost ($)

Questionnaire (PAR-Q) (Appendix B) and signed a written informed consent (Appendix A) prior to participating in the study. Height was measured without shoes using a stadiometer and weight was also assessed without shoes in light clothing using a calibrated physician's scale. In addition, each subject's stride length was determined prior to participation in the study. To determine stride length, subjects were asked to take 20 strides at their normal walking pace on an outdoor track. The total distance was divided by 20, to calculate average stride length. Physical characteristics of the subjects are presented in Table 2.

The subjects then took part in a series of walks around a 400-m outdoor track. Pedometer placement was standardized by placing it on the belt or waistband, in the mid-line of the thigh, consistent with the manufacturers' recommendations. Pedometers with a variable sensitivity switch (OM, OR) were always placed in the middle setting. Devices of the same model were worn on both the right and left sides of the body while the subject walked a lap around the 400-m track. Then, two other devices of the same model were tested during a subsequent lap around the track to determine intra-model reliability. This procedure was repeated until 4 pedometers representing each of the 10 models were tested. The actual steps taken were determined by a researcher using a hand-tally counter. The researcher walked behind the subject to avoid influencing the subject's pace. Each subject walked at his/her own normal walking speed and the amount of time it took to complete the lap was measured in order to calculate walking speed. The testing took place over the course of one to four days and the subjects wore the same pair of shoes for all trials.

Table 2. Physical characteristics of subjects

	Males	Females
Age (yrs)	34.7±12.6 (22-55)	43.1±19.9 (22-69)
Height (cm)	182.4±4.3 (175-188)	165.0±6.6 (157.5-178)
Weight (kg)	92.5±15.0 (74.5-117.3)	69.3±12.5 (53.2-90.9)
BMI ($kg \cdot m^{-2}$)	27.7±4.0 (22.2-33.6)	25.5±4.9 (18.6-32.1)
Stride length (m)	.79±.07 (.70-.90)	.71±.08 (.60-.85)

Values are mean ± SD (range)
BMI = Body Mass Index

Statistical Analysis

All analyses were performed using SPSS 11.0.1 for Windows (SPSS Inc., Chicago IL). For all analyses, an alpha of 0.05 was used to denote statistical significance. A 2-way repeated measures ANOVA (model x side) was used to assess differences between pedometers worn on the right and left sides of the body and to determine if significant differences existed between pedometer models. Paired t-tests were used to determine if the pedometer-estimated steps were significantly different from the actual steps taken. Cronbach's alpha was used to assess the intra-model reliability among pedometers of the same model. An alpha value of 0.80 was used to denote statistically significant intra-model reliability (12).

Bland-Altman (5) plots were constructed to show the dispersion of the individual pedometer error scores around zero. This is a widely accepted technique to show the accuracy of biomedical devices (27). In this manner, the mean error score can be illustrated and the 95% prediction interval (i.e., 95% confidence interval for the individual observations) can also be shown. Individual error scores that have a tight prediction interval around zero signify a more accurate device.

Results

The average self-selected walking speed was 96.5 $m \cdot min^{-1}$ and ranged from 77.3 to 114.9 $m \cdot min^{-1}$. There was no significant difference ($P>0.05$) between pedometers worn on the right and left sides of the body. However, there was a significant difference ($P<0.05$) among the 10 pedometer models. To determine accuracy, an error score (actual steps minus pedometer steps) was computed and compared to zero. Individual error scores of zero would indicate that there was no difference between the estimated and actual steps taken, while negative scores represent overestimations and positive scores represent underestimations. Figure 1 displays the mean error scores between the actual steps taken and the pedometer-measured steps. The OR significantly overestimated the actual number of steps taken (P<0.05). The SL330 significantly underestimated the actual number of steps (P<0.05). The remaining pedometers had mean values that neither over- nor under-estimated the true number of steps taken. However, as we will show, three models (NL, DW, KZ) were clearly more accurate than the other models.

Table 3 displays the mean error scores and the 95% prediction intervals. Figures 2-4 show the Bland-Altman plots for various pedometer models. For convenience, the y-axes are standardized to highlight the differences in accuracy between pedometers. The NL, DW, and KZ models were exceptionally accurate, having 95% prediction intervals that were within ± 17 steps (out of an average of 513) from zero. The WL, SK, SL345, FR, and OR were moderately accurate, having 95% prediction intervals that were within ± 100 steps from zero. Finally, the OM and SL330 were the least accurate, having 95% prediction intervals that were within ± 188 steps from zero.

As shown in Table 4, the intra-model reliability (among 4 pedometers of a single model) was >0.80 in all pedometers with the exception of the SL330. The intra-model reliability was exceptionally high (>0.99) in the KZ, OM, NL, and the DW. However, despite high reliability, the OM had poor accuracy.

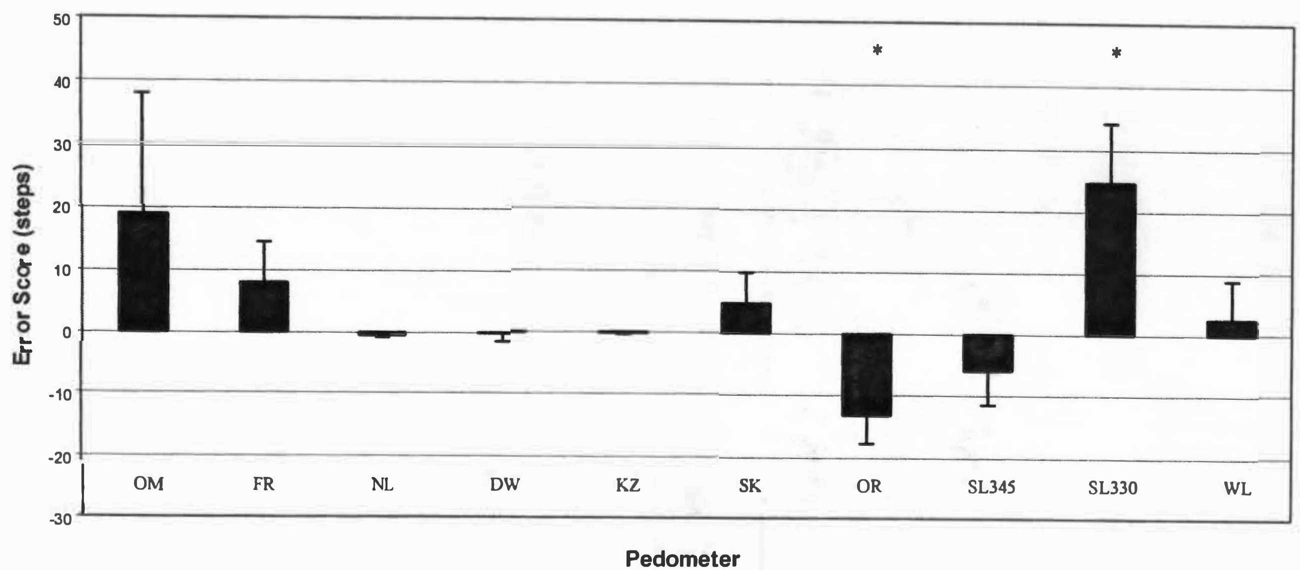

Figure 1. Mean error scores (Actual – Pedometer) ± SE in number of steps during a 400-m track walk at self-selected speeds * P<0.05.

Table 3. Error scores (Actual – Pedometer) in number of steps during a 400-m track walk at self-selected speeds.

Pedometer	Mean	SD	95% Prediction Interval
FR	8.0	42.6	(93.1, -77.2)
KZ	-.2	1.5	(2.7, -3.2)
NL	-.5	2.1	(3.7, -4.6)
OM	19.0	84.5	(188.1, -150.1)
OR	-13.3*	27.6	(41.9, -68.6)
SL330	24.7*	70.5	(165.7, -116.4)
SL345	-6.0	37.2	(68.4, -80.3)
WL	2.6	40.0	(82.6, -77.4)
SK	4.8	31.5	(67.8, -58.2)
DW	-.1	8.4	(16.7, -16.9)

SD= Standard Deviation
Negative scores correspond to overestimations and positive scores represent underestimations of actual steps taken.
* $P<0.05$

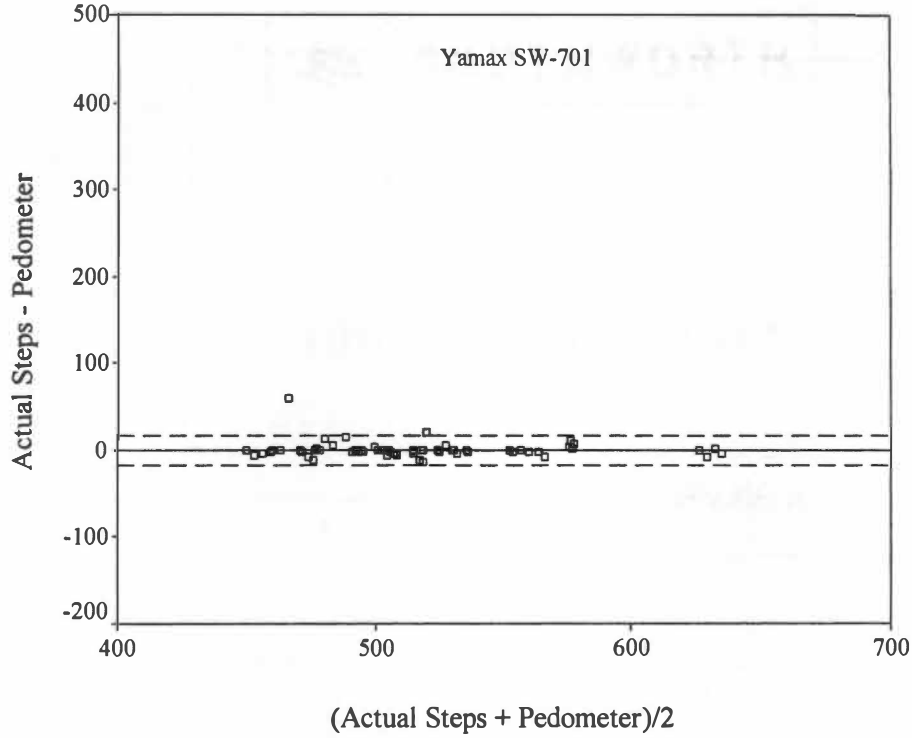

Figure 2. Representative Bland-Altman plot for the Yamax Digi-Walker SW-701 (DW) which was one of the three most accurate pedometers. Solid horizontal line = mean error score, dashed linesa= 95% prediction intervals (i.e., 95% Confidence Intervals of the individual observations).

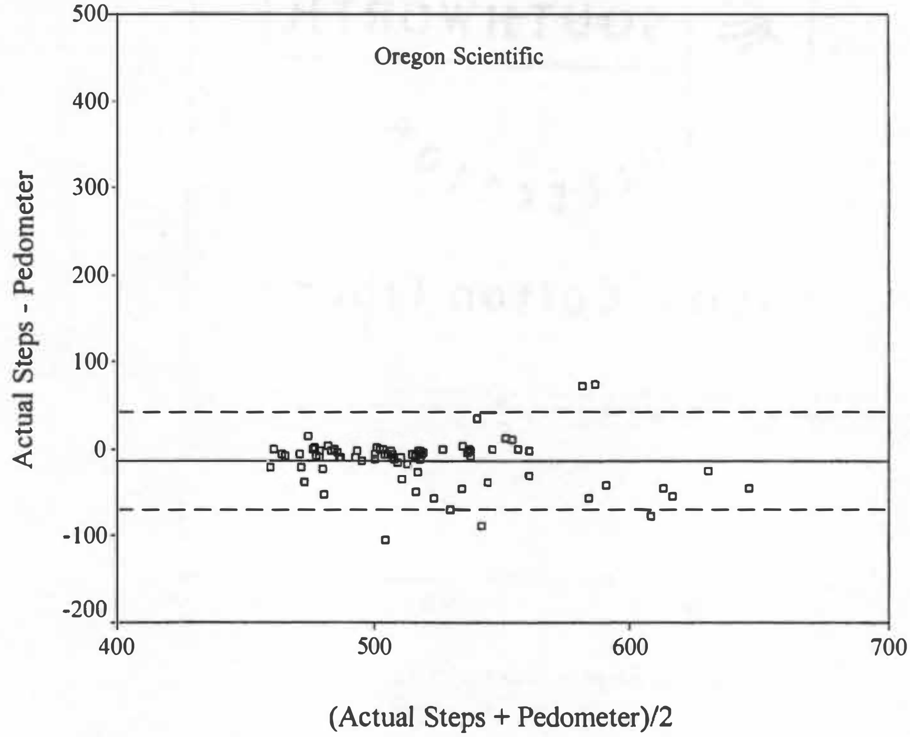

Figure 3. Representative Bland-Altman plot for the Oregon Scientific PE316CA (OR) which was among the four moderately accurate pedometers. Solid horizontal line = mean error score, dashed linese= 95% prediction intervals (i.e., 95% Confidence Intervals of the individual observations).

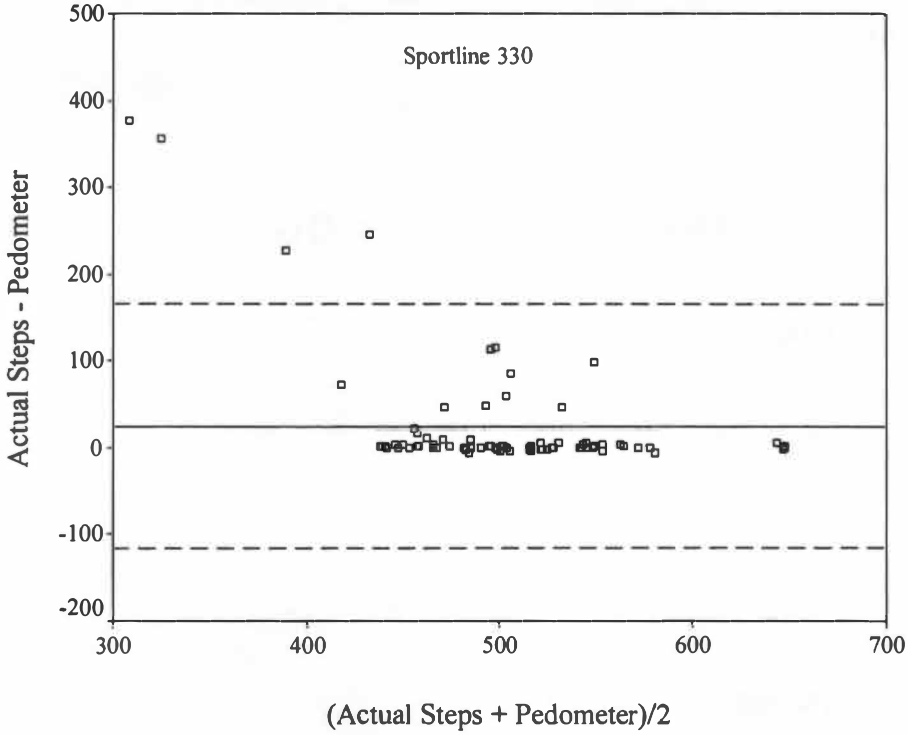

Figure 4. Representative Bland-Altman plot for the Sportline 330 (SL330) which was one of the two least accurate pedometers. Solid horizontal line = mean error score, dashed lines = 95% prediction intervals (i.e., 95% Confidence Intervals of the individual observations).

Table 4. Intra-model reliability for each of the 10 different pedometer models.

Pedometer	Chronbach's Alpha
Freestyle Pacer Pro	.90
Kenz Lifecorder	.998
New Lifestyles NL-2000	.995
Omron HJ-105	.991
Oregon Scientific PE316CA	.924
Sportline 330	.76
Sportline 345	.87
Walk4Life LS2525	.885
Yamasa Skeletone	.935
Yamax Digi-Walker SW-701	.992

Table 5 displays the mean difference in actual distance walked and the pedometer-calculated distance. Negative scores represent overestimations and positive scores indicate underestimations by the pedometer. There were significant differences ($P<0.05$) in five of the six pedometers that calculated distance, with the SL345 approximating distance more closely than all other models. To determine accuracy in calculating distance, the estimated distance from the pedometer was subtracted from the actual distance walked and this difference score was compared to zero.

Discussion

In the current study, eight of the ten pedometers tested yielded mean values that were not significantly different from the actual steps taken at self-selected walking speeds. However, the KZ, NL, and DW were the only pedometers accurate to withine± 3% of the actual steps taken, 95% of the time. These three pedometers differed from the actual steps taken by less than 17 steps during a 400-m walk (totaling about 513 steps). Interestingly, these pedometers are all made in Japan, and they all met the Japanese Industrial Standard set by the Ministry of Industry and Trading regulations (7), which requires less than a three percent margin of error (3 steps out of 100). The intra-model reliability for the KZ, NL, and DW was also very high (>0.99), suggesting adequate quality control and tight manufacturing tolerances. These pedometers would appear to be suitable for use in research studies.

Four of the other pedometers (WL, SK, SL345, FR) had moderate accuracy. They displayed values that were withine± 20% of the actual steps taken, 95% of the time. These four models predicted the actual steps to within ± 100 steps during a 400-m walk.

Table 5. Error scores (Actual – Pedometer) in distance (m) during a 400-m track walk at self-selected speeds.

Pedometer	Mean	Std. Error	95% Confidence Intervals
FR	29*	8	(11, 47)
OM	37*	16	(4, 70)
OR	75*	10	(55, 94)
SL345	12	8	(-6, 30)
WL	33*	8	(17, 50)
DW	25*	6	(12, 37)

Negative scores correspond to overestimations and positive scores represent underestimations of actual distance walked* $P<0.05$.

