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ORIGINAL ARTICLE

The Health Benefits of a Pedometer-Based 100,000 Steps/Week Physical Activity Program

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Abstract

Purpose Pedometers can be an effective tool to increase step counts in a physically inactive population. In a more active population, pedometers may also be useful for further increasing physical activity and improving cardiovascular disease risk factors. Our purpose was to assess the adherence and determine the health impact of a 100,000 steps/week (14,286 steps/day) goal in a somewhat-active (7500–9999 steps/day) to active (10,000–12,500 steps/day) population.

Methods Thirty-two apparently healthy subjects, 13 males (age 44 ± 14 years) and 19 females (age 39 ± 13 years) who had a baseline activity level between 7500 and 12,500 steps/day, were studied. Participants were assessed prior to and 16 weeks after completing a 100,000 steps/week intervention. Pre- and post-assessments of health included body composition, resting blood pressure, blood lipid profile, fasting blood glucose, and a 3-min walk test to estimate cardiorespiratory fitness.

Results Fifty-three percent of participants adhered (≥ 90,000 steps/week) to the 100,000 steps/week physical activity program yet all participants increased their stepping by 23,303 ± 11,480 steps/week. With increased stepping, significant improvements in body composition were observed. Improvements included reduced body mass index (pre: 27.2 ± 3.6 kg/m^2; post: 26.9 ± 3.6 kg/m^2; $P = 0.026$), reduced total percent body fat (pre: 35.7 ± 9.9%; post: 34.3 ± 10.4%; $P < 0.001$), and reduced waist circumference (pre: 83.8 ± 10.2 cm; post: 81.5 ± 10.0 cm; $P = 0.001$). An unexpected increase was observed for low density lipoprotein cholesterol (pre: 109.7 ± 22.7 mg/dL; post: 117.6 ± 20.4 mg/dL; $P < 0.05$).

Conclusions Individuals who were previously somewhat-active or active can gain additional health benefits, particularly improvements in body composition, by increasing to 100,000 steps/week with the use of a pedometer.

Keywords Physical activity · Pedometer · Body composition · Adherence · Dose–response

Introduction

Physical inactivity and obesity are two of the most significant public health problems in developed countries. To reduce these health problems, various organizations recommend that adults aim for a minimum of 30 min/day of moderate-intensity aerobic physical activity 5 days/week, vigorous-intensity physical activity for a minimum of 20 min/day on 3 days/week, or some combination of the two [10, 15, 21]. While benefits are observed when meeting these minimum recommendations, there are additional benefits when greater amounts of physical activity are performed due to the positive dose–response relationship between physical activity and health [16]. For example, exceeding the minimum physical activity recommendations is associated with decreased risk for coronary heart disease [18], as well as improved fitness and blood lipid levels [9]. Furthermore, greater amounts of physical activity are recommended for weight loss when no dietary intervention is implemented [7].

The use and availability of activity monitors have significantly increased in recent years and these devices represent an effective tool for maintaining or increasing physical activity levels [2, 4, 6, 8, 17]. Pedometers are an inexpensive type of activity monitor and when they are provided to physically inactive individuals, greater amounts of steps are accumulated compared to those without a pedometer [2, 17]. Previous research is mixed regarding the impact of pedometers on markers of health, but the increases in steps can be

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associated with improvements in various markers of health such as improved body weight or body mass index [2, 6, 8, 11, 17]. Contributing to the success of pedometer interventions is the creation of daily step goals [17]. A common goal of interventions is 10,000 steps/day, as achieving this number of steps is similar to meeting physical activity recommendations [20]. However, the dose–response relationship between physical activity and health suggests a greater step goal could provide additional health benefits.