Three pedometer models were judged to be unacceptable under the conditions in which they were tested. The OR consistently tended to over-estimate the actual number of steps, possibly due to a high sensitivity for recording steps. As a result, the OR significantly over-estimated the mean number of steps ($P<0.05$). The SL330 and OM were the least accurate pedometers; they displayed values that were within $\pm$ 37% of the actual steps taken, 95% of the time. These two models predicted the actual steps to within a $\pm$ 188 steps during a 400-m walk. Only the SL330 significantly under-estimated the mean number of steps taken. However, in both of these pedometers, there was a tendency to grossly underestimate steps, particularly in obese subjects (BMI $\geq$ 30 $kg \cdot m^{-2}$). Thus, these pedometers would be poor choices for use with obese individuals.

There have been conflicting results regarding pedometer accuracy in obese individuals (BMI $\geq$30 $kg \cdot m^{-2}$). Shephard et al. (18) reported that the Sportline pedometer was less accurate in obese subjects compared with non-obese subjects as evidenced by greater mean absolute error scores in the obese. However, Swartz et al. (19) demonstrated that the Yamax SW-200 pedometer was accurate in lean, overweight, and obese subjects. Their results are consistent with those in the current study in showing that the Yamax SW-701 was accurate over a wide range of BMI's (18.6-33.6 $kg \cdot m^{-2}$). (These two models use the same internal mechanism for recording steps; they differ only in the functions that are displayed). Some other pedometers (OM and SL330) grossly underestimated steps taken by obese subjects. It should be noted, however, that the OM was accurate in individuals with both normal BMI's (18-24.9 $kg \cdot m^{-2}$) and those classified as overweight (25-29.9 $kg \cdot m^{-2}$). It is possible that in obese individuals, especially those with a significant amount of abdominal fat, the angle of the pedometer when clipped to the belt or waistband compromises its ability to count steps accurately.

Although the accuracy of pedometers for assessing distance was also examined, the results should be interpreted with caution. To calculate distance, the following formula is used:

Distance = steps x stride length

Pedometer models differ in the precision with which stride length can be entered. For example, some pedometers allow the operator to input stride length to the nearest inch, while others only allow stride length to be input to the nearest 0.25 ft. Furthermore, only one stride length can be programmed into a pedometer, so if a subject changes his/her stride length after the calibration procedure, the distance estimated will be inaccurate. For most pedometers, distance was underestimated because the subjects had longer strides (and thus took fewer steps) during the 400-m track walk than in the 20-step calibration procedure. The SL345 was the only pedometer that did not significantly underestimate distance. However, this is because the SL345 overestimated the number of steps taken. Since most researchers choose to report pedometer data as steps, it would be inappropriate to conclude that the SL345 is the most accurate pedometer.

Recent U.S. physical activity recommendations have encouraged Americans to accumulate at least 30 minutes of moderate physical activity on most, preferably all, days of the week (14,26). Dr. Hatano of Japan has proposed an alternative recommendation. He believes that taking 10,000 steps per day would be effective for cardiovascular disease prevention (7). Hatano has found that increased ambulatory activity is associated with lower levels of blood pressure and subcutaneous fat (8). Hatano also estimated that a 60 kg Japanese male would expend at least 333 kcal/day in walking 10,000 steps per day. Previous research indicates that this amount (>2000 kcals/wk) appears to be protective against heart attacks (13). In addition, longitudinal studies have demonstrated that walking 10,000 steps per day results in improvements in cardiovascular disease risk factors in sedentary, at-risk populations (11,20).

Electronic pedometers have gained widespread acceptance among physical activity researchers over the past decade (4) and the use of pedometers has become increasingly popular with the continued publicity of the 10,000 steps per day recommendation (9,15). Thus, it is essential that the pedometer display accurate results. Wilde, et al. (28) showed that by adding a 30-minute walk to their daily routine, subjects increased their step counts from 7,220 to 10,030 steps per day. This study indicates that for sedentary women, including a daily 30-minute walk in their schedule will generally allow them to meet both physical activity recommendations, suggesting that the two are roughly equivalent. However, pedometer accuracy can have a significant impact on the number of steps counted over the course of a day. A study conducted by Tudor-Locke et al. compared the Yamax SW-200 with the CSA model 7164 actigraph (a research grade accelerometer) and showed an 1,800 step/day difference between the two types of step counters (21). It was suggested that this difference is due to variations in the sensitivity of the two devices. Thus, since 1,800 steps may represent a relatively large portion of a person's daily step count and because it is possible for two step-counters to differ by this amount, it is essential that the pedometer accurately report steps taken.

The electronic pedometer has limitations as a research tool (6) including its inability to provide information related to non-ambulatory activity (i.e., cycling, weight training, and swimming). Nevertheless, it does have some distinguishing characteristics that make it useful as a motivational tool for promoting physical activity. First, the pedometer continuously monitors physical activity whether it is incidental or intentional. Studies have shown recall of ubiquitous, moderate activities (e.g., walking) is less accurate than recall of structured, vigorous activities (3,16). Thus, a device that is capable of continuously monitoring ambulatory activity would be beneficial for those interested in the assessment of physical activity. Second, the pedometer can serve as a feedback tool, providing immediate information on accumulated ambulatory activity and serving as a reminder to be physically active. While earlier criticisms of pedometers included their inability to store data (6), two of the pedometers assessed in this study, the NL and KZ pedometers are capable of storing up to 7 and 42 days worth of data, respectively, in one-day epochs. This makes these pedometers an appealing option for researchers who want to eliminate the potential bias of subjects recording their own data.

This study is in agreement with the study conducted by Bassett et al. in demonstrating that considerable variation in accuracy exists among pedometers (2). Likewise, both studies indicated that a Yamax brand pedometer (DW-500 or SW-701) was one of the best in regard to its accuracy and reliability. However, other pedometers that were unavailable at the time of the previous study have been shown to very accurate and reliable as well (NL and KZ). An ideal objective instrument is one that is low in cost, easy to administer to large groups, unobtrusive to the subject, and accurate (6). While most pedometers displayed mean step scores that were not significantly different from the actual steps taken at self-selected walking speeds, some were distinctly better than others as indicated by individual error scores that had a tight prediction interval around zero. Due to the variation that exists among pedometers in regard to the manufacturing specifications, mechanism and sensitivity of each device, not all pedometers count steps accurately. Thus, it is important for researchers who use pedometers to assess physical activity to know the accuracy and reliability of their instruments.

Acknowledgements

The authors would like to thank Cary Springer of the UT Statistical Consulting Services for supporting the data analysis in this study.

References

1. American College of Sports Medicine: *ACSM's Guidelines for Exercise Testing and Prescription* (6th ed.). Philadelphia: Lippincott Williams & Wilkins, 2000, pp. 5,7.
2. Bassett D. R., B. E. Aisworth, S. R. Leggett, C. A. Mathien, J. A. Main, D. C. Hunter, and G. E. Duncan. Accuracy of five electronic pedometers for measuring distance walked. *Med. Sci. Sports Exerc.* 28:1071-1077, 1996.
3. Bassett, D.eR., A. L. Cureton, and B. E. Ainsworth. Measurement of daily walking distance-questionnaire versus pedometer. *Med. Sci. Sports Exerc.* 32:1018-1023, 2000.
4. Bassett, D.eR. and S. J. Strath. Use of Pedometers to Assess Physical Activity. In: *Physical Activity Assessments for Health-Related Research.* G.J. Welk (Ed.) Champaign, IL: Human Kinetics, 2002, p. 166, 169.
5. Bland, J.eM. and D. G. Altman. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1:301-310, 1986.
6. Freedson, P. S. and K. Miller. Objective monitoring of physical activity using motion sensors. *Res. Q. Exerc. Sport* 71:21-29, 2000.
7. Hatano Y. Use of the pedometer for promoting daily walking exercise. *ICHPER Journal* 29:4-8, 1993.
8. Hatano, Y. Prevalence and use of pedometer. *Res. J. of Walking* 1:45-54, 1997.
9. Hellmich N. Journey to better fitness starts with 10,000 steps. *USA Today* June 29, 1B, 1999.

10. Iwane, M., M. Arita, S. Tomimoto, O. Satani, M. Matsumoto, K. Miyashita, and I. Nishio. Walking 10,000 steps/day or more reduces blood pressure and sympathetic nerve activity in mild essential hypertension. *Hypertens. Res.* 23:573-580, 2000.

11. Moreau K. L., R. DeGarmo, J. Langley, C. McMahon, E.iT. Howley, D.iR. Bassett, and D. L. Thompson. Increasing daily walking lowers blood pressure in postmenopausal women with boderline to stage 1 hypertension. *Med. Sci. Sports Exerc.* 33:1825-1831, 2001.

12. Nunnally, J.iC. Assessment of Reliability In: *Psychometric Theory*. New York, NY: McGraw-Hill, 1978, p. 245.

13. Paffenbarger, R. S., A. L. Wing, and R. T. Hyde. Physical activity as an index of heart attack risk in college alumni. *Am. J. Epidemiol.* 108:161-175, 1978.

14. Pate, R. R., M. Pratt, S. M. Blair, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 273:402-407, 1995.

15. Quittner, J. High-Tech Walking. *Time* July 24, 2000.

16. Richardson, M. T., A. S. Leon, D. R. Jacobs, B. E. Ainsworth, and R. Serfass. Comprehensive evaluation of the Minnesota Leisure-Time Physical Activity Questionnaire. *J. Clin. Epidemiol.* 47:271-281, 1994.

17. Sequeira, M. M., M. Rickenbach, V. Wietlisbach, B. Tullen, and Y. Schutz. Physical activity assessment using a pedometer and its comparison with a questionnaire in a large population survey. *Am. J. Epidemiol.* 142: 989-999, 1995.

18. Shepherd, E. F., E. Toloza, C. D. McClung, and T. P. Schalzried. Step activity monitor: Increased accuracy in quantifying ambulatory activity. *J. Orthop. Res.* 17:703-708, 1999.

19. Swartz A. M., D. R. Bassett, B. Moore, D. L. Thompson, and S. J. Strath. Effects of body mass index on the accuracy of an electronic pedometer. *Int. J. Sports Med.* 24:588-593, 2003.

20. Swartz A. M., D. L. Thompson. Increasing daily walking improves glucose tolerance in overweight women. *Prev. Med.* 37:356-362, 2003.

21. Tudor-Locke, C., B. E. Ainsworth, R. W. Thompson, and C. E. Matthews. Comparison of pedometer and accelerometer measures of free-living physical activity. *Med. Sci. Sports Exerc.* 34:2045-2051, 2002.

22. Tudor-Locke C., B. E. Ainsworth, M. C. Whitt, R. W. Thompson, C. L. Addy, and D. A. Jones. The relationship between pedometer-determined ambulatory activity and body composition variables. *Int. J. Obes. Rel. Metab. Disord.* 25:1571-1578, 2001.

23. Tudor-Locke C., R. C. Bell, A. M. Myers, S. B. Harris, N. Lauzon, and N. W. Rodger. Pedometer-determined ambulatory activity in individuals with type 2 diabetes. *Diabetes Res. Clin. Pract.* 55:191-199, 2002.

24. Tudor-Locke C. and A. M. Myers. Challenges and opportunities for measuring physical activity in sedentary adults. *Res. Q. Exerc. Sport* 31:91-100, 2001.

25. Tudor-Locke, C. E. and A. M. Myers. Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Res. Q. Exerc. Sport* 72:1-12, 2001.

26. U.S Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996.

27. White, W. B., P. Lund-Johansen, and P. Omvik. Assessment of four ambulatory blood pressure monitors and measurements by clinicians versus intraarterial blood pressure at rest and during exercise. *Am. J. Cardiol.* 65:60-66, 1990.

28. Wilde B. E., C. L. Sidman, and C. B. Corbin. A 10,000-step count as a physical activity target for sedentary women. *Res. Q. Exerc. Sport* 72:411-414, 2001.

29. Yamanouchi, K., T. Shinozaki, K. Chikada, et al. Daily walking combined with diet therapy is a useful means for obese NIDDM patients not only to reduce body weight but also to improve insulin sensitivity. *Diabetes Care* 18:775-778, 1995.

PART IV

PEDOMETER MEASURES OF FREE-LIVING PHYSICAL ACTIVITY: COMPARISON OF 13 MODELS

Abstract

Purpose: The purpose of this study was to compare the step values of multiple brands of pedometers over a 24-hour period. The following 13 electronic pedometers were assessed in the study: Accusplit Alliance 1510 (AC), Freestyle Pacer Pro (FR), Colorado on the Move (CO), Kenz Lifecorder (KZ), New-Lifestyles NL-2000 (NL), Omron HJ-105 (OM), Oregon Scientific PE316CA (OR), Sportline 330 (SL330) and 345 (SL345), Walk4Life LS 2525 (WL), Yamax Skeletone EM-180 (SK), Yamax Digi-Walker SW-200 (YX200) and the Yamax Digi-Walker SW-701 (YX701). **Methods:** Ten males (39.5 ± 16.6 yr), (mean ± SD), and ten females (43.3 ± 16.6 yr) ranging in BMI from 19.8 to 35.4 $kg \cdot m^{-2}$ wore two pedometers for a 24-hour period. The criterion pedometer (YX200) was worn on the left side of the body and a comparison pedometer was worn on the right. Steps counted by each device were recorded at the end of the day for each of the thirteen pedometers. **Results:** Subjects took an average of 9,244 $steps \cdot d^{-1}$. The KZ, YX200, NL, YX701 and SL330 yielded mean values that were not significantly different from the criterion. The FR, AC, SK, CO, and SL345 significantly underestimated steps ($P<0.05$) and the WL, OM, and OR significantly overestimated steps ($P<0.05$) when compared to the criterion. In addition, some pedometers underestimated by 25% while others overestimated by 45%. **Conclusion:** The KZ, YX200, NL, and YX701 appear to be suitable for most research purposes. Given the potential for pedometers in physical activity research, it is necessary that there be consistency across studies in the measurement of "steps per day".

Key Words: steps, step counter, 24-hours, motion sensor, walking

Introduction

The objective quantification of physical activity is a challenge to those involved in research and practice. Traditionally, physical activity has been assessed using questionnaires, but there are limitations in subjects' recall ability, especially for ubiquitous, light- or moderate-intensity activities (9). Thus, there has been interest in using objective monitors to record physical activity.

Pedometers are a type of motion sensor that are low-cost, unobtrusive, accurate (1,4,11), and their output (steps or distance) is easily comprehendible. Pedometers are typically worn on the belt or waistband and respond vertical accelerations of the hip during gait cycles. They provide data on steps and some models estimate distance traveled and energy expenditure. Although pedometers measure ambulatory activity, they do not capture all types of physical activity (swimming, weight lifting, bicycling, etc.). Nevertheless, walking is one of the most common forms of activity and is readily captured by a pedometer. These devices are becoming increasingly popular in physical activity research on clinical interventions, community-wide interventions, surveillance, and international comparisons. A recent *PubMed* search revealed that the number of studies using pedometers nearly doubled (32 vs. 60) from 1993-1997 to 1998-2002.

Pedometers have several practical applications. They can be used to: 1) distinguish between individuals who vary based on steps$\cdot d^{-1}$, 2) measure increases in physical activity with interventions, 3) conduct cross-study comparisons of different populations, 4) compare time trends in physical activity. In addition, members of the general public are interested in using pedometers to determine whether they are meeting step recommendations. However, if the differences in steps between pedometer brands are large and a variety of brands are being used, then it becomes impossible to use pedometers for these purposes.

Pedometer models differ in regard to cost ($10-200) and internal mechanisms. There are at least three basic types of mechanisms including the spring-suspended lever arm with metal-on-metal contact, magnetic reed proximity switch, and an accelerometer type (4,11). The first mechanism uses a spring-suspended horizontal lever that moves up and down in response to the hip's vertical accelerations. This movement opens and closes an electrical circuit; the lever arm makes an electrical contact (metal-on-metal contact) and a step is registered. The second type of mechanism is a magnetic reed proximity switch. This type also uses a spring-suspended horizontal lever arm, however, with this mechanism a magnet is attached to the lever arm, and it is the magnetic field that causes two overlapping pieces of metal encased in a glass cylinder (magnetic reed proximity switch) to touch, resulting in a step being counted. The third type uses an accelerometer-type mechanism consisting of a horizontal beam and a piezo-electric crystal. The walking motion generates a sinusoidal curve when vertical acceleration is plotted against time. This mechanism uses zero crossings of the acceleration vs. time curve to detect steps.

A second issue is sensitivity, which is related to the internal mechanism, and is a function of the vertical acceleration "threshold" needed to trigger a step. Previous studies (1,4,11) have shown that these differences may translate into variations in accuracy among pedometer models. Some models have been shown to be accurate over a fixed distance (1,11) or at a variety of treadmill speeds (1,4) compared to direct observation of steps. However, no study has compared pedometer models under free-living conditions over 24 hours. This is an important issue because pedometer output is often reported as "steps per day".

One of the difficulties in assessing pedometer accuracy under free-living conditions is the lack of a "gold standard". Although pedometer accuracy can be assessed by counting steps in controlled laboratory experiments, it is not feasible to assess pedometer accuracy in this manner over 24 hours. Therefore, it was decided to use a single pedometer (Yamax SW-200) as the criterion. In controlled laboratory settings, the Yamax SW series pedometers have been consistently shown to be one of the most accurate (4,11). In addition, the Yamax pedometer is commonly used in applied research (7,8,13,16). The purpose of this study was to compare the step values of multiple brands of pedometers over the course of a 24-hour period.

Methods

Pedometers

The criterion pedometer selected for this study was the Yamax SW-200 (YX200). The SW series pedometer has performed very well in previous validation studies. The SW-701 (which has the same mechanism as the SW-200) consistently gave values within 3% of actual steps taken during a self-paced walk, on an individual basis (10). Moreover, this pedometer gave mean step counts that were within 1% of actual steps. At walking speeds ranging from 54 to 107 $m \cdot min^{-1}$, the SW-701 was the only one out of 10 models that did not differ significantly from actual steps taken (4). Finally the SW-200 pedometer was found to have similar accuracy in normal weight, overweight, and moderately obese individuals (12).