To classify individuals based on pedometer data, Tudor-Locke and Bassett [20] developed steps per day activity quintiles ranging from "sedentary" (< 5000 steps/day) to "highly active" (> 12,500 steps/day). Although individuals within a "somewhat active" (7500–9999 steps/day) to "active" (10,000–12,500 steps/day) population may already be relatively healthy, based on the evidence supporting a dose–response relationship between physical activity and health, increasing step counts to the highly active category in this population, could still provide an adequate stimulus to produce weight loss and favorably alter cardiovascular risk factors. Previous research has focused on inactive individuals. But pedometer interventions for active individuals also need to be examined. Therefore, the primary purpose of this study was to determine the effects of an intervention promoting a "highly active" weekly step count on body composition and other cardiovascular disease risk factors in a somewhat-active to active population. With the aim of having all subjects increase their daily step count by an average of at least 2000 steps/day, subjects were provided with an easy to understand goal of completing 100,000 steps/week (14,286 steps/day). This step goal also allowed for subjects to accumulate the activity over the course of 7 days, instead of needing to meet a goal each of the 7 days. A secondary purpose of the study was to assess adherence to this weekly step goal to better understand the feasibility of the step goal in a free-living environment.

Methods

Thirty-five subjects, 15 males (41 ± 14 years) and 20 females (38 ± 12 years), volunteered to participate in this study. Subjects were included if they were between the ages of 18–60 years old, were free from any health condition that might limit their ability to ambulate, and were classified as either somewhat active (7500–9999 steps/day) or active (10,000–12,500 steps/day) at baseline [20]. All subjects underwent a prescreening, which included a detailed health history questionnaire to identify any exclusion criteria. Subjects taking medications were not excluded but those who fell into the moderate risk category as defined by the American College of Sports Medicine [10], required a physician's clearance to participate in this study. All subjects were informed of the risks associated with participating in the study and provided written informed consent before participating. All methods and procedures were approved by the Institutional Review Board at Ball State University.

Baseline Physical Activity Assessment

Baseline physical activity was assessed with a sealed NL series pedometer (New-Lifestyles, Inc., Lee's Summit, MO, USA). The pedometer was placed on the belt or waistband, in the midline of the thigh, consistent with the manufacturer's recommendation. Prior to wearing the pedometer, the accuracy of the pedometer was checked by a member of the research team to ensure that it measured 20 steps accurately (± 2 steps). Subjects were instructed to wear the pedometer, which was sealed to prevent any feedback, for 7 consecutive days during all waking hours, except while showering or swimming. Additionally, a pedometer log sheet was completed by subjects to record if they forgot to wear the pedometer or had any unusual events that prevented them from being physically active. Subjects were encouraged not to change their normal activities during the one-week period to determine their true baseline level of physical activity.

Baseline Risk Factor Measurements

Following the 7-day baseline physical activity assessment, subjects reported to the Human Performance Laboratory for a second visit and were assessed for cardiovascular risk factors and body composition. Subjects reported to the lab in a fasted state while having refrained from exercise for the previous 12 h. Resting blood pressure was taken in accordance to procedural recommendations from the National High Blood Pressure Education Program [5]. Venous blood samples were then drawn by a trained phlebotomist, with samples sent for analysis to Pathologist Associated Labs, Inc., Muncie IN, which follows laboratory standards of the National Cholesterol Education Program [14]. Measures of total cholesterol, high density lipoprotein (HDL), calculated low density lipoprotein (LDL), triglycerides, and glucose were determined from enzymatic analysis using a cobas® 8000 modular analyzer (Roche Diagnostics, Belgium).

Next, each subject had their height and weight measured [without shoes and minimal clothing (light sweats or shorts and T-shirt)] using a wall-mounted stadiometer and calibrated physician scale, respectively. Subjects were instructed to void their bladder prior to these assessments. Waist circumference was measured at the narrowest part of the torso above the umbilicus and below the xiphoid process. Total percent body fat, android percent fat, gynoid percent fat, and bone mineral density (BMD) were assessed via total body dual energy X-ray absorptiometry (DXA) (GE Lunar DXA system, Chicago, IL, USA).

To estimate fitness, a surrogate measure of cardiorespiratory fitness was performed. Each subject completed a standardized sub-maximal exercise bout of 3 min on a treadmill at 3 mile/h (4.8 km/h) with a 3% grade ("3–3–3 TM Test"), with a 1-min warm-up at 2.5 mile/h (4.0 km/h) and 0% grade. Heart rate was recorded with a telemetry monitor, rating of perceived exertion (RPE) using the Borg Scale (6–20), and blood pressure via the auscultatory technique were obtained at the end of 3 minutes.