Thirteen models of commercially available electronic pedometers were assessed in this study: Accusplit Alliance 1510 (AC), Freestyle Pacer Pro (FR), Colorado on the Move (CO), Kenz Lifecorder (KZ), New-Lifestyles NL-2000 (NL), Omron HJ-105 (OM), Oregon Scientific PE316CA (OR), Sportline 330 (SL330) and 345 (SL345), Walk4Life LS 2525 (WL), Yamax Skeletone EM-180 (SK), Yamax Digi-Walker SW-200 (YX200) and the Yamax Digi-Walker SW-701 (YX701).

Participants

Ten male (39.5 $\pm$ 16.6 yr) and ten female adults (43.3 $\pm$ 16.6 yr) ranging in BMI from 19.8 to 35.4 $kg \cdot m^{-2}$ volunteered to participate in the study. The procedures were reviewed and approved by the Institutional Review Board (IRB) at the University of Tennessee. Each subject completed a Physical Activity Readiness Questionnaire (PAR-Q) (Appendix B) and signed a written informed consent (Appendix A) prior to participating in the study. Height was measured without shoes using a stadiometer and weight was also assessed without shoes in light clothing using a calibrated physician's scale. Physical characteristics of the participants are presented in Table 1.

Protocol

All participants wore the Yamax SW-200 (criterion) on the left side of the body and a comparison model on the right side for a 24-hour period, except when sleeping or showering. Each subject was tested over thirteen days, and the order of testing was randomized for the various pedometer models. (On one of these days the YX200 model was compared to a YX200 on the opposite side of the body to test for left vs. right side

Table 1. Physical characteristics of participants.

	Men (N=10)	**Women (N=10)**	**All Subjects (N=20)**
Age (yr)	39.5 ± 16.6	43.3 ± 16.6	41.4 ± 16.3
Height (cm)	181.6 ± 5.6	164.6 ± 7.3	173.1 ± 10.8
Weight (kg)	89.2 ± 17.3	66.6 ± 8.6	77.9 ± 17.7
BMI ($kg \cdot m^2$)	26.9 ± 4.6	24.6 ± 3.2	25.8 ± 4.1
$Steps \cdot day^{-1}$	9525 ± 2349	8963 ± 2466	9244 ± 3727

Values are Mean ± Standard Deviation
BMI = Body Mass Index

differences.) Previous studies using the same brand of pedometer have shown that there is no statistically significant difference between pedometers worn on the right and left sides of the body (1,4,11). Among the 20 participants, five devices of each model were tested to provide a more representative sample.

Pedometer placement was standardized by placing it on the belt or waistband, in the midline of the thigh, consistent with the manufacturers' recommendations. Pedometers with a variable sensitivity switch (OM, OR) were always placed in the middle setting. Subjects were instructed to put the pedometers on each morning and reset each device to zero, with the exception of two models (KZ, NL), which have internal clocks and reset on their own at midnight. Subjects then wore the pedometers over the course of the entire day and wrote the values down on a log sheet before going to bed each night. This procedure was repeated until all thirteen pedometers were compared to the criterion. The subjects were instructed not to wear the pedometers on Sundays due to the fact that significantly fewer steps are usually taken on Sundays compared with all other days of the week (2).

Statistical Analysis

All analyses were performed using SPSS 11.0.1 for Windows (SPSS, Inc., Chicago, IL). For all analyses, an alpha of 0.05 was used to denote statistical significance. A difference score (comparison – criterion) was computed and compared to zero. Difference scores of zero would indicate that there was no difference between the criterion pedometer and the comparison pedometer. Positive difference scores represent overestimations and negative scores represent underestimations. A two-way repeated measures ANOVA was used to determine if there was a significant difference between the mean difference scores of various pedometers and to determine if there was a significant difference in the mean difference scores between genders. Independent t-tests were used to determine if the comparison models were significantly different from the criterion.

Bland-Altman (3) plots were constructed to show the distribution of the individual (criterioni– comparison) scores around zero. This is a standard method to show the accuracy of biomedical devices (18). In this manner, the mean difference (criterioni– comparison) can be illustrated and the 95% prediction interval (i.e., 95% confidence interval for the individual observations) can also be shown. Pedometers that have a tight prediction interval around zero are more accurate.

Results

Subjects took an average of 9,244 steps$\cdot d^{-1}$ according to the criterion pedometer. There was no significant interaction between pedometer model and gender and there were no significant gender differences ($P>0.05$). However, there were significant differences ($P<0.05$) among the 13 pedometer models. Figure 1 displays the mean difference scores expressed as a percentage of the steps counted by the criterion pedometer. Table 2 displays mean difference scores, standard deviations, and 95% confidence intervals for each pedometer model. The FR, AC, SK, CO, SL345 significantly underestimated steps while the WL, OM and the OR significantly overestimated ($P<0.05$). Figures 2-4 show the Bland-Altman plots for various pedometer models. The Oregon Scientific pedometer

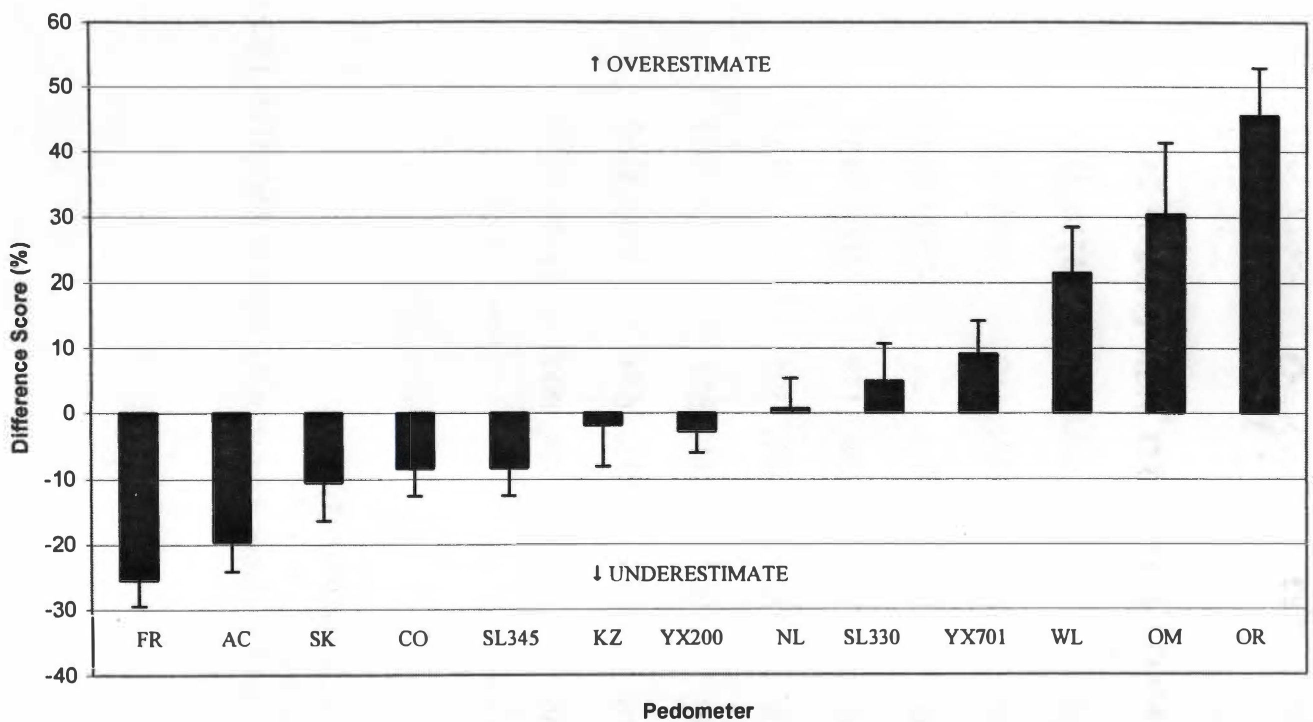

Figure 1. Mean difference scores [(Comparison – Criterion Pedometer)/Criterion] ± SE as a percentage of the criterion estimated steps over a 24-hour period. Positive difference scores represent overestimations and negative difference scores indicate underestimations of steps compared to the criterion pedometer.

Table 2. Difference scores (comparison – criterion pedometer) in number of steps over a 24-hour period.

PEDOMETER		MEAN	SD	95% CI	95% PI
FR	*	- 2445	2157	-3454, -1436	-6672, 1782
AC	*	- 2189	2697	-3451, -926	-7475, 3098
SK	*	- 1161	2279	-2228, -94	-5629, 3307
CO	*	- 1042	2146	-2407, -38	-5249, 3164
SL345	*	- 997	1872	-1873, -121	-4666, 2673
KZ		- 703	1537	-1422, 17	-3716, 2311
YX200 #		- 372	1685	-1161, 417	-3675, 2931
NL		206	1539	-514, 926	-2809, 3222
YX701		426	1547	-298, 1149	-2606, 3457
SL330		443	1885	-439, 1325	-3251, 4137
WL	†	1099	1833	241, 1957	-2493, 4691
OM	†	2266	3019	853, 3679	-3652, 8183
OR	†	3636	2662	2390, 4882	-1583, 8854

SD = Standard Deviation
CI = Confidence Interval
PI = Prediction Interval
* Significantly lower than the criterion ($P<0.05$)
† Significantly higher than the criterion ($P<0.05$)
# This pedometer is also sold under the names Accusplit AE120 and Walk4Life LS2000

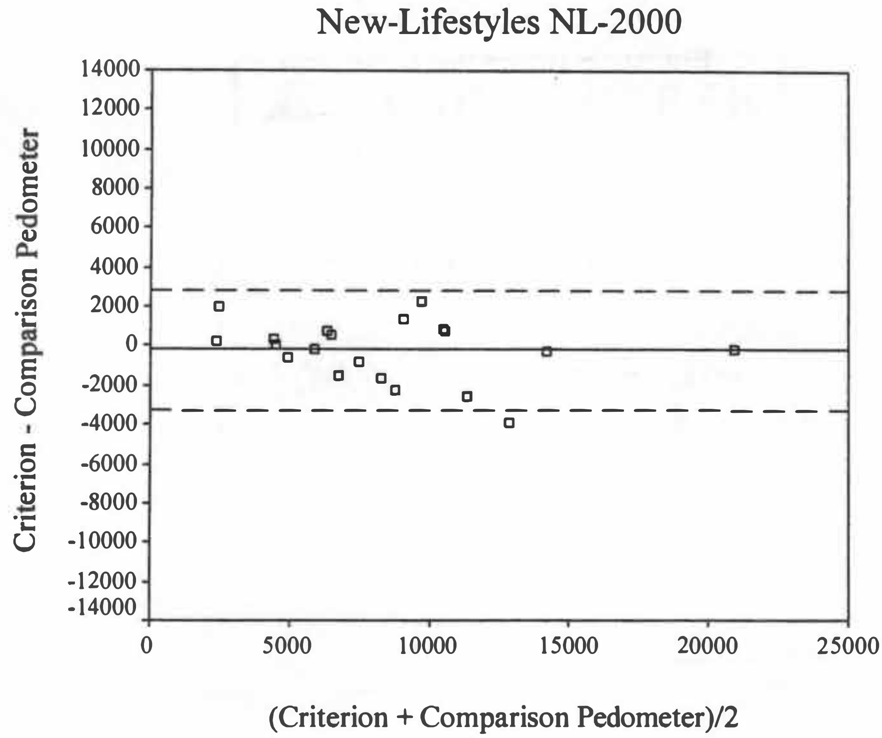

Figure 2. Representative Bland-Altman plot for the New Lifestyles NL-2000 (NL) which was one of the five most accurate pedometers. Solid horizontal line = mean error score, dashed lines = 95% prediction intervals (i.e., 95% Confidence Intervals of the individual observations).

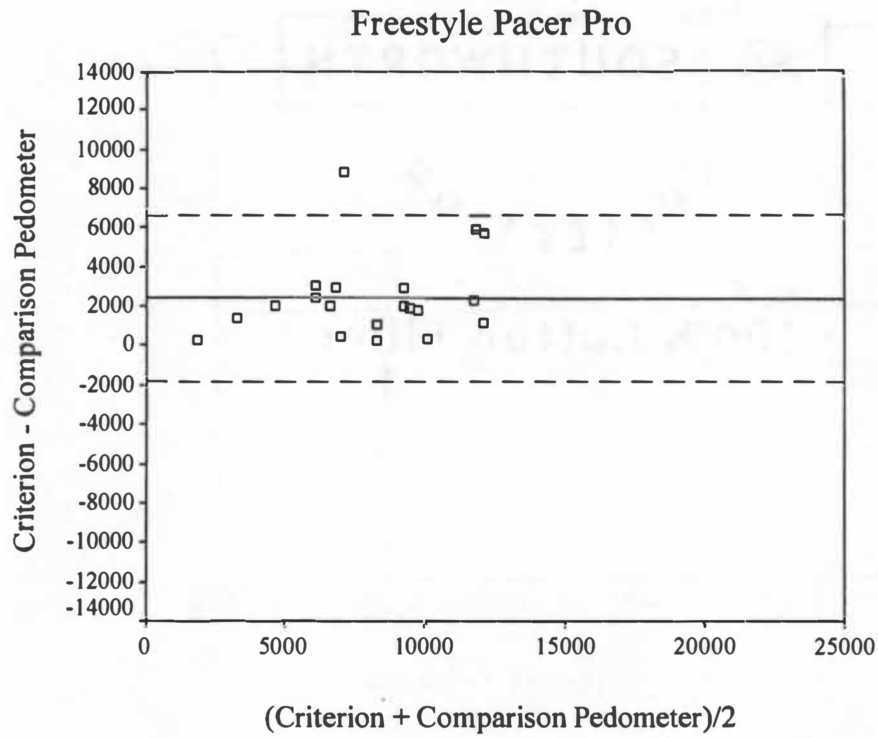

Figure 3. Representative Bland-Altman plot for the Freestyle Pacer Pro (FR) which was among the five pedometers that significantly underestimated steps ($P<0.05$) compared with the criterion ($P<0.05$). Solid horizontal line = mean error score, dashed lines = 95% prediction intervals (i.e., 95% Confidence Intervals of the individual observations).

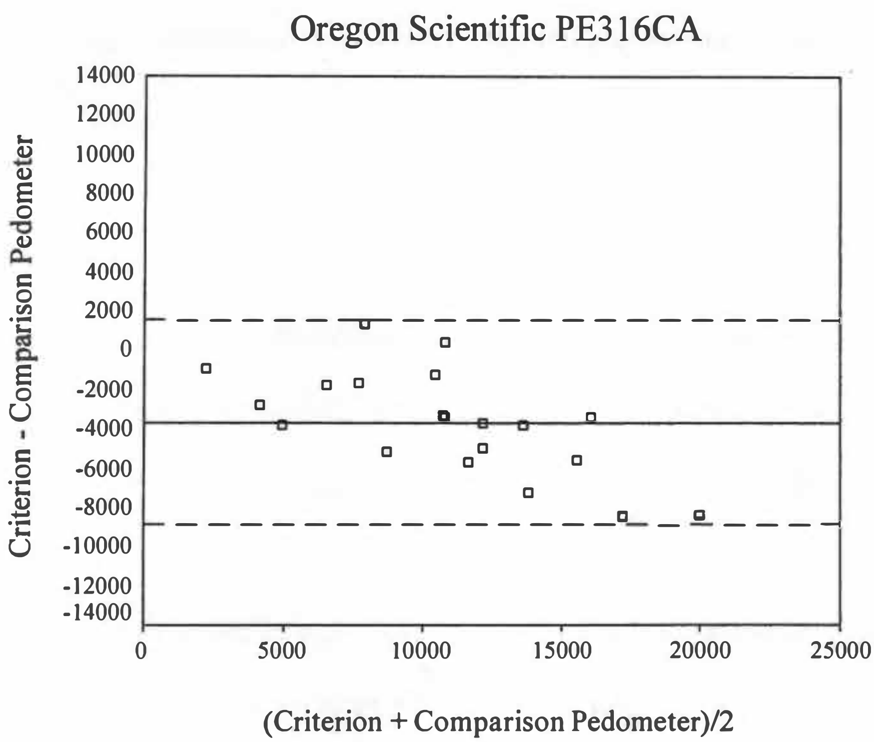

Figure 4. Representative Bland-Altman plot for the Oregon Scientific PE316CA (OR) which was one of three pedometers that significantly overestimated steps compared with the criterion (P<0.05). Solid horizontal line = mean error score, dashed linese= 95% prediction intervals (i.e., 95% Confidence Intervals of the individual observations).

appeared to overestimate steps to a greater extent at higher step counts. However, this was an isolated case as other models did not show this type of systematic error.

Discussion

In the current study, five (KZ, YX200, NL, YX701, SL330) of the thirteen pedometers tested yielded mean values that were not significantly different from the criterion. Five (FR, AC, SK, CO, SL345) pedometers significantly underestimated steps and three (WL, OM, OR) significantly overestimated steps, compared to the criterion (YX200).

The statistical power in the present study was adequate to detect a 10% difference among pedometer brands. This roughly coincided with what we considered to be a meaningful difference. For research purposes, we suggest using one of the models that did not significantly differ from the criterion. The pedometers that met this standard are the KZ, YX200, NL, YX701, and SL330. However, given the fact that statistical significance is a function of sample size (15), some emphasis should be placed on practical significance. Thus, we suggest that the CO and SL345, which were significantly different from the criterion but had mean values within 10% of the criterion would be suitable choices for physical activity promotion purposes.