Physical Activity Intervention

The intervention period lasted 16 weeks. Over the first 4 weeks, subjects were instructed to gradually increase their physical activity level to 100,000 steps/week (14,286 steps/day). The rate of increase was dictated by each subject's baseline step count. For each subject, the difference in the step count goal and their baseline value was first calculated, then divided by 4. Subjects then increased their step count by this calculated amount each week, for 4 weeks (e.g. a subject with a baseline of 80,000 steps/week would increase their step count by 5000 each week). Subjects were then encouraged to maintain 100,000 steps/week for the last 12 weeks of the intervention and also to open the pedometer throughout the day for immediate feedback with regards to reaching their targeted number of steps. Adherence (average weeks 4–16) was assessed for this study to determine whether individuals were able to obtain the 100,000 steps/week goal throughout the 16-week intervention. Similar to the criterion used by Morss et al. [13], acceptable adherence was defined as completing at least 90% of the total amount of activity prescribed that would equate to averaging > 90,000 steps/week (12,857 steps/day) from week 4 to the end of the study.

Each subject was asked to record their steps per day and the time they put the pedometer on/off and report this either by e-mail or in person at the end of each week. Subjects were given feedback via e-mail on a weekly basis on whether or not they were meeting the step goal of 100,000 steps/week. The feedback consisted of simple messages to congratulate them on meeting the target or providing encouragement to them if they did not reach the target. Following the 16-week intervention period, subjects returned to the laboratory and repeated all the baseline measurements.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 25, IBM Corporation, Armonk, New York, USA). To explore the potential influence of pre-intervention step counts on changes in the health measures, subjects were placed into groups based on pre-intervention step counts: somewhat active (7500–9999 steps/day) or active (10,000–12,500 steps/day) [20]. The pre- to post-intervention differences between the somewhat active and active groups were analyzed using a two-way repeated measures analysis of variance (ANOVA). Gender differences were not analyzed due to the imbalance between males and females in the somewhat active and active groups. Statistical significance was designated at the $P < 0.05$ level. Interactions are reported at $P < 0.1$. Data are presented throughout the paper as mean ± SD.

Results

Thirty-five individuals met the initial inclusion criteria based on baseline step counts within the somewhat active or active categories. Of the 35 participants (15 male, 20 female) who met all study criteria and initiated the intervention, 32 (13 males, 19 females) completed the study. Two males and 1 female voluntarily withdrew from the study because they no longer wanted to participate. Thus, results are reported on the remaining 32 subjects who completed the study, of which 20 were considered somewhat active at baseline (11 male, 9 female) and 12 who were considered active at baseline (2 male, 10 female). Data from one somewhat active male was excluded from the lipid profile analysis due to poorly controlled Type 1 diabetes.

Over the final 12 weeks of the intervention, all participants increased stepping compared to baseline ($P < 0.001$). The somewhat active group accumulated an average of 90,186 ± 11,033 steps/week and the active group averaged 96,900 ± 9253 steps/week. There was a statistically significant group × intervention interaction ($P = 0.003$) as the increase in steps per week was greater for the somewhat active group (27,768) compared to the active group (15,862) (Fig. 1). Among the 32 subjects who completed the study, 53% (9 of the 20 somewhat active and 8 of the 12 active) adhered (> 90,000 steps/week) to the intervention. Although not all subjects were able to meet the adherence criteria, 25 out of 32 subjects (19 somewhat active and 6 active) increased an average of 20% steps from their baseline step count.

Overall, improvements were observed in body weight (pre: 76.9 ± 12.5 kg; post: 76.0 ± 12.8 kg; $P = 0.012$), body mass index (pre: 27.2 ± 3.6 kg/m^2; post: 26.9 ± 3.6 kg/m^2; $P = 0.026$), waist circumference (pre: 83.8 ± 10.2 cm; post: 81.5 ± 10.0 cm; $P = 0.001$), total body fat (pre: 35.7 ± 9.9 %; post: 34.3 ± 10.4%; $P < 0.001$), and android fat (pre: 43.6 ± 10.9%; post: 41.6 ± 11.8%; $P < 0.001$). Pre- and post-intervention values for each group are provided in Table 1. There was a significant interaction for body weight ($P = 0.029$) and percent gynoid fat ($P = 0.014$) (Fig. 2); the subjects within the somewhat-active group had greater reductions in body weight and