The following pedometer determined steps per day activity classifications have been proposed: <5,000 sedentary, 5000-7,499 inactive, 7500-9,999 somewhat active, ≥10,000 active (17). Having standardization among pedometer brands is necessary to ensure that such a classification scheme for activity status is meaningful. If a pedometer yields mean scores that are not within ±10% of the criterion, the risk of misclassification increases, making it difficult to compare results across studies. In addition, given that the same pedometer model on the right and left hip can differ by 5%, this suggests that an acceptable difference of less than 10% may be too strict. It is important to note that an acceptable difference of 10% applies only to free-living conditions. Laboratory type validations must be held to a higher standard as suggested in previous publications (4,11).

Schneider et al. (11) previously showed that the KZ, NL, and YX701 were the most accurate pedometers at counting steps during a 400-m track walk at a self-selected pace. These three pedometers are all made in Japan and they all met the Japanese Industrial Standard set by the Ministry of Industry and Trading regulations (5) which requires less than a three percent margin of error (3 steps out of 100). Interestingly, these same three devices (KZ, NL, and YX701) were among the five pedometers that were not significantly different from the criterion (YX200) in the present study.

Crouter et al. (4) also showed that the KZ, NL, and YX701 were among the most accurate pedometers at counting steps on the treadmill at speeds ranging from 54 to 107 $m \cdot min^{-1}$. These three pedometers, along with the WL, showed acceptable accuracy (recording at least 88% of actual steps) at a slow speed (54 $m \cdot min^{-1}$) and thus were considered a good choice for research studies. In that study, these same three pedometers were among six that gave mean values within $\pm$1% of the actual steps taken at 80 $m \cdot min^{-1}$ and above.

There are four plausible explanations for the step counting discrepancy that exists among pedometer models. First, models may differ in their vertical acceleration threshold required to trigger a step. This feature is related to the internal mechanism of the device, which has been described in a previous publication (11). Those devices that are highly sensitive compared to the criterion model are prone to overestimate steps while those that are less sensitive would likely underestimate steps. The Yamax SW-200 requires an acceleration ≥0.35 g to register a step (16). Tudor-Locke et al. (16) compared a pedometer (YX200) and the CSA model 7164 accelerometer/step counter over a 24-hour period and found a significant difference in mean step counts with the YX200 counting 1,845 fewer steps per day than the CSA. This difference was attributed to the CSA's lower vertical acceleration threshold required to record a step compared with the YX200 (0.30 g vs. 0.35 g). Although the lower threshold of the CSA makes it more likely to capture steps at slower walking speeds, it is also apt to detect non-ambulatory activity such as twisting, fidgeting, and bending as well as mechanical vibration (e.g., motor vehicle travel) (7). Second, some pedometers (FR, AC, SL345) are programmed to only begin recording steps after four consecutive steps have been taken. For example, if an individual took just four steps and then stopped, the steps would not be counted. However, if he took five or more consecutive steps, each step would be counted (the first four steps do not appear on the output screen but the fifth step registers as a five and every step is counted individually thereafter). This feature would logically result in an underestimation in steps when compared with a device that counts every step regardless of whether or not they were taken in succession. Third, some devices may be more accurate than others in overweight or obese subjects. In an individual with a significant amount of abdominal obesity, the pedometer may not be vertically aligned resulting in decreased accuracy (11). Finally, one device (OR) has been shown to frequently double-count steps (11), which explains the overestimation in this study.

Previous studies have shown that waist-mounted pedometers gave mean values within ±12% at speeds ≥ 80 m·min^{-1} (1,4) although they tend to underestimate steps taken at slower walking speeds. A gait laboratory study found that the self-selected walking speed of 200 healthy adults averaged 84 m·min^{-1} (14). Taken together, this might lead one to conclude that most pedometers would yield fairly similar values (steps per day) in free-living adults. However, the present study found large mean error scores between pedometers, ranging from an underestimation of 25% to an overestimation of 45%, for 24-hour data. This suggests that a large percentage of steps taken throughout the day might be accumulated at slower speeds or in light activity. For future studies, we recommend the selection of a pedometer model that compares closely with the criterion model used in the current study. This would help to ensure standardization of free-living pedometer data.

Hatano (5) has proposed that taking 10,000 steps per day would be effective for cardiovascular disease prevention. He estimates that a 60 kg Japanese male would expend at least 333 kcal per day in walking 10,000 steps. Earlier research indicates that this amount (>2000 kcals per wk) appears to be protective against heart attacks (9). Alternatively, Hill has proposed that weight gain could be eliminated by some combination of increasing energy expenditure and decreasing energy intake by 100 kcal per day (6). He notes that energy expenditure can be increased by 100 kcal per day by walking an extra mile each day. Hill states that "Walking a mile, whether done all at once or divided up across the day, burns about 100 kcal, which would theoretically completely abolish the energy gap and hence weight gain for most of the population. A mile of walking for most people is only about 2,000 to 2,500 extra steps…" (6). Whether one's goal is to take 10,000 steps per day or to increase normal daily walking by 2,000 steps per day, it is essential that the pedometer counts are standardized. In this study, there were several individual occasions where the comparison pedometer gave values that under or overestimated steps by 35 to 60%, respectively. These inconsistencies in pedometer-estimated steps would make it difficult to measure progress towards meeting various daily step goals.

In conclusion, the present study shows that there are differences between models in pedometer measures of free-living physical activity. Five pedometers appear to give similar values for steps per day compared to the criterion (YX200). However, one of these (SL330) was shown to be unreliable in a previous study (11), and therefore cannot be recommended. The remaining four pedometers (KZ, YX200, NL, and YX701) seem to be suitable for applied physical activity research. In order to standardize results across studies, researchers should use one of these pedometers or demonstrate the equivalence of a different pedometer using a similar research design. Given the increasing use of pedometers in physical activity research, it is imperative that there be consistency across studies in the measurement of "steps per day".

Acknowledgements

The authors would like to thank Cary Springer of the UT Statistical Consulting Services for supporting the data analysis in this study.

References

1. Bassett D.éR., B. E. Ainsworth, S. R. Leggett, C. A. Mathien, J. A. Main, D. C. Hunter, and G. E. Duncan. Accuracy of five electronic pedometers for measuring distance walked. *Med. Sci. Sports Exerc.* 28:1071-1077, 1996.
2. Bassett, D. R., A. L. Cureton, and B. E. Ainsworth. Measurement of daily walking distance-questionnaire versus pedometer. *Med. Sci. Sports Exerc.* 32:1018-1023, 2000.
3. Bland, J. M. and D. G. Altman. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1:301-310, 1986.
4. Crouter, S. E., P. L. Schneider, M. Karabulut, and D.éR. Bassett. Validity of ten electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc.* 35:1455-1460, 2003.
5. Hatano Y. Use of the pedometer for promoting daily walking exercise. *ICHPER Journal* 29:4-8, 1993.
6. Hill, J. O., H. R. Wyatt, G. W. Reed, and J. C. Peters. Obesity and the environment: Where do we go from here? *Science* 299:853-855, 2003.
7. Le Masurier, G. and C. Tudor-Locke. Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med. Sci. Sports Exerc.* 35:867-871, 2003.
8. Moreau K. L., R. DeGarmo, J. Langley, C. McMahon, E. T. Howley, D. R. Bassett, and D. L. Thompson. Increasing daily walking lowers blood pressure in postmenopausal women with boderline to stage 1 hypertension. *Med. Sci. Sports Exerc.* 33:1825-1831, 2001.

9. Montoye, H. J., H. C. G. Kemper, W. H. M. Saris, and R. A. Washburn. Measuring Physical Activity and Energy Expenditure. Champaign, IL: Human Kinetics, 1996, pp. 3,102.

10. Paffenbarger, R. S., A. L. Wing, and R. T. Hyde. Physical activity as an index of heart attack risk in college alumni. *Am. J. Epidemiol.* 108:161-175, 1978.

11. Schneider, P. L., S. E. Crouter, O. Lukajic, and D.aR. Bassett. Accuracy and reliability of ten pedometers for measuring steps over a 400-m walk. *Med. Sci. Sports Exerc.* 35:1779-1784, 2003.

12. Swartz A. M., D. R. Bassett, B. Moore, D. L. Thompson, and S. J. Strath. Accuracy of the electronic pedometer in obese, overweight and normal weight adults. *Int. J. Sports Med.*, 24:588-592, 2003.

13. Swartz A. M. and D. L. Thompson. Increasing daily walking improves glucose tolerance in overweight women. *Prev. Med.* 37:356-362, 2003.

14. Temes, W. C. Cardiac Rehabilitation. In: Essentials of Cardiopulmonary Physical Therapy. E. A. Hillegass and H. S. Sadowsky (Eds.) Philadelphia, PA: W.B. Saunders Company, 1994, p. 641.

15. Thomas, J. R. and J. K. Nelson. Research Methods in Physical Activity. Champaign, IL: Human Kinetics, 1996. p.110.

16. Tudor-Locke, C., B. E. Ainsworth, R. W. Thompson, and C. E. Matthews. Comparison of pedometer and accelerometer measures of free-living physical activity. *Med. Sci. Sports Exerc.* 34:2045-2051, 2002.

17. Tudor-Locke, C. and D.aR. Bassett. How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med.* 34 :1-8, 2004.

18. White, W. B., P. Lund-Johansen, and P. Omvik. Assessment of four ambulatory blood pressure monitors and measurements by clinicians versus intraarterial blood pressure at rest and during exercise. *Am. J. Cardiol.* 65:60-66, 1990.

PARTeV

EFFECTS OF A 10,000 STEPS PER DAY GOAL

IN OVERWEIGHT MEN VS. WOMEN

Abstract

Purpose: The purpose of this study was to compare the effects of a 10,000 steps per day exercise prescription on body composition, cardiovascular risk factors and adherence in overweight men vs. women. **Methods:** 20 men (48 $\pm$ 6 yrs) (mean$\pm$ SD) and 37 women (46 $\pm$ 8 yrs) who were overweight or obese participated in a 10,000 steps per day intervention. Body weight, body mass index (BMI), percent body fat, fat mass, fat-free mass, waist circumference, hip circumference, systolic blood pressure, diastolic blood pressure, and heart rate were determined at baseline, after 20 weeks and again after 36 weeks. A blood lipid profile was assessed at baseline and after 36 weeks. Participants were not given any instruction regarding dietary intake. **Results:** 15 men and 24 women (68%) completed the 36-week intervention. In response to a 10,000 steps per day exercise prescription, they increased daily walking from 5,232 to 9,159 steps per day. Men and women experienced similarly significant improvements in body weight, BMI, percent body fat, fat mass, waist and hip circumferences, and HDL-C. When the effects of adherence to the exercise prescription were examined, the adherers significantly reduced body weight, BMI, percent body fat, fat mass, and waist and hip circumferences after 36 weeks, whereas the non-adherers experienced little or no change in these variables. **Conclusion:** The 10,000 steps per day exercise prescription was effective at producing weight loss in overweight, middle-aged men and women. These results suggest that this amount of activity is an effective strategy for weight management in this population.

Key Words: intervention, pedometer, walking, weight loss, adherence

Introduction

It is well established that obesity is a major public health problem in the United States and other developed countries. Current data indicate that the prevalence of overweight and obesity among U.S. adults is 65.7 and 30.6%, respectively (15). The prevalence of obesity has increased in males and females and across all ages from NHANES II (1976-1980), NHANES III (1988-1994) and the continuous NHANES (1999-2000) (10). Due to the negative health consequences associated with obesity (38) and the high annual healthcare costs associated with its treatment (5), it is essential to develop programs designed to prevent and treat this disease.

Excess body weight and physical inactivity are risk factors for chronic disease and coronary heart disease mortality (20). It is likely that a decline in physical activity (12) resulting from labor-saving devices (27) has contributed to the obesity epidemic in the United States. Despite the abundance of literature supporting the health benefits associated with leading a physical activity lifestyle, 55% of Americans remain either inactive or insufficiently active (4). As a result, Healthy People 2010 has placed physical activity among its leading health indicators which reflect the major public health concerns of the United States (52). However, debate exists regarding the amount of activity needed to provide optimal health benefits. This has led to the emergence of numerous exercise prescriptions and recommendations that encourage participation in various amounts of activity.

Among the more popular is the 10,000 steps per day goal described by Hatano (14). It originated in Japan and it is becoming increasingly popular in the United States (16, 53). However, despite the popularity of this exercise prescription, few longitudinal studies have attempted to determine the potential health benefits associated with doing this amount of activity (36, 48) and none have compared its effects on body weight and body composition in overweight men vs. women. In addition, it is not yet established whether 10,000 steps per day is a feasible goal for sedentary, overweight adults.

It is well known that two aspects of energy balance can affect body weight: energy intake and energy expenditure. A reduction in energy intake is typically more effective than an increase in energy expenditure at producing short term (<6 months) weight loss (19, 44, 34). However, obesity treatments utilizing a reduction in energy intake alone have poor long-term effects, as most dieters regain all of the weight loss within 2 to 3 years (25, 44). An increase in energy expenditure is another option for producing weight loss. Studies have shown that exercise interventions without dietary restriction can result in significant reductions in body weight (36, 39, 41) and this approach has been shown to be important in long-term maintenance of weight loss (24, 44).

Some studies have indicated that exercise-induced changes in body weight differ in men vs. women (7, 23, 46). Whether exercise is prescribed with a minimum level of energy expenditure per session or for a specific time and intensity, men often experience greater changes in body weight than women following an exercise intervention (7, 18, 23, 46). One study found that 225 minutes of moderate-to-vigorous intensity exercise consisting of primarily walking was ineffective at producing weight loss in women, but resulted in a 5.2 kg reduction in body weight in men after 16 months (8). Another study of similar length found that 2000 kcal of energy expenditure per week, although inadequate for weight loss in women, resulted in a 5.1 kg weight loss in men (46).

Interestingly, in both of these studies, women actually experienced slight, nonsignificant increases in body weight in response to the exercise intervention.

Despite the presence of an apparent gender effect regarding exercise-induced weight loss, other studies have shown that exercise can be effective at producing a significant amount of weight loss in men (29, 39) and women (13, 36) in the absence of caloric restriction. However, given the potential for a gender effect in response to exercise along with the paucity of studies examining the 10,000 steps per day goal, it would be valuable to compare the responses of men and women to this popular exercise prescription. Therefore, the purpose of this study was to determine the effects of a 10,000 steps per day exercise prescription on body composition, cardiovascular risk factors and adherence in overweight men vs. women.

Methods

Participants

Fifty-seven sedentary, overweight or obese, middle-aged men and women between 30-55 years of age volunteered to participate in the study. Participants were not dieting for weight loss and were relatively weight stable (within 4% of their current body weight) for the three months prior to the intervention. Inclusion criteria for the participants were: age between 30-60 years, body mass index (BMI) between 25-45 $kg \cdot m^{-2}$, the ability to follow instructions and record data, and the ability to walk 1 mile without pain or discomfort. The exclusion criteria were: history of myocardial infarction, angina, stroke, heart failure, or uncontrolled cardiac arrhythmias; resting blood pressure greater than 180 mm Hg systolic and 100 mm Hg diastolic; current cigarette smoking; exercise exceeding 7,300 steps per day or 90 minutes of moderate intensity activity per week; currently taking weight loss medications or prescription medication that may impair physical performance. Volunteers were recruited by flyers posted in public buildings, newspaper advertisements, community presentations and word of mouth. Prior to their participation, the study was verbally explained, and each participant read and signed an informed consent form (Appendix C). The informed consent form was approved by the University of Tennessee and the University of Tennessee Medical Center Institutional Review Boards and included sufficient information to ensure their knowledgeable consent. A health history questionnaire was completed by all participants prior to the study to screen for any contraindications to exercise (Appendix D).

Study design

The intervention lasted 36 weeks. The two weeks prior to the intervention served as a baseline period and data from this phase were used to screen participants to confirm that they were inactive (≤7,300 steps per day). Participants were instructed not to change their normal activities during the two-week baseline period. All participants were given a waist-mounted Digi-Walker SW-200 electronic pedometer (Yamax, Inc., Tokyo, Japan) along with instructions on the proper use of the pedometer. The Digi-Walker SW series pedometers have consistently scored among the most accurate in previous validation studies (6, 42, 28) and are reported to have similar accuracy in normal weight, overweight and moderately obese individuals (47). Prior to the two-week baseline period, pedometer accuracy was verified by having each participant take 20 steps down a straight hallway (50, 51). They were encouraged to regularly repeat this 20-step test to confirm pedometer accuracy. The participants were instructed to wear the pedometer each day during all waking hours, except when taking a shower or swimming. All participants were asked to record the number of steps per day along with the time the pedometer was put on and the time it was taken off.

After the baseline period, preliminary measures were obtained. At this point, all participants were given a physical activity prescription that led up to a goal of accumulating at least 10,000 steps per day. The first week they were encouraged to take 7,000 steps per day, the second week 8,000 steps per day, the third week 9,000 steps per day, and by the fourth week they were instructed to walk at least 10,000 steps per day.

Protocol

The study protocol required four visits to the laboratory. The first visit included an introduction to the study, reading and signing the informed consent form; completing a health history questionnaire; and pedometer/activity log distribution and instruction. Participants were also given a three-day dietary record form and instructions for use (Appendix E). Each participant was asked to complete the dietary record during the week prior to the second visit. The second visit included anthropometric measurements (i.e., body composition, girth measurements, body weight and height); resting heart rate and blood pressure assessment; and a blood lipid profile. The third visit occurred 20 weeks after the start of the intervention. Anthropometric measurements and resting heart rate and blood pressures measurements were repeated at this time point. A dietary record form with instructions was provided at the third visit and participants were asked to complete the record and return it for subsequent analysis. The fourth visit occurred at the end of the 36-week intervention and included a repeat of all the preliminary measurements. A dietary record form was mailed out two weeks prior to the fourth visit with instructions for completion. Blood samples were drawn at the outpatient laboratory at the University of Tennessee Medical Center and analyzed for blood lipid content by Dynacare Tennessee (Knoxville, TN). All other laboratory measurements were made in the Applied Physiology Laboratory at the University of Tennessee.