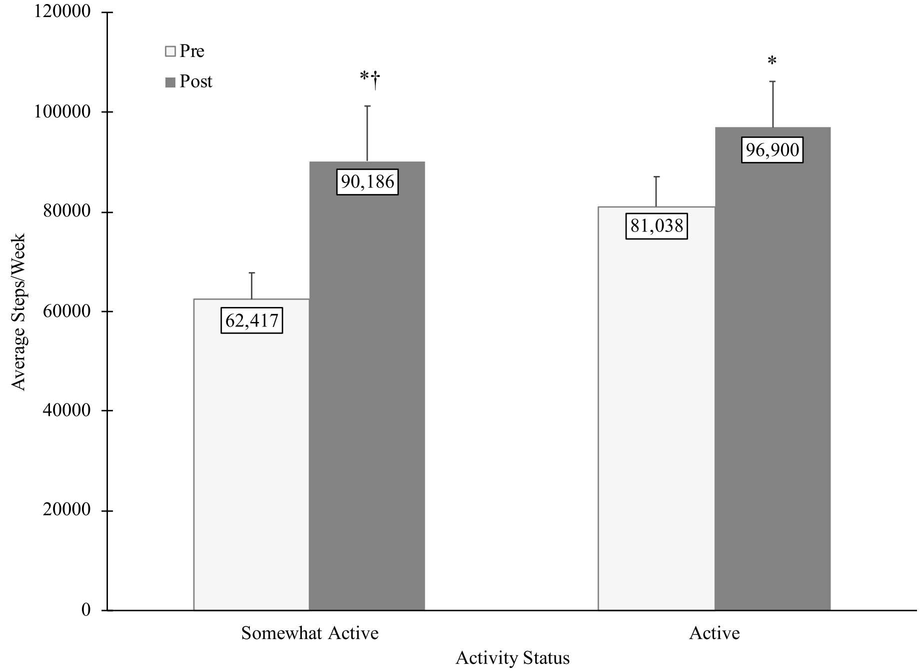


Fig. 1 Comparison of average steps per week between the active and somewhat active groups before and after a 16-week pedometer-based intervention. *Significantly different from pre-intervention value. †Significant interaction effect; a greater increase in steps compared to the active group

Table 1 Cardiovascular disease risk factors at the beginning and the end of the 100,000 steps/week intervention [somewhat active: $n=20$ (for lipid analysis $n=19$); active: $n=12$]

	Somewhat active		Active	
	Pre (mean ± SD)	Post (mean ± SD)	Pre (mean ± SD)	Post (mean ± SD)
Weekly step count	62,417 ± 5336	90,186 ± 11,033*†	81,038 ± 6004	96,900 ± 9253*
Body weight (kg)	79.8 ± 12.4	78.7 ± 12.7*†	72.1 ± 11.7	71.5 ± 12.3*
Height (m)	1.63 ± 0.08		1.71 ± 0.08‡	
Body mass index (kg/m^2)	27.4 ± 3.8	27.0 ± 3.9*	26.9 ± 3.2	26.7 ± 3.2*
Waist circumference (cm)	85.4 ± 10.8	82.7 ± 10.2*	81.2 ± 8.8	79.6 ± 9.7*
Total body fat (%)	34.2 ± 10.3	32.4 ± 11.0*	38.3 ± 9.0	37.5 ± 8.9*
Gynoid fat (%)[a]	40.9 ± 11.7	38.5 ± 11.8*†	46.3 ± 8.4	45.7 ± 8.2
Android fat (%)[b]	43.0 ± 11.5	40.5 ± 12.5*	44.6 ± 10.2	43.6 ± 10.8*
Bone mass density (g/cm^3)	1.224 ± 0.093	1.226 ± 0.094	1.216 ± 0.132	1.229 ± 0.122
Resting systolic blood pressure (mmHg)	107.1 ± 10.5	108.0 ± 11.9	102.5 ± 11.4	105.5 ± 13.7
Resting diastolic blood pressure (mmHg)	72.7 ± 6.8	72.1 ± 8.0	67.2 ± 8.0	69.2 ± 6.5
Total cholesterol (mg/dL)	195.4 ± 25.0	197.2 ± 26.2	179.1 ± 27.3	189.1 ± 22.5
HDL (mg/dL)	54.0 ± 11.9	53.7 ± 11.2	62.5 ± 21.5	59.0 ± 15.9
LDL (mg/dL)	118.3 ± 22.5	121.3 ± 22.5	96.1 ± 15.5 ‡	111.9 ± 15.7*†
Triglycerides (mg/dL)	115.8 ± 56.4	110.5 ± 57.8	103.5 ± 43.2	90.7 ± 28.2
Fasting blood glucose (mg/dL)	89.3 ± 9.8	90.6 ± 8.0	90.6 ± 7.4	89.5 ± 5.4