Resting Heart Rate and Blood Pressure

Each participant was asked to sit quietly for five to ten minutes after which resting heart rate and blood pressure was measured. Heart rate was taken at the radial pulse for 15 seconds and then multiplied by four to determine beats per minute. The heart rate was taken in triplicate. Blood pressure was measured by the same investigator using a sphygmomanometer and a stethoscope in accordance with the guidelines provided by the American Society of Hypertension (1). The average of the two closest heart rate and blood pressure measurements served as the resting values.

Blood Lipid Profile

A 10 ml blood sample was collected from the antecubital vein following a 12 hour overnight fast. Following centrifugation, the serum was removed and analyzed by the colorimetric method (2 reagent format) using the Abbott Aeroset chemistry analyzer (Abbott Laboratories, Abbot Park, IL). Controls were run daily for all tests and used to verify system performance and to monitor accuracy and precision.

Anthropometric Measures

Anthropometric measures included body composition, girth, weight, and height. Body composition was assessed using whole body plethysmography (BOD POD ® Body Composition System, Life Measurement Instruments, Concord, CA). The BOD POD utilizes the inverse relationship between volume and pressure to determine body volume, which is then used to calculate body density. Using the Siri equation (43), body density was used to calculate percent body fat. The primary advantage of the BOD POD is that it determines body density based on air displacement rather than on water immersion and is therefore, simpler and quicker than hydrostatic weighing (33). In addition, studies have shown that BOD POD estimates of body composition are not significantly different from those determined by hydrostatic weighing, which is a widely accepted criterion method (32). The participants sat inside a sealed chamber wearing a lycra/nylon swimsuit and swim cap. Body volume was corrected for thoracic gas volume using a prediction equation based on age, gender, and height (33). Girth measurements were assessed at the waist (narrowest part of the torso) and the hips (maximal circumference at the buttocks above the gluteal fold) in accordance with the Anthropometric Standardization Reference Manual by Lohman, Roche, and Martorell (3). Body weight (kg) was measured using a calibrated physician's scale (Health-o-meter, Bridgeview, IL), and height (cm) was measured using a stadiometer (Seca Corp., Columbia, MD), also in accordance with standard practices (11). Every attempt was made to measure body weight at approximately the same time of day each time subjects were tested.

Physical Activity Log

During the screening and intervention periods, participants were instructed to record the time the pedometer was put on, the time it was taken off, and the total number of daily steps in a physical activity log each day. Physical activity logs were returned to the Principal Investigator every other week either by fax or mail.

Dietary Assessment

All participants completed a three-day dietary record at baseline, 20 weeks, and 36 weeks. The dietary record was explained to each participant in detail including how to properly describe the food item, the amount eaten, and how it was prepared. All items consumed within the three-day period were recorded by the participant and analyzed using Nutritionist Pro software (First Data Bank Inc., San Bruno, CA). Analyses were examined to determine if the participants changed their dietary habits over the intervention period.

Investigator/Participant Contact

Participants were asked to attend an informational session every other week for the first two months and then monthly thereafter. The purpose of the informational session was to confirm that the participant was completing the task asked of them, to address any questions or comments the participant may have had, and to provide an educational session on a variety of topics. Participants were also given pamphlets (HealthPartners, Inc. Minneapolis, MN) that included a description of the health benefits of walking, motivational tips, and ideas for accumulating steps. Participants were encouraged to contact the Principal Investigator by phone or e-mail with questions or comments regarding the walking program.

Data Analysis

An on-treatment analysis was performed on all participants who completed the intervention, irrespective of adherence. In clinical settings, the on-treatment analysis is used to assess change in health variables in response to being given a behavioral or pharmaceutical prescription. In addition, to determine the physiological efficacy of taking 10,000 steps per day, a separate analysis was also performed on those participants who successfully adhered to the exercise prescription. In order to maintain clear separation of those who adhered to the exercise prescription and those who did not, acceptable adherence was defined as taking an average of 9,500 steps per day or more from week 4 to week 36. Most studies assessing this variable typically define acceptable adherence as attending a large percentage of the exercise sessions (26).

All statistical analyses were performed using SPSS 11.5 for Windows (SPSS Inc., Chicago IL). For all analyses, an alpha of 0.05 was used to denote statistical significance. Independent samples t-tests were used to compare the baseline characteristics between genders. Repeated measures analyses of variance (ANOVA's) were used to compare the effects of gender and adherence on body weight, body composition, girth measurements, blood pressure, heart rate, and blood lipid profile in response to taking 10,000 steps per day for 36 weeks. Correlational analyses were used to assess relationships between the change in daily step counts ($steps \cdot d^{-1}$) and the changes in dependent variables. Paired t-tests were used to assess changes within groups over the course of the intervention. A 2 x 2 Chi-Square analysis was used to assess adherence to the intervention.

Results

One hundred nineteen individuals met the initial criteria based on a telephone interview. Of these, 57 participants (20 men, 37 women) met all study criteria and initiated the intervention and 39 (15 men, 24 women) participated for the duration of the study (Figure 1). Among the 39 participants who completed the study, 10 men and 10 women were able to adhere to the exercise prescription defined a priori as averaging 9,500 steps per day or more. Participants wore the pedometer for more than 15 hours per day on average over the course of the intervention. The baseline characteristics of the participants who completed the first half of the study are presented in Table 1. Significant baseline differences between men and women were found for height, percent body fat, fat mass, fat-free mass, hip circumference, and HDL-C. A chi-square analysis showed that adherence to the exercise prescription was not significantly different between men and women.

Analyses of variance (ANOVA's) were used to examine the effect of gender and adherence over time. Due to the absence of any significant 3-way interactions (gender x adherence x time), separate models were run to look at the effects of gender (gender x time) and adherence (adherence x time) in response to the intervention. For both men and women, significant improvements were noted for body weight, BMI, percent body fat, fat mass, waist circumference, hip circumference, and HDL-C (Tables 2 and 3).

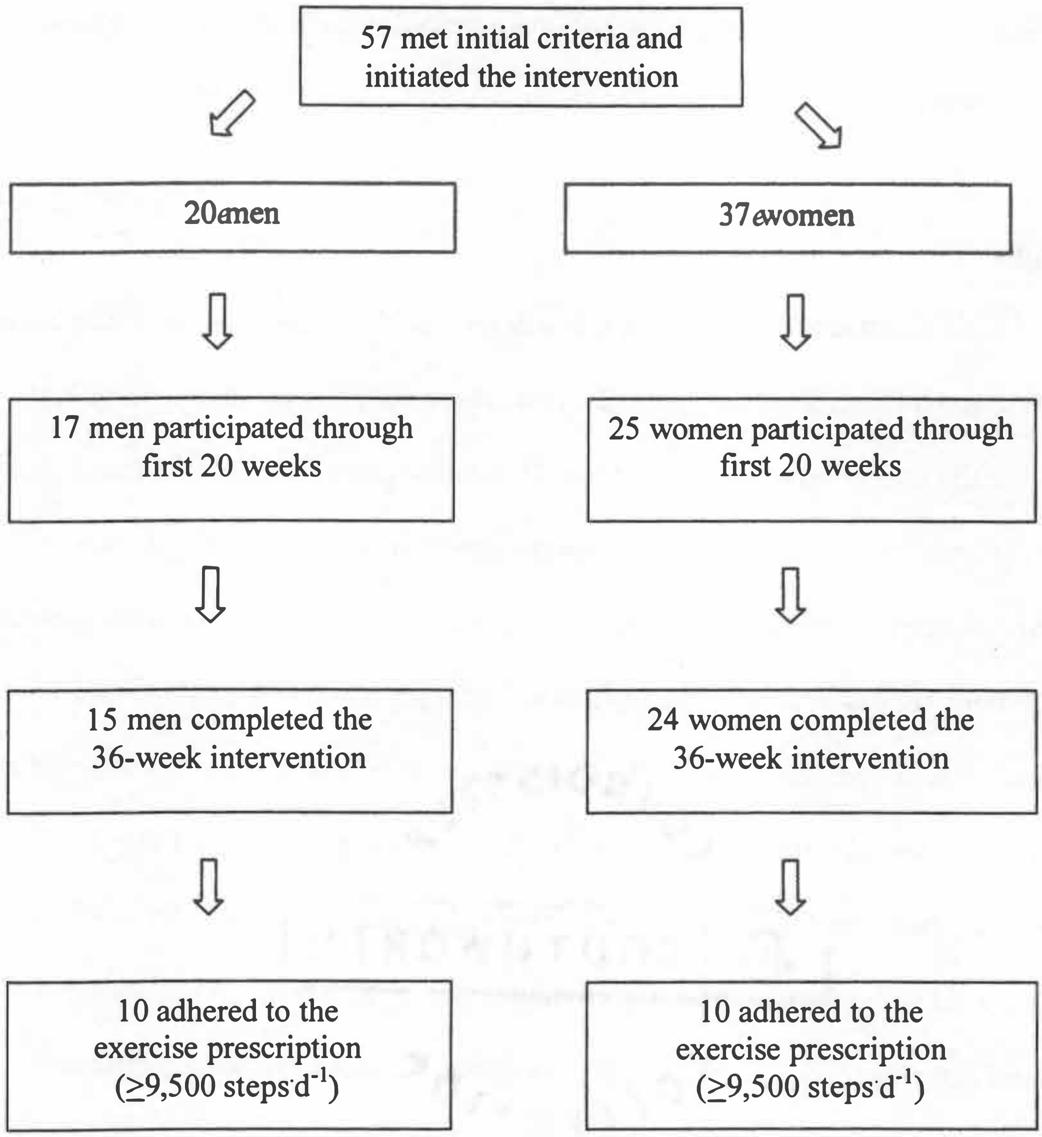

Figure 1. Participation Flowchart.

Table 1. Baseline characteristics of men (n=17) and women (n=25) who completed at least 20 weeks.

Variable	Men	Women
Age, yrs	45 ± 7	47 ± 6
Steps$\cdot d^{-1}$	5218 ± 1484	5276 ± 1089
Height, cm*	178.7 ± 6.6	166.5 ± 5.9
Weight, kg	105.4 ± 19.3	94.9 ± 16.1
BMI, kg$\cdot m^{-2}$	32.9 ± 5.0	34.2 ± 5.0
Body fat, %*	34.8 ± 6.5	48.3 ± 5.2
Fat mass, kg*	37.7 ± 13.2	46.4 ± 11.9
Fat-free mass, kg*	68.0 ± 7.9	48.6 ± 6.3
Waist Circumference, cm	108.6 ± 10.1	102.6 ± 12.8
Hip Circumference, cm*	113.0 ± 10.5	123.1 ± 13.3
SBP, mmHg	127 ± 12	121 ± 12
DBP, mmHg	85 ± 5	83 ± 7
HR, beats$\cdot min^{-1}$	70 ± 10	73 ± 11
TC, mg$\cdot dl^{-1}$	182 ± 34	191 ± 31
Triglycerides, mg$\cdot dl^{-1}$	147 ± 56	122 ± 64
HDL-C, mg$\cdot dl^{-1}$*	39 ± 9	54 ± 14
LDL-C, mg$\cdot dl^{-1}$	113 ± 30	113 ± 26

Data are given as mean ± SD.
* Significant difference between men and women ($P<0.05$)
M (Men), W (Women), BMI (body mass index), SBP (systolic blood pressure), DBP (diastolic blood pressure), HR (heart rate), TC (total cholesterol), HDL-C (high-density lipoprotein), LDL-C (low-density lipoprotein)

Table 2. Dependent variables measured at baseline, 20 weeks, and 36 weeks for men (n=15) and women (n=24) who completed the intervention.

Variable	Gender	Baseline	20 weeks	36 weeks
Weight (kg)	Men	106.8 ± 19.2	103.4 ± 19.6	102.6 ± 20.6
	Women	94.3 ± 16.1	92.8 ± 15.2	92.6 ± 15.1
	Total	99.1 ± 18.2[a]	96.8 ± 17.5[b]	96.4 ± 17.8[b]
BMI ($kg \cdot m^{-2}$)	Men	33.1 ± 5.1	31.9 ± 5.0	31.6 ± 5.3
	Women	33.9 ± 4.9	33.4 ± 4.7	33.3 ± 4.6
	Total	33.6 ± 4.9[a]	32.8 ± 4.8[b]	32.7 ± 4.9[b]
Body fat (%)	Men	34.8 ± 6.4	32.6 ± 6.7	31.7 ± 7.2
	Women	48.1 ± 5.2	46.3 ± 5.6	46.7 ± 5.2
	Total	42.9 ± 8.6[a]	41.1 ± 9.0[b]	41.0 ± 9.4[b]
Fat mass (kg)	Men	38.1 ± 13.2	34.8 ± 13.6	33.8 ± 13.9
	Women	45.9 ± 11.9	43.5 ± 10.8	43.9 ± 10.8
	Total	42.9 ± 12.9[a]	40.2 ± 12.5[b]	40.1 ± 12.9[b]
Fat-free mass (kg)	Men	69.0 ± 7.7	69.0 ± 7.7	69.2 ± 8.0
	Women	48.5 ± 6.4	49.6 ± 6.9	49.2 ± 6.4*
	Total	56.6 ± 12.2[a]	56.9 ± 11.9[b]	56.8 ± 12.1[ab]
Waist Circ. (cm)	Men	109.2 ± 10	106.2 ± 10.5	106.4 ± 12.3
	Women	102.5 ± 13.1	101.5 ± 13.1	101.0 ± 12.1
	Total	105.2 ± 12.3[a]	103.3 ± 12.3[b]	103.1 ± 12.4[b]
Hip Circ. (cm)	Men	113.8 ± 10.6	110.7 ± 10.3	111.1 ± 12.6
	Women	122.7 ± 13.4	120.4 ± 12.9	120.7 ± 12.9
	Total	119.2 ± 13.0[a]	116.7 ± 12.8[b]	117.1 ± 13.5[b]
SBP (mm Hg)	Men	127 ± 12	123 ± 12	126 ± 15
	Women	120 ± 12	125 ± 14	119 ± 14
	Total	123 ± 12	124 ± 13	122 ± 14
DBP (mm Hg)	Men	85 ± 5	84 ± 5	82 ± 6
	Women	83 ± 7	82 ± 8	82 ± 9
	Total	84 ± 7	83 ± 7	82 ± 8
HR ($beats \cdot min^{-1}$)	Men	70 ± 9	71 ± 10	71 ± 11
	Women	73 ± 11	73 ± 11	72 ± 9
	Total	72 ± 10	73 ± 11	72 ± 10

Values with different superscripts indicate significant differences within groups ($P<0.05$). Pairwise comparisons were done only on total values.
*Indicates a significant difference in the way men and women responded over the course of the intervention.

Table 3. Blood lipid profiles measured at baseline and 36 weeks for men (n=13) and women (n=23) who completed the intervention.

Variable	Gender	Baseline	36 weeks
TC ($mg\cdot dl^{-1}$)	Men	181 ± 36	174 ± 38
	Women	190 ± 31	193 ± 29
	Total	187 ± 33	186 ± 33
Triglycerides ($mg\cdot dl^{-1}$)	Men	140 ± 52	135 ± 76
	Women	125 ± 63	110 ± 59
	Total	130 ± 59	119 ± 66
HDL-C ($mg\cdot dl^{-1}$)	Men	40i± 9	42 ± 10
	Women	53 ± 14	56i± 10
	Total	48 ± 13[a]	51 ± 12[b]
LDL-C ($mg\cdot dl^{-1}$)	Men	113 ± 30	105 ± 32
	Women	112 ± 27	115 ± 25
	Total	113 ± 28	111 ± 27

Values with different superscripts indicate significant differences from baseline to 36 weeks ($P<0.05$). Pairwise comparisons were done only on total values. Two men and one woman were excluded from the lipid profile analysis due to changes in cholesterol-altering medication.

Only the change in fat-free mass differed significantly between men and women in response to the intervention with the women experiencing a slight but significant increase in this variable. Figures 2 and 3 show the changes in daily step counts and body weight among men and women in response to the intervention. Two men and two women were excluded from the blood pressure and heart rate measurements due to changes in medications that may alter these variables. Two men and one woman were excluded from the lipid profile analysis due to changes in cholesterol-altering medication.

A repeated measures ANOVA was also done on all men and women who adhered to the exercise prescription for the full 36 weeks (data not presented). Again, fat-free mass was the only variable that responded differently between men and women. Significant improvements were noted for body weight, BMI, percent body fat, fat mass, waist circumference, and hip circumference.

Due to the lack of significant differences between men and women in the response to the intervention (except for fat-free mass), an analysis was performed on the combined group to compare those who adhered to the exercise prescription and those who did not. At baseline, there were no significant differences between any variables when comparing the adherers with the non-adherers. A repeated measures ANOVA showed that the adherers experienced significant improvements in body weight, BMI, percent body fat, fat mass, waist circumference and hip circumference (Tables 4 and 5). Little or no changes were seen in the non-adherers, although they did significantly increase their daily step counts by 2500 $steps \cdot d^{-1}$. Figures 4 and 5 show the changes in daily step counts and body weight among the adherers and the non-adherers.