[a]Gynoid fat is defined as the fat distributed around the hips, buttocks, and thighs

[b]Android fat is defined as the fat distributed around the chest and abdomen

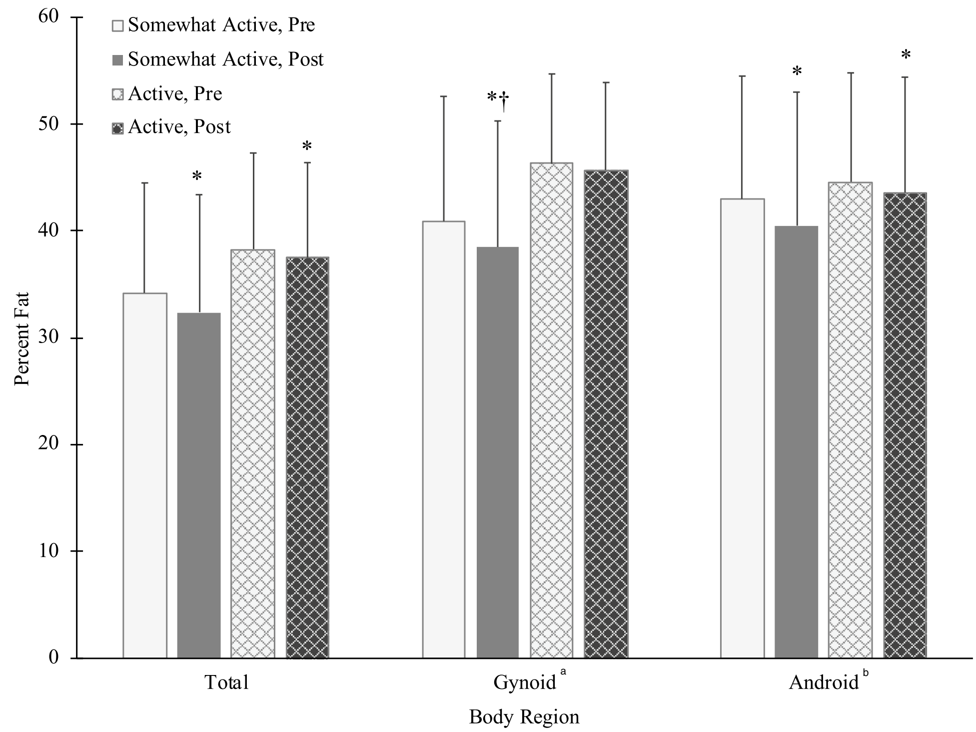
*Significantly different than pre-intervention value

†Significant interaction effect

‡Significantly different than the pre-intervention value of the somewhat active group

gynoid fat compared to the active group. There was a trend for the somewhat-active group to have greater decreases in total percent body fat ($P=0.051$) and percent android fat ($P=0.064$) (Fig. 2). Interestingly, when body composition changes were compared between those who adhered to the

Fig. 2 Comparison of body composition between the active and somewhat active groups before and after a 16-week pedometer-based intervention. [a]Gynoid fat is defined as the fat distributed around the hips, buttocks, and thighs. [b]Android fat is defined as the fat distributed around the chest and abdomen. *Significantly different from pre-intervention value. †Significant interaction effect; a greater decrease compared to the active group



targeted step count and those who failed to meet the target, there were no significant differences ($P = 0.341$).

No significant differences occurred following the intervention in blood pressure, HDL, or fasting blood glucose (Table 1). A trend for improvement in triglycerides was observed with an intervention effect that approached significance ($P = 0.062$). An unexpected significant intervention effect was observed with LDL increasing ($P < 0.001$) and there was a trend for increases in total cholesterol ($P = 0.052$). For LDL, there was a significant interaction illustrating the intervention effect was driven by an increase in the active group ($P = 0.034$).

For the 3–3–3 TM fitness test, no significant differences were observed with the exercise heart rate response, exercise systolic blood pressure response, or exercise diastolic blood pressure response (Table 2). A significant interaction for RPE occurred as the somewhat active group demonstrated a reduction from an average RPE rating of 11.0 down to 9.6 following the intervention compared to the active group, which did not change significantly (RPE rating of 9.2 pre and 9.5 post).

Discussion

The present study examined the adherence and the health effects of walking 100,000 steps/week on cardiovascular disease risk factors among those who were already considered somewhat active to active. This step goal is likely to fall somewhere between minimum recommendations

Table 2 Exercise response during the 3–3–3 treadmill fitness test at the beginning and the end of the 100,000 steps/week intervention (somewhat active, $n = 20$; active, $n = 12$)

	Somewhat active		Active	
	Pre (mean ± SD)	Post (mean ± SD)	Pre (mean ± SD)	Post (mean ± SD)
Heart rate (bpm)	107.7 ± 12.6	106.8 ± 15.2	102.5 ± 12.8	101.6 ± 8.6
Systolic blood pressure (mmHg)	117.9 ± 11.1	120.2 ± 14.3	112.5 ± 11.9	116.7 ± 9.8
Diastolic blood pressure (mmHg)	71.3 ± 7.7	72.2 ± 9.1	67.0 ± 8.2	71.0 ± 7.4
Rating of perceived exertion	11.0 ± 2.0	9.6 ± 2.1*†	9.2 ± 1.9‡	9.5 ± 1.1

*Significantly different than pre-intervention value

†Significant interaction effect

‡Significantly different than the pre-intervention value of the somewhat active group

to accumulate 30 min of moderate intensity activity on 5 or more days/week for the promotion and maintenance of health [10, 15, 21] and that of the Institute of Medicine (IOM), which recommends that healthy adults participate in 60 min of daily moderate-intensity physical activity to prevent weight gain and accrue additional, weight-independent health benefits from physical activity [3]. Adherence to the intervention was only 53%, yet the goal of 100,000 steps/week was still effective for increasing step counts. The extent of the increase in steps differed between groups with the somewhat active group increasing their weekly steps by ~ 28,000 compared to an increase of ~ 16,000 steps for the active group. Similar to the results of some pedometer interventions with inactive subjects, the present pedometer intervention was effective for improving body composition measures within an active population in only 16 weeks.

The present study was unique in that an ambitious step count goal was implemented (100,000 steps/week). Of the 32 subjects who completed the 16-week intervention, 17 adhered to the weekly step goal (accumulated > 90,000 steps/week), representing an adherence rate of 53%. This adherence rate is similar to that of Schneider et al. [19] who reported a 50% adherence rate to a 10,000 steps/day (70,000 steps/week) recommendation targeting previously inactive, overweight adults. The adherence rate in the present study, however, is higher when taking into account the number of subjects who started the intervention but voluntarily withdrew. In the present study, the adherence rate of those who started the study was 54% (19 of 35 starters) while Schneider et al. report an adherence of 34%. The greater adherence rate in the present study may suggest that individuals who are already somewhat active to active are more inclined to complete and adhere to an activity recommendation than a previously sedentary population. Overall though, the adherence rate in the present study is similar to that of a recent review that reported an average of 59% and a range of 40–86% adherence in intervention studies [12]. Furthermore, it is noteworthy that although the adherence was only 53%, all subjects increased their step count compared to baseline levels.