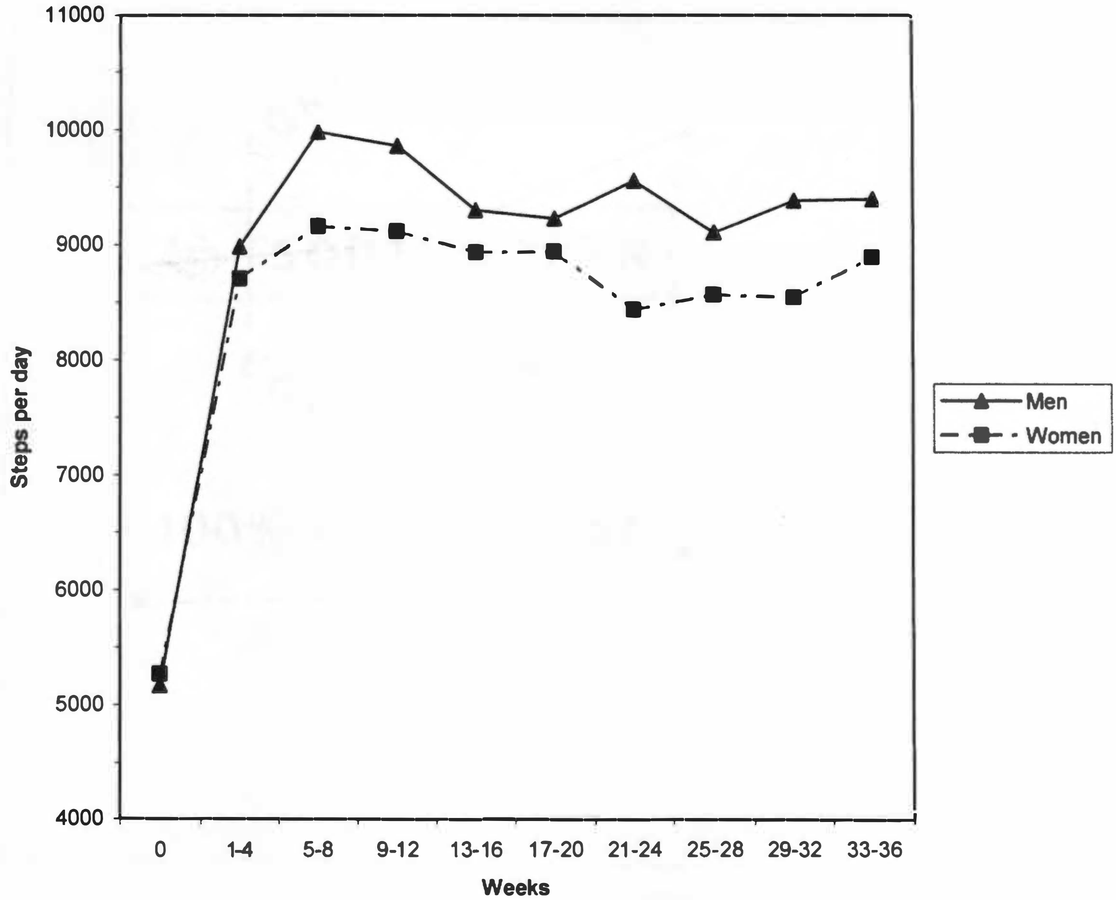

Figure 2: A comparison of changes in daily step counts among men and women in response to a 10,000 steps per day intervention.

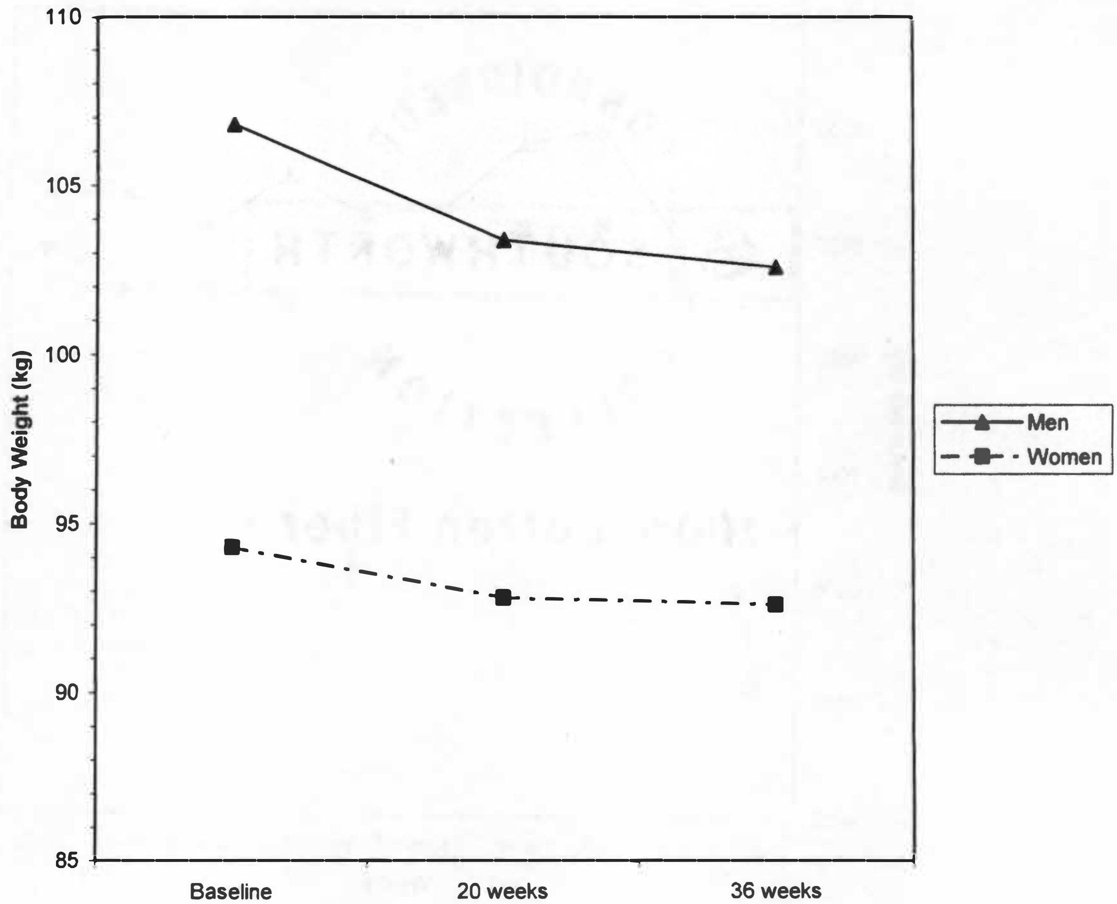

Figure 3: A comparison of changes in body weight among men and women in response to a 10,000 steps per day intervention.

Table 4. Dependent variables measured at baseline, 20 weeks, and 36 weeks in adherers (n=20) and non-adherers (n=19).

Variable	Baseline	20 weeks	36 weeks
Weight, kg			
Adherers	99.8 ± 21.1[a]	97.0 ± 20.5[b]	95.3 ± 20.7[b]
Non-adherers	95.2 ± 14.9	94.6 ± 13.6	95.5 ± 13.5
BMI, kg·m^{-2}			
Adherers	33.5 ± 5.3[a]	32.5 ± 5.1[b]	31.9 ± 5.1[b]
Non-adherers	32.4 ± 4.0	32.2 ± 3.8	32.5 ± 3.8
Body fat, %			
Adherers	40.6 ± 8.7[a]	38.3 ± 8.5[b]	37.4 ± 9.2[b]
Non-adherers	44.8 ± 8.8[a]	43.5 ± 9.2[b]	44.3 ± 8.7[ab]
Fat mass, kg			
Adherers	41.0 ± 13.7[a]	37.8 ± 13.1[b]	36.3 ± 13.5[b]
Non-adherers	43.0 ± 12.5[a]	41.5 ± 11.8[b]	42.6 ± 11.5[a]
Fat-free mass, kg			
Adherers	59.1 ± 12.9	59.5 ± 12.2	59.4 ± 12.5
Non-adherers	52.6 ± 10.8[a]	53.4 ± 10.8[b]	53.4 ± 10.7[b]
Waist Circ, cm			
Adherers	106.7 ± 11.4[a]	104.7 ± 11.5[b]	103.6 ± 12.2[b]
Non-adherers	100.2 ± 11.3	99.7 ± 11.9	100.2 ± 11.3
Hip Circ, cm			
Adherers	117.0 ± 13.0[a]	114.4 ± 12.7[b]	114.1 ± 13.7[b]
Non-adherers	118.7 ± 12.5[a]	117.2 ± 12.0[b]	117.8 ± 12.2[ab]
SBP, mmHg			
Adherers	126 ± 14	126 ± 15	126 ± 17
Non-adherers	118 ± 10	122 ± 12	117 ± 11
DBP, mmHg			
Adherers	85 ± 7	84 ± 8	83 ± 9
Non-adherers	82 ± 6	82 ± 6	81 ± 7
HR, beats·min^{-1}			
Adherers	75 ± 12	74 ± 12	74 ± 11
Non-adherers	70 ± 10	72 ± 10	70 ± 8

Values with different superscripts indicate significant differences ($P<0.05$) within groups.

Table 5. Blood lipid profiles measured at baseline and 36 weeks in adherers (n=16) and non-adherers (n=17).

Variable	Baseline	36 weeks
TC, $mg \cdot dl^{-1}$		
Adherers	192 ± 37	187 ± 38
Non-adherers	182 ± 30	187 ± 32
Triglycerides, $mg \cdot dl^{-1}$		
Adherers	143 ± 67	131 ± 86
Non-adherers	120 ± 50	108 ± 44
HDL-C, $mg \cdot dl^{-1}$		
Adherers	46e± 13[a]	50 ± 14[b]
Non-adherers	48 ± 11[a]	52 ± 10[b]
LDL-C, $mg \cdot dl^{-1}$		
Adherers	117 ± 29	111 ± 28
Non-adherers	109 ± 28	113 ± 30

Values with different superscripts indicate significant differences (P<0.05) within groups.

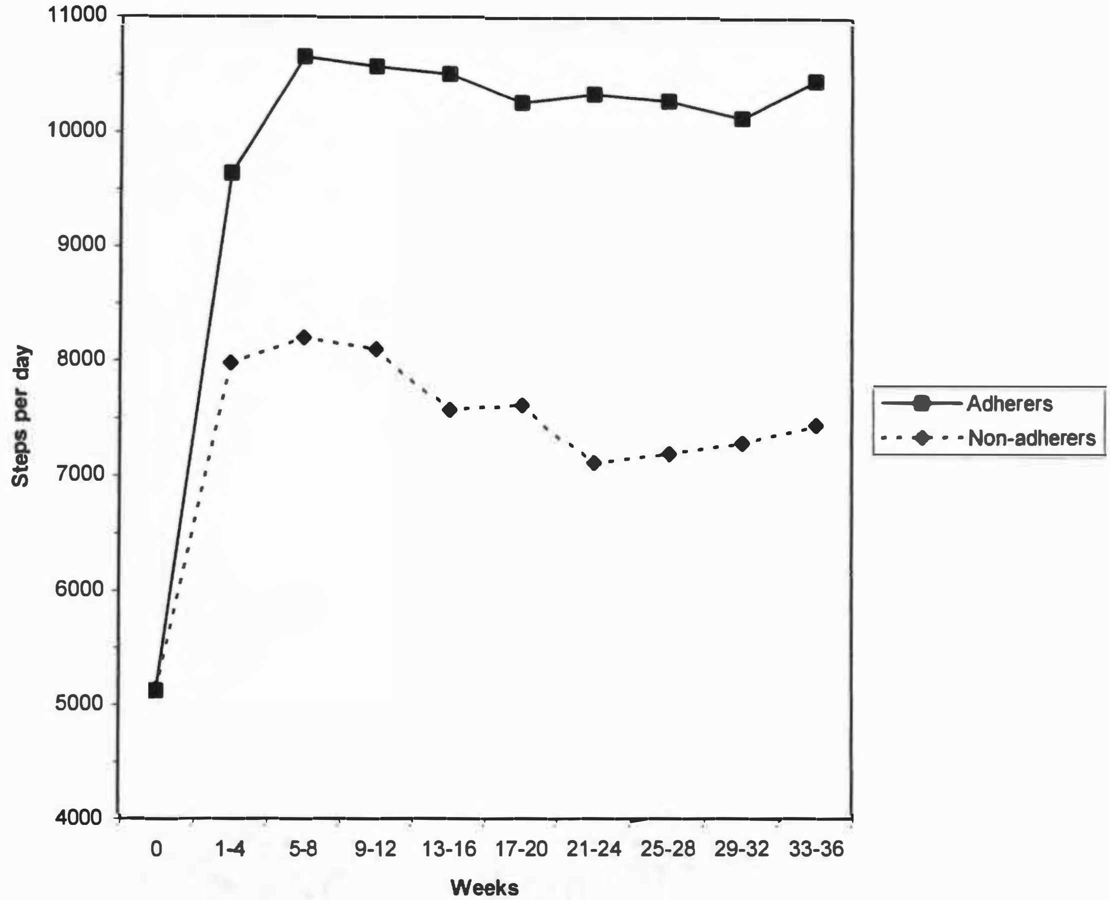

Figure 4: A comparison of changes in daily step counts among the adherers and non-adherers in response to a 10,000 steps per day intervention.

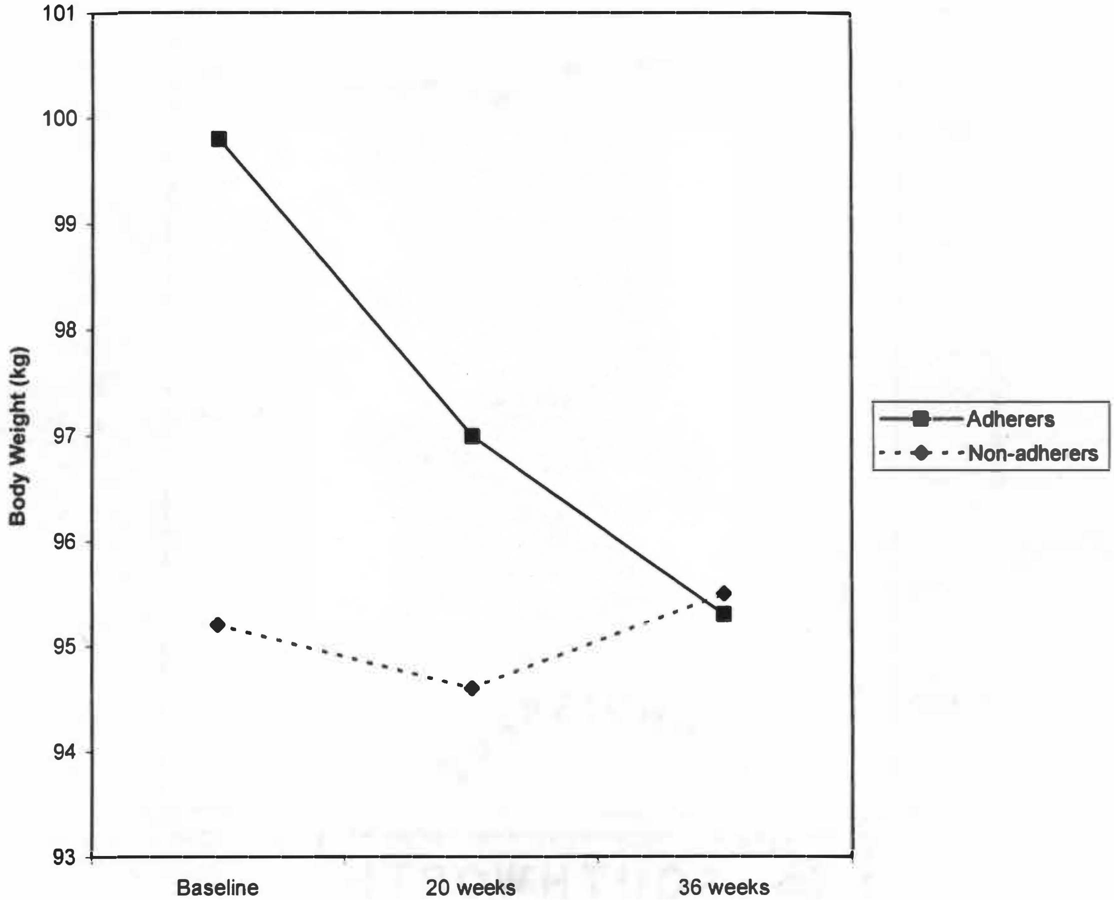

Figure 5: A comparison of changes in body weight among the adherers and non-adherers in response to a 10,000 steps per day intervention.

Partial correlations were used to assess the relationship between the increase in daily walking over 36 weeks and the change in dependent variables while controlling for changes in energy intake and initial body weight. There were significant correlations noted between the increase in daily step counts ($steps \cdot d^{-1}$) and the changes in body weight ($r = -.42$), BMI (-.42), hip circumference (-.41), percent body fat (-.44), and fat mass (-.45). A marginal partial correlation ($P<0.10$) was found between the increase in daily step counts and the change in waist circumference (-.35). Pearson correlations were used to assess the relationship between the increase in daily walking and the change in dependent variables over the course of the intervention. A significant correlation was found between the increases in daily step counts and HDL-C (.45).

No statistically significant differences were found between men (2498, 2315, 2711 kcal at baseline, 20 weeks, and 36 weeks) and women (2194, 2091, and 1993 kcal at baseline, 20 weeks, and 36 weeks) for total energy intake or macronutrient composition (carbohydrate, protein, and fat) across the 36-week intervention. In addition, no significant within gender changes were noted in any of these dietary variables. Likewise, no statistically significant differences were noted between the adherers and non-adherers, nor did either group significantly change any of the abovementioned dietary variables over the course of the study.

Discussion

On-treatment

The on-treatment analysis showed that overweight men and women given a 10,000 steps per day exercise prescription experienced significant improvements in body weight, BMI, percent body fat, fat mass, waist and hip circumferences, and HDL-C. The only factor that responded differently between genders was fat-free mass. However, the change in fat-free mass in both genders was very small (<1 kg) and is unlikely to be considered clinically significant. These findings suggest that a 10,000 steps per day program is effective at improving body weight and body composition in previously sedentary, overweight adults.

We recognize that statistical significance is largely a function of sample size (49). Based on the difference in weight loss between men and women, it would have taken 104 individuals (52 men and 52 women) to detect a significant difference in this variable (80% power). Nonetheless, this study indicates that the gender difference in response to this exercise intervention was not as large as what some previous studies have found since men and women responded to a 10,000 steps per day goal in a similar manner.

To determine if there was a dose-response relationship between the change in daily step counts and the dependent variables, a partial correlation was used to compare the increase in daily walking with the change in all dependent variables after controlling for baseline body weight along with any change in energy intake over the course of the intervention. Significant correlations were found between the increase in daily step counts and the changes in body weight, BMI, percent body fat, fat mass and hip circumference. This suggests that the greater the increase in daily walking, the greater the improvement in body weight and body composition variables.

Adherers vs. Non-adherers

In comparing men who adhered to the exercise prescription to women who adhered, once again little effect of gender was seen. This suggests that walking 10,000 steps per day is equally efficacious for weight loss in sedentary, overweight men and women.

Given that men and women responded similarly, a comparison was made between those who adhered to the exercise prescription with those who did not. Both adherers and non-adherers significantly increased daily walking (by 5,275 and 2,472 $steps \cdot d^{-1}$, respectively). Although the increase in daily walking was significant for both groups, only the adherers showed significant improvements in body weight, BMI, percent body fat, fat mass, waist circumference, and hip circumference after 36 weeks. In contrast, those who did not adhere to the exercise prescription had little or no change in these variables.

Although no significant differences were apparent in regard to body weight or fat mass change between men and women in response to the intervention, men tended to lose a little more weight and fat mass than women. This is partly due to the fact that the men were heavier than the women, and heavier individuals expend more calories per step. Thus, for a given increase in daily walking the men would have expended more calories, which favored the tendency to lose more weight. In addition, men showed a trend towards greater adherence to the 10,000 steps per day exercise prescription which could also have been a contributing factor.

Comparison to Literature

An increase in physical activity has long been considered a potential tool for weight management. Several studies have assessed the effect of walking on body weight in men or women. Pollock et al. (40) found that a 20-week, moderate-to-high intensity walking program for 160 minutes per week in middle-aged men resulted in a statistically significant 1.3 kg of weight loss. Similarly, Moreau et al. (36) showed that adding a 3-km daily walk to the normal activity (4,300 steps$\cdot d^{-1}$ increase) of postmenopausal women also resulted in a significant weight loss of 1.3 kg after 24 weeks. Other walking studies have also noted weight loss in both genders (13, 29, 35, 37). However, not all studies have found walking to be effective at producing weight loss. Hinkleman and Nieman (17) showed that a 15-week, moderate intensity walking program, 5 days per week for 45 minutes per session did not result in significant reductions in body weight or fat mass in overweight women. Snyder et al. (45) also found that a 32-week walking program for 150 minutes per week was not sufficient to produce significant changes in body weight or body composition in overweight females.

Studies that have evaluated the gender effect have shown that men lose more weight than women in response to an exercise intervention (2, 7, 23, 46). Donnelly et al. (7) showed that after 16 months of moderate-intensity exercise that progressed up to 225 minutes per week, only men lost a significant amount of body weight and fat mass. Men lost 5.3 kg of body weight and 5.0 kg of fat mass after 9 months, at which point weight loss leveled off and did not change significantly for the remainder of the study. In contrast, women showed a trend towards an increase in body weight (0.6 kg) and decrease in fat mass (-0.2 kg). Snyder-Heelan et al. (46) also found that men were more successful in regard to weight loss than women following a 66-week intervention. In this study, exercise was adjusted to result in 400 kcal of energy expenditure per session, 5 days per week. Similar to the findings of Donnelly et al. (7), men in this study lost 5.1 kg of body weight while women had a slight but statistically insignificant increase in body weight (0.8 kg).

The current study shows close agreement with the findings of both Donnelly et al. and Snyder-Heelan et al. in regard to the change in body weight in men, but differs with regard to the changes in body weight in women. However, the current study is in agreement with the findings of Moreau et al. (36) concerning the amount of weight loss in women. The current study found that both sedentary, overweight men and women lose weight if they walk 10,000 steps per day. It is unclear why some previous exercise interventions failed to produce weight loss in women. Possible explanations are that, in some studies, women expended less energy (due to lower adherence or smaller body size), increased their energy intake to compensate for the increase in exercise energy expenditure, or they unintentionally decreased their habitual physical activity.

<u>Lipid Profile and Blood Pressure</u>

High-density lipoprotein values increased similarly in both men and women and in the adherers and non-adherers. In addition, there was a significant correlation between the increase in daily walking and the increase in HDL-C. Consistent with other findings

(31), the women in this study had significantly higher baseline HDL-C levels than the men. However, unlike other studies, women were not more resistant than men to exercise-induced changes in HDL-C (17, 30).

There were no significant changes in blood pressure or heart rate among men and women or among the adherers and non-adherers. This is due to the fact that most of the participants had initial resting blood pressure values that were in the normal range. Thus, a lack of change in these variables is consistent with finding that blood pressure changes are likely to be minimal in normotensive individuals (9, 21, 22, 40).

Summary

The 10,000 steps per day exercise prescription was effective at increasing daily walking and resulted in significant improvements in body weight, BMI, percent body fat, fat mass, waist circumference, hip circumference, and HDL-C in overweight, middle-aged men and women. In addition, those who adhered to the exercise prescription experienced significantly greater improvements in body weight and body composition when compared with those who did not adhere. These results suggest that the 10,000 steps per day exercise prescription is an effective tool for weight management and should be considered as a strategy for dealing with the current obesity epidemic.

Acknowledgements

The authors would like to thank Cary Springer of the UT Statistical Consulting Services for supporting the data analysis in this study. This research was supported by the James D. Moran and Monica Moran Dissertation Award and the Charlie and Mai Coffey Endowment in Exercise Science.

References

1. American Society of Hypertension - Public Policy Committee. Recommendations for routine blood pressure measurement by indirect cuff sphygmomanometry. *Am. J. Hypertens.* 5:207-209, 1992.

2. Ballor, D. L. and R. E. Keesey. A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass and fat-free mass in males and females. *Int. J. Obes.* 15:717-726, 1991.

3. Callaway, C. W., W. C. Chumlea, C. Bouchard, et al. Circumferences. In: *Anthropometric Standardization Reference Manual.* T. G. Lohman, A. F. Roche, and R. Martorell (Eds.) Champaign, IL: Human Kinetics Books, 1988, pp. 44-47.

4. Centers for Disease Control and Prevention - Morbidity and Mortality Weekly Report. *Prevalence of Physical Activity, Including Lifestyle Activities Among Adults - United States, 2000-2001*, 2003, pp. 764-769.

5. Colditz, G. A. Economic costs of obesity and inactivity. *Med. Sci. Sports Exerc.* 31:S515-S521, 1999.

6. Crouter, S. E., P. L. Schneider, M. Karabulut, and D.aR. Bassett. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med. Sci. Sports Exerc.* 35:1455-1460, 2003.

7. Donnelly, J.æE., J. O. Hill, D. J. Jacobsen, et al. Effects of a 16-month randomized controlled exercise trial on body weight and composition in young, overweight men and women. *Arch. Intern. Med.* 163:1343-1350, 2003.

8. Donnelly, J. E., D. J. Jacobsen, K. Snyder-Heelan, R. Seip, and S. Smith. The effects of 18 months of intermittent vs continuous exercise on aerobic capacity, body weight and composition, and metabolic fitness in previously sedentary, moderately obese females. *Int. J. Obes.* 24:566-572, 2000.

9. Duncan, J. J., N. F. Gordon, and C. B. Scott. Women walking for health and fitness. *JAMA*. 266:3295-3299, 1991.

10. Flegal, K. M., M. D. Carroll, C. L. Ogden, and C. L. Johnson. Prevalence and Trends in Obesity Among U.S. Adults, 1999-2000. *JAMA*. 288:1723-1727, 2002.

11. Gordon, C. C., W. C. Chumlea, and A. F. Roche. Stature, Recumbent Length, and Weight. In: *Anthropometric Standardization Reference Manual*. T. G. Lohman, A. F. Roche, and R. Martorell (Eds.) Champaign, IL: Human Kinetics Books, 1988, pp. 3-8.

12. Grundy, S. M., G. Blackburn, M. Higgins, R. Lauer, M. G. Perri, and D. Ryan. Physical activity in the prevention and treatment of obesity and its comorbidities: evidence report of independent panel to assess the role of physical activity in the treatment of obesity and its comorbidities. *Med. Sci. Sports Exerc.* 31:S502-S508, 1999.

13. Gwinup, G. Effect of exercise alone on the weight of obese women. *Arch. Intern. Med.* 135:676-680, 1975.

14. Hatano, Y. Use of the pedometer for promoting daily walking exercise. *ICHPER J.* 29:4-8, 1993.

15. Hedley, A. A., C. L. Ogden, C. L. Johnson, M. D. Carroll, L. R. Curtin, and K. M. Flegal. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999-2002. *JAMA*. 291:2847-2850, 2004.

16. Helmrich, N. Journey to better fitness starts with 10,000 steps. *USA Today*. June 29, 1999.

17. Hinkleman, L. L. and D. C. Nieman. The effects of a walking program on body composition and serum lipids and lipoproteins in overweight women. *J. Sports Med. Phys. Fitness*. 33:49-58, 1993.

18. Jakicic, J. M., K. Clark, E. Coleman, et al. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. *Med. Sci. Sports Exerc.* 33:2145-2156, 2001.

19. Jakicic, J.aM. and K. I. Gallagher. Exercise considerations for the sedentary, overweight adult. *Exerc. Sports Sci. Rev.* 31:91-95, 2003.

20. Katzmarzyk, P. T., I. Janssen, and C. I. Ardern. Physical inactivity, excess adiposity and premature mortality. *Obes. Rev.* 4:257-290, 2003.

21. Kelley, D. A., K. A. Kelley, and Z. V. Tran. Aerobic exercise and resting blood pressure: A meta-analytic review of randomized, controlled trials. *Prev. Cardiol.* 4:73-80, 2001.

22. Kelley, G. A. Effects of aerobic exercise in normotensive adults: a brief meta-analytic review of controlled clinical trials. *South Med. J.* 88:42-46, 1995.

23. Kirk, E. P., J.iE. Donnelly, D. J. Jacobsen, and C. Gibson. Time-course and gender effects in aerobic capacity and body composition for overweight individuals: Midwest exercise trial (MET). *Med. Sci. Sports Exerc.* 34:S120 [abstract], 2002.

24. Klem, M. L., R. R. Wing, M. T. McGuire, H. M. Seagle, and J. O. Hill. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. *Am. J. Clin. Nutr.* 66:239-246, 1997.

25. Kramer, F. M., R. W. Jeffery, and J. L. Forster. Long-term follow-up of behavioral treatement for obesity: patterns of weight regain among men and women. *Int. J. Obes.* 13:123-136, 1989.

26. Kraus, W. E., J. A. Houmard, B. D. Duscha, et al. Effects of the amount and intensity of exercise on plasma lipoproteins. *New Engl. J. Med.* 347:1483-1492, 2002.

27. Lanningham-Foster, L., L. J. Nysse, and J. A. Levine. Labor saved, calories lost: The energetic impact of domestic labor-saving devices. *Obes. Res.* 11:1179-1181, 2003.

28. Le Masurier, G. C., S. M. Lee, and C. Tudor-Locke. Motion sensor accuracy under controlled and free-living conditions. *Med. Sci. Sports Exerc.* 36:905-910, 2004.

29. Leon, A. S., J. Conrad, D. B. Hunninghake, and R. Serfass. Effects of a vigorous walking program on body composition, and carbohydrate and lipid metabolism of obese young men. *Am. J. Clin. Nutr.* 33:1776-1787, 1979.

30. Leon, A. S. and O. A. Sanchez. Response of blood lipids to exercise training alone or in combination with dietary intervention. *Med. Sci. Sports Exerc.* 33:S502-S515, 2001.

31. Lokey, E. A. and Z. V. Tran. Effects of exercsie training on serum lipid and lipoprotein concentrations in women: A meta-analysis. *Int. J. Sports Med.* 10:424-429, 1989.

32. McCrory, M. A., T. D. Gomez, E. M. Bernauer, and P. A. Mole. Evaluation of new air displacement plethysmograph for measuring human body composition. *Med. Sci. Sports Exerc.* 27:1686-1691, 1995.

33. McCrory, M.iA., P.iA. Mole, T. D. Gomez, K. G. Dewey, and E. M. Bernauer. Body composition by air-displacement plethysmography by using predicted and measured thoracic gas volumes. *J. Appl. Physiol.* 84:1475-1479, 1998.

34. Miller, W. C., D. M. Koceja, and E. J. Hamilton. A meta-analysis of the past 25 years of weight loss research using diet, exercise, or diet plus exercise intervention. *Int. J. Obes.* 21:941-947, 1997.

35. Miyatake, N., H. Nishidawa, A. Morishita, et al. Daily walking reduces visceral adipose tissue areas and improves insulin resistance in Japanese obese adults. *Diabetes Res. Clin. Pract.* 58:101-107, 2002.

36. Moreau, K. L., R. Degarmo, J. Langley, et al. Increasing daily walking lowers blood pressure in postmenopausal women. *Med. Sci. Sports Exerc.* 33:1825-1831, 2001.

37. Parkkari, J., A. Natri, P. Kannus, et al. A controlled trial of the health benefits of regular walking on a golf course. *Am. J. Med.* 109:102-108, 2000.

38. Pi-Sunyer, F. X. Medical hazards of obesity. *Ann. Intern. Med.* 119:655-660, 1993.

39. Pollock, M. L. Prescribing exercise for fitness and adherence. In: *Exercsie adherence: It's impact on public health.* R. K. Dishman (Ed.) Champaign, IL: Human Kinetics, 1988, pp. 259-277.

40. Pollock, M. L., H. S. Miller, R. Janeway, A. C. Linnerud, B. Robertson, and V. R. Effects of walking on body composition and cardiovascular function of middle-aged men. *J. Appl. Physiol.* 30:126-130, 1971.

41. Ross, R., D. Dagnone, P. J. H. Jones, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. *Ann. Epidemiol.* 133:92-103, 2000.

42. Schneider, P. L., S. E. Crouter, and D. R. Bassett. Pedometer measures of free-living physical activity: Comparison of 13 models. *Med. Sci. Sports Exerc.* 36:331-335, 2004.

43. Siri, N. E. Body compostion from fluid spaces and density. In: *Techniques for Measuring Body Composition.* J. Brozek and A. Henschel (Eds.) Washington, D.C.: National Academy of Science, 1961, pp. 223-224.

44. Skender, M. L., G. K. Goodrick, D. J. DelJunco, et al. Comparison of 2-year weight loss trends in behavioral treatments of obesity: Diet, exercise and combination interventions. *J. Am. Diet. Assoc.* 96:342-346, 1996.

45. Snyder, K. A., J. E. Donnelly, D. J. Jacobsen, G. Hertner, and J. M. Jakicic. The effects of long-term, moderate intensity, intermittent exercise on aerobic capacity, body composition, blood lipids, insulin and glucose in overweight females. *Int. J. Obes.* 21:1180-1189, 1997.

46. Snyder-Heelan, K. A., D. J. Jacobsen, J. O. Hill, S. Johnson, and J. E. Donnelly. Differences in body weight changes between males and females in response to exercise. *Med. Sci. Sports Exerc.* 33:S138 [abstract], 2001.

47. Swartz, A. M., D. R. Bassett, J. B. Moore, D. L. Thompson, and S. J. Strath. Effects of body mass index on the accuracy of an electronic pedometer. *Int. J. Sports Med.* 24:588-592, 2003.

48. Swartz, A. M. and D. L. Thompson. Increasing daily walking improves glucose tolerance in overweight women. *Prev. Med.* 37:356-362, 2003.

49. Thomas, J. R. and J. K. Nelson. Becoming Acquainted with Statistical Concepts. In: *Research Methods in Physical Activity* Champaign, IL: Human Kinetics, 1996, p. 110.

50. Tudor-Locke, C. Taking steps toward increased physical activity: Using pedometers to measure and motivate. *Research Digest.* 3:1-8, 2002.

51. Tudor-Locke, C. and A. M. Myers. Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Res. Q. Exerc. Sport* 72:1-12, 2001.

52. U.S. Department of Health and Human Services. Understanding and Improving Health. In: *Healthy People 2010* Washington, DC: U.S. Government Printing Office, 2000.

53. Uhlman, M. Pedometers popularity taking off. *The Philadelphia Inquirer*. Oct. 3, 2002.

APPENDICES

APPENDIX A

PARTS III, IV

INFORMED CONSENT FORM

INFORMED CONSENT FORM

The Validation of Electronic Pedometers

Investigator: Patrick L. Schneider

Address:

The University of Tennessee
Department of Health, Safety, and Exercise Science
1914 Andy Holt Ave.
Knoxville, TN 37919

Telephone: 865-974-5091

Purpose

You are invited to participate in a research study. The purpose of this study is to examine the use of electronic pedometers to measure steps taken, distance walked, and caloric expenditure. If you give your consent, you will be asked to participate in one part of the study. The section checked below is the part of the study you are volunteering for. Before exercising, you will be given a brief questionnaire to determine your health status and you will be measured for height and weight in the laboratory.

Procedures

_____ Part 1. Course validation – You will take 20 strides and the total distance covered will be divided by 20 to determine stride length. You will then be asked to walk around a 400 meter outdoor track a total of 2 times for each pedometer of the same brand. A total of 12 different brands of pedometers will be tested. Therefore, you will be asked to walk around the 400 meter track a total of 24 times which is equivalent to 6 miles. A researcher will accompany you on each walk, manually counting each step. The testing will take place over the course of 1-5 days and will require a total of about 2-4 hours of your time.