A step count of 10,000 steps/day is analogous to meeting the minimum physical activity recommendations [20]. While some reviews suggest activity monitors do not impact markers of health [6, 8, 11], others have highlighted that increasing step counts to 10,000 steps/day is associated with improvements in body weight or body mass index among physically inactive subjects [2, 17]. An average body weight loss of 1.27 kg over 16 weeks is reported in a recent review of pedometer interventions [17] and is similar to the decrease observed in the present study (1 kg over 16 weeks). Although changes to body weight were relatively small, a longer duration intervention could produce more clinically meaningful weight loss and could lead to BMI levels within the healthy weight classification. Furthermore, our findings support the health-related value of increasing physical activity as measures of total, gynoid, and android fat were all improved, as was waist circumference. Additionally, the findings from the current study support that adults who are already somewhat active or active may also obtain favorable body composition changes with increases in daily steps.

To date, most of the literatures on body composition changes with pedometer interventions have dealt with increasing physical activity levels in inactive or irregularly active populations to meet minimum recommended levels [2, 17, 19]. However, a dose response relationship exists with physical activity and exceeding the minimum physical activity recommendations is associated with improved fitness [9, 16]. Although not all variables improved, some measures in the present study are consistent with the dose–response relationship between physical activity and measures of health. The somewhat active subjects experienced greater improvements in gynoid body fat, with a trend ($P \leq 0.089$) for greater improvements in total percent fat and android body fat. This is likely due to the greater change in physical activity level as the somewhat active group increased their weekly steps totals by ~ 28,000 compared to an increase of ~ 16,000 steps for the active group. For already active individuals, a higher step count goal or better adherence may be needed to have additional improvements in body composition.

In the present study, fitness was estimated using the 3–3–3 TM Test. A decrease in RPE was observed in the somewhat active group following the pedometer intervention, while no significant change was observed in the active group. This is likely due to the greater increase in step count by the somewhat active group during the intervention compared to the active group. Future research involving a direct measure of fitness is needed to better determine the effectiveness of the intervention on aerobic fitness.

Given the population examined in the present study ("somewhat active" and "active"), it was not surprising that significant improvements in other risk factors were not observed. No subject in the present study had a resting blood pressure ≥ 140/90 mmHg and all subjects fell within the normal ranges for blood lipid values, reducing the likelihood of significant improvements in these measurements. Unexpectedly, LDL significantly increased, although post-intervention values still fell within normal healthy limits. The degree of change in stepping did not explain the differences between subjects who had increased or decreased LDL. Subjects were encouraged not to alter their dietary habits during the study period, however, dietary intake was not assessed in the current study and may be a factor in the observed lipid changes. Additionally, subjects who were taking medications for lipids were included in the study and these medications were not controlled for in the analysis, which may have also influenced the changes. It is also possible with the smaller sample size that these LDL findings represent a Type I error. Of particular note, in subjects with impaired fasting blood glucose measured at baseline, there was a trend for positive change in fasting blood glucose observed following the intervention. Fasting blood glucose decreased (average decrease of 13 mg/dL) to healthy levels in 4 of the 5 subjects with impaired fasting glucose, reflecting a greater likelihood of these individuals preventing or delaying the onset of developing Type 2 diabetes [1].

The use of a pedometer along with a simple step goal to increase daily physical activity levels was a key strength of the study. There were some limitations associated with the study. The study had a relatively small sample size. Also, the intensity level of which physical activity is performed can influence changes to risk factors [10] but intensity was not measured in the present study. While participants increased their weekly step count, it is unknown if they also altered speed/intensity (i.e. walking vs. running). Additionally, understanding the adherence to the step goal was a research question in the present study so tighter regulation of adherence was not enforced. As a result, adherence to the intervention was not universal and may have influenced the level of improvements observed. Increased adherence could result in further improvements in body composition measures and/or other cardiovascular disease risk factors and should be examined in future research.

In conclusion, a pedometer intervention for individuals who are already somewhat active or active can effectively increase physical activity. A goal of 100,000 steps/week is associated with improved body weight and body composition. In agreement with the known physical activity dose–response, larger improvements in body composition were observed in the group which had greater increases in weekly step count. The intervention did not improve other common cardiovascular disease risk factors, which were already within the healthy range. Interventions which further increase physical activity in already activity individuals may provide additional health benefits.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest and thank the participants for volunteering their time.

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