_____ Part 2. Effects of walking speed – You will be asked to walk on the treadmill at 2.0, 2.5, 3.0, 3.5, and 4.0 mph (5 minutes per stage). The effects of walking speed on the accuracy of each of the 10 brands of pedometers being tested will be examined. The testing will take place over the course of 3-5 days and will require about 4-5 hours of your time. You will be asked to wear a nose-clip and mouthpiece, and breathe into a device to measure oxygen uptake for each of the five 25 minute trials you will be asked to complete. The liters of oxygen actually consumed will be compared against the estimated value from the pedometer. You will also have your resting metabolic rate measured using the nose-clip and mouthpiece for 40 minutes on a separate day from the walking trials.

_____ Part 3. 24-hour comparisoni– You will be asked to wear a Yamax SW-200 pedometer on one hip and another model on the other for 24 hours and record the number of steps registered on both pedometers at the end of each day. A comparison will then be made between the Yamax SW-200 and the comparative model. A total of 12 pedometers will be compared to the Yamax SW-200, which will require a total of 12 days of testing. You will not be asked to do any activities beyond which you would normally do on any other day. You will be given instructions on how to use each pedometer and will not be asked to return to the laboratory until all 12 pedometers have been compared.

Risks and Benefits

There are very few risks associated with moderate exercise. The risks include abnormal blood pressure responses and heart rhythm disturbances. These risks of participating in this study are equivalent to the risks of activities requiring moderate exertion (yard work, light sport activities, etc.) that you engage in during everyday activities. The benefits to participation include knowledge of your stride length, and exposure to a device that may provide accurate information about "steps taken" and "distance walked." You will also be given information on your resting metabolic rate.

Confidentiality

The information obtained from these tests will be treated as privileged and confidential and will consequently not be released to any person without your consent. However, the information will be used in research reports or presentations, but your name and other identity will not be disclosed.

Right to Ask Questions and to Withdraw

You are free to decide whether or not to participate in this study and are free to withdraw from the study at any time.

Before you sign this form, please ask questions about any aspects of the study which are unclear to you.

Consent

By signing this paper, I am indicating that I understand and agree to take part in this research study.

_______________________________ Date ____________________
Your signature

_______________________________ ____________________
Researcher's signature Date

APPENDIX B

PARTS III, IV

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

Physical Activity Readiness Questionnaire (PAR-Q)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO 1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?

YES NO 2. Do you feel pain in your chest when you do physical activity?

YES NO 3. In the past month, have you had chest pain when you were not doing physical activity?

YES NO 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

YES NO 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

YES NO 6. Do you know of <u>any other reason</u> why you should not be doing physical activity?

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name ____________________________________

Signature _________________________________ Date ____________________

APPENDIX C

PART V

INFORMED CONSENT FORM

INFORMED CONSENT FORM

TITLE OF STUDY: A comparison of the 10,000 steps per day recommendation in overweight men vs. women: the effects on cardiovascular risk factors and adherence

Investigator: Patrick L. Schneider, M.S.

Address: The University of Tennessee
Department of Health and Exercise Science
1914 Andy Holt Ave.
Knoxville, TN 37996

Telephone: 865-974-5091

Co-Investigators: David Bassett, Ph.D.
Kenneth Bielak, M.D.

PURPOSE

You are invited to participate in a research study examining the effects of a 36-week walking program on adherence, weight loss and cardiovascular risk factors. This study will provide information on the relationship between walking 10,000 steps per day and specific health benefits. The research will take place at both the University of Tennessee and the University of Tennessee Medical Center. This study will begin in the Summer of 2003 and will conclude in the Spring of 2004 and will involve 100 participants.

PROCEDURES

If you choose to participate in this study, you will report to the Applied Physiology Laboratory, Room 310 in the Health, Physical Education and Recreation (HPER) building at the University of Tennessee on four separate occasions: prior to the study to complete necessary paperwork described below (this visit), at baseline, 18 weeks, and 36 weeks for the measurement of a variety of health related variables. Each occasion is expected to last about 1 hour. Prior to any testing, you will complete a questionnaire regarding your health history, exercise training habits, and your readiness to adopt a physical activity program. The health history form will be used to ensure that the testing is safe for you. You will be asked to report to the laboratory in a rested condition not having consumed food 12 hours prior to testing. Your will also be asked to refrain from alcohol consumption and exercise for 12 hours prior to the test. On two occasions, you will be asked to report to the outpatient laboratory at the University of Tennessee Medical Center for a blood cholesterol test.

On each of your visits, you will report to the laboratory between 6:00 and 10:00 a.m. after a 12-hour overnight fast. Your blood pressure and heart rate will be measured three times while you are sitting in a chair after you have rested quietly for five minutes. Your body composition will be determined by measuring your height, weight, waist and hip circumferences, and body fat percentage. Two different techniques

(Tanita® and Bod Pod®) will be used to assess body fat percentage. The Tanita®, is a device that is similar in appearance to a bathroom scale. You will be asked to stand on the "scale" with bare feet, dressed in a swimsuit for approximately one minute. This device estimates your body fatness by measuring the resistance to a small electrical current that is passed from the scale through your body. You will not be able to feel the current and this test is harmless. The Bod Pod®, is a whole body chamber that uses changes in air pressure within the chamber to determine body volume. Your body volume will be measured as you sit for approximately 3 minutes in a sealed chamber wearing a lycra swimsuit. During this time you will be able to breathe normally and view your surroundings. Along with your body weight, body volume is used to estimate body fatness. When you report to the outpatient laboratory at the University of Tennessee Medical Center, a needle will be inserted into your forearm and a small blood sample (7 cc, about 1 ½ teaspoons) will be taken to be later analyzed for blood cholesterol levels. The blood will be disposed of immediately after the blood cholesterol measurement is complete.

You will be given an electronic pedometer to wear throughout the day during the entire study. You will be asked to record the number of steps shown on the pedometer at the end of the day for two weeks. This information will allow us to determine your current average weekly walking distance. You will also be given a three-day dietary record form and will be asked to record the food and drink that you consume for three days.

WALKING PROGRAM

After completion of all the baseline measures, you will then be given a recommendation that leads up to taking at least 10,000 steps per day for 36 weeks. The first week you will be asked to take 7,000 steps per day. The second, 8,000 steps per day. The third, 9,000 steps per day. And on the fourth week you will be asked to take at least 10,000 steps per day. You will be asked to walk at a self-selected, comfortable pace. In order to get at least 10,000 steps per day, you will have to do some walking beyond that required by your normal daily routine. This additional walking can be accumulated in several short bouts or can be done all at once. Your walking steps, along with the time that you put the pedometer on in the morning and the time that you take it off in the evening will be recorded on a daily log sheet. You will also be asked to attend a one-hour informational session every other week for the first two months and then monthly thereafter. The informational sessions are intended to allow you to ask questions or make comments about the walking program and to provide you with educational information on a variety of health related topics.

RISKS ASSOCIATED WITH PARTICIPATION

The potential risks that may occur while participating in this study are those associated with any type of exercise: injury to muscles and/or joints, dizziness, headache, and in very rare instances heart attack. However, these risks are minimal in healthy individuals, and the investigators are trained to conduct these types of experiments. In addition to the pain and/or discomfort associated with taking a small blood sample to determine your blood lipid profile (cholesterol), you may experience some local bruising, tenderness and/or an area of infection where blood samples were taken. Trained technicians will perform the blood sampling technique and sterile procedures will be used to minimize this risk. In regard to the walking program, you will be walking at a self-selected pace.

BENEFITS ASSOCIATED WITH PARTICIPATION

This study will provide information on the relationship between taking 10,000 steps per day for 36 weeks and specific health benefits in males vs. females. You will benefit by acquiring valuable information on your current health status including: blood lipid profile, body composition, and resting heart rate and blood pressure. If you participate in the walking program, you may obtain some health and fitness benefits by participating in the walking program and developing a positive exercise habit. You will also get experience with the pedometer that will provide information on steps taken over the course of a day.

ALTERNATIVES TO PARTICIPATION

As an alternative to participating in this study, you may choose to not participate.

CONFIDENTIALITY

The information obtained from the tests will be treated as privileged and confidential and will consequently not be released to any person without your consent. All the information collected will be coded by a subject number rather than by name and will be kept in a locked file cabinet by Patrick Schneider. However, the information will be used in research reports or presentations, but your name and other identity will not be disclosed.

COMPENSATION AND TREATMENT FOR INJURY

I understand that I am not waiving any legal rights or releasing the University of Tennessee or its agents from liability for negligence. I understand that, in the event of physical injury resulting from research procedures the University of Tennessee does not have funds budgeted for compensation either for lost wages or for medical treatment. In the unlikely event that physical injury occurs as a result of participating in this study, financial compensation is not automatically available and medical treatment will not be provided free of charge. If a physical injury should occur over the course of the study, immediately notify the primary investigator, Patrick Schneider (see below for phone and office numbers).

QUESTIONS

If you have questions or concerns at any time during the course of this investigation or after you complete the study, you may contact Patrick Schneider at (865) 974-5091. Patrick Schneider's office is located in the HPER Building in Room 303. If at any time during this study, events occur that will impact your ability to participate (i.e., you sustain a training injury, you are ill, etc.), you should inform Patrick Schneider immediately. You may also contact the chairman of the University of Tennessee Graduate School of Medicine Institutional Review Board at (865) 544-9781 if you have any questions about your rights as a participant in this study or your rights as a research subject.

PAYMENT FOR PARTICIPATION

As a volunteer in this study, you will not receive any payment in exchange for your participation.

COSTS OF PARTIPATION

There will not be any additional costs to you as a result from participating in this study.

VOLUNTARY PARTICIPATION

As a volunteer in this study, it is your right to withdraw from this investigation at any time. If you decide to withdraw from this study, you will in no way be penalized. If you are unable to adhere to the walking program, you will be asked to continue wearing the pedometer and continue completing the physical activity log. In addition, you will also be asked to attend the 18-week and 36-week measurement sessions.

CONSENT

I have read or have had read to me the description of the research study as outlined above. The investigator or his representative has explained the study to me and has answered all of the questions I have at this time. I have been told of the potential risks, discomforts, side effects and adverse reactions as well as the possible benefits of the study. I freely volunteer to participate in the study. I understand that I do not have to take part in this study and that my refusal to participate will involve no penalty or loss of rights to which I am entitled. I further understand that I am free to later withdraw my consent and discontinue participation in this study at any time. I understand that refusing to participate later or withdrawing from the study will not adversely affect my subsequent medical care.

____ __________

Signature of Research Subject or Legally Authorized Representative   Date

____ __________

Signature of Witness   Date

____ __________

Signature of Principal Investigator   Date

APPENDIX D

PART V

HEALTH HISTORY QUESTIONNAIRE

HEALTH HISTORY QUESTIONNAIRE

NAME ______________________________ DATE ___________________

DATE OF BIRTH ______________________ AGE ______________

ADDRESS ____

____

PHONE NUMBERS (HOME) _____________ (WORK) _________________

e-mail address: ______________________________

When is the best time to contact you? ______________________________________

When is the best time for you to attend a one-hour informational session to be held every other week for the first two months of the program and then monthly thereafter?
Weekdays: am _____ pm _____ Weekends: am _____ pm ____
Please list specific days or times if necessary ______________________________________

Please answer the following questions. This information will only be used for research purposes and will not be made public. Please answer these questions based on physical exercise in which you regularly engage. **This should not include daily work activities such as walking from one office to another.**

1. Do you regularly engage in exercise? Yes/No If yes, please describe.

____

____

2. On average, how many times per week do you engage in exercise training?

   0 ____ 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____

3. On average, how long do you exercise each time?
   0-19 minutes _______ 20-40 minutes ______ more than 40_______

4. How long have you been exercising at this level?
   Less than 6 months ______
   6 – 12 months ______
   1 – 2 years ______
   3 or more years ______

MEDICAL HISTORY

Past History:

Have you ever been diagnosed with the following conditions? Please check the appropriate column.

	Yes	No	Don't Know
Rheumatic fever	( )	( )	( )
Heart murmur	( )	( )	( )
High Blood Pressure	( )	( )	( )
Any heart problem	( )	( )	( )
Lung Disease	( )	( )	( )
Seizures	( )	( )	( )
Irregular heart beat	( )	( )	( )
Bronchitis	( )	( )	( )
Emphysema	( )	( )	( )
Diabetes	( )	( )	( )
Asthma	( )	( )	( )
Kidney Disease	( )	( )	( )
Liver Disease	( )	( )	( )
Severe Allergies	( )	( )	( )
Orthopedic problems	( )	( )	( )
Hyper- or Hypothyroidism	( )	( )	( )
AIDS	( )	( )	( )
Heparin Sensitivity	( )	( )	( )

Present Symptoms Review:

Have you recently had any of the following symptoms? Please check if so.

Chest Pain	( )	Frequent Urination	( )
Shortness of breath	( )	Blood in urine	( )
Heart palpitations	( )	Burning sensations	( )
Leg or ankle swelling	( )	Severe headache	( )
Coughing up blood	( )	Blurred vision	( )
Low blood sugar	( )	Difficulty walking	( )
Feeling faint or dizzy	( )	Weakness in arm	( )
Leg numbness	( )	Significant emotional problem	( )

Do you smoke? Yes/No   If yes, how many per day? ___________

Are you currently trying to lose weight (through diet, exercise, and/or medication)? Yes/No

Are you taking any medications? Yes/No

If yes, please describe: ____

On average, how many alcoholic drinks do you consume per week? ________________

Can you walk 1 continuous mile without pain or discomfort? _______________

OTHER INFORMATION
Whom should we notify in case of an emergency?

Name ______________________________

Address ______________________________

Phone # ______________________________

I have been given the opportunity to ask questions about any of the above items that were unclear, and I have answered all questions completely and truthfully to the best of my knowledge.

SIGNATURE ______________________________ DATE ____________________

APPENDIX E

PART V

DIETARY RECORD INSTRUCTIONS

Dietary Record Instructions

1. Use the Dietary Record Forms provided to record everything you eat or drink for 3 consecutive days – two weekdays and one weekend day.
2. Indicate the name of the FOOD ITEM, the AMOUNT eaten, how it was PREPARED (fried, boiled, broiled, etc.), and the TIME the food was eaten. If the item was a brand name product, please include the name. Try to be accurate about the amounts eaten. Measuring with measuring cups and spoons is best, but if you must make estimates, use the following guidelines:
   - Fist is about 1 cup
   - Tip of Thumb is about 1 teaspoon
   - Palm of the hand is about 3 ounces of meat (about the size of a deck of cards)
   - Tip of Thumb is about 1 ounce of cheese
3. Try to eat what you normally eat and record everything. The project will only be useful if you are HONEST about what you eat. The information you provide is confidential.
4. MILK: Indicate whether milk is whole, low fat (1 or 2%), or skim. Include flavoring if one is used.
5. VEGETABLES and FRUITS: One average serving of cooked or canned fruits and vegetables is about a half cup. Fresh whole fruits and vegetables should be listed as small, medium or large. Be sure to indicate if sugar or syrup is added to fruit and list if any margarine, butter, cheese sauce, or cream sauce are added to vegetables. When recording salad, list items comprising the salad separately and be sure to include salad dressing used.
6. EGGS: Indicate method of preparation (scrambled, fried, poached, etc.) and number eaten.
7. MEAT / POULTRY / FISH: Indicate approximate size or weight in ounces of the serving. Be sure to include any gravy, sauce or breading added.
8. CHEESE: Indicate kind, number of ounces or slices, and whether it is made from whole milk, part skim, or is low calorie.
9. CEREAL: Specify kind, whether cooked or dry, and measure in terms or cups or ounces. Remember that consuming 8 oz. of cereal is not the same as consuming one cup of cereal. 1 cup of cereal generally weighs about 1 ounce.
10. BREAD and ROLLS: Specify kind (whole wheat, enriched wheat, rye, etc.) and number of slices.
11. BEVERAGES: Include every item you drink excluding water. Be sure to record cream and sugar used in tea and coffee, whether juices are sweetened or unsweetened and whether soft drinks are diet or regular.
12. FATS: Remember to record all butter, margarine, oil and other fats used in cooking or on food.
13. MIXED DISHESi/ CASSEROLES: List the main ingredients and approximate amount of each ingredient to the best of your ability.
14. ALCOHOL: Be honest. Record amounts in ounces. Specify with "light" or "regular" beer.

Dietary Record Form

Name: ___________________________

Date: _______________ (Please use a new copy for each day)

Food Item	Amount	Time

Express approximate measures in cups (c), Tablespoons (T), teaspoons (t), grams (g), ounces (oz), pieces, etc.

Dietary Record Form

Name: ___________________________
Date: _______________ (Please use a new copy for each day)

Food Item	Amount	Time

Express approximate measures in cups (c), Tablespoons (T), teaspoons (t), grams (g), ounces (oz), pieces, etc.

Dietary Record Form

Name: ________________________

Date: ______________ (Please use a new copy for each day)

Food Item	Amount	Time

Express approximate measures in cups (c), Tablespoons (T), teaspoons (t), grams (g), ounces (oz), pieces, etc.

VITA

Patrick L. Schneider was born and raised in Sparta, Wisconsin. He attended Winona State University in Winona, Minnesota where he received his Bachelor of Science degree in Exercise Science. Patrick then entered the graduate program in Adult Fitness/Cardiac Rehabilitation at the University of Wisconsin-La Crosse. In 1999, Patrick received his Master of Science degree and became certified as an ACSM Exercise Specialist. Upon graduation, Patrick worked for two years as a Clinical Exercise Physiologist at Franciscan Skemp Healthcare in La Crosse, Wisconsin. In 2001, he began the graduate program in Exercise Science at the University of Tennessee where he served as a Graduate Teaching Associate. Following the completion of the Doctor of Philosophy degree in Education in 2004, Patrick assumed a faculty position at Ball State University in Muncie, Indiana.