Sedentary Time and Physical Activity in Older Women Undergoing Exercise Training

XUEWEN WANG, CHARITY B. BRENEMAN, JOSHUA R. SPARKS, and STEVEN N. BLAIR

Department of Exercise Science, University of South Carolina, Columbia, SC

ABSTRACT

WANG, X., C. B. BRENEMAN, J. R. SPARKS, and S. N. BLAIR. Sedentary Time and Physical Activity in Older Women Undergoing Exercise Training. *Med. Sci. Sports Exerc.*, Vol. 52, No. 12, pp. 2590–2598, 2020. Older adults have low rates meeting the physical activity (PA) guidelines and high sedentary time. Low PA and excessive sedentary time have been linked to adverse health outcomes. Less is known about whether exercise training influences sedentary time and PA in various intensities. **Purpose:** This study aimed to examine the effects of a 16-wk aerobic exercise training on time spent being sedentary and on light-intensity PA (LPA) and moderate- to vigorous-intensity PA (MVPA) and step numbers in older women. **Methods:** Inactive women (n = 61; age = 65.5 ± 4.3 yr) participated in moderate-intensity walking of either a low or a moderate dose (33.6 and 58.8 kJ·kg^{-1} body weight per week, respectively). They wore a SenseWear Mini Armband at baseline and at end intervention to determine sedentary, LPA, and MVPA time and step numbers. **Results:** Time being sedentary, or spent on LPA and MVPA, did not change differently by exercise groups with different doses (all P values for group–time interaction >0.580). Overall, time being sedentary reduced from baseline to end intervention by approximately 39 min·d^{-1} (P < 0.001), and LPA increased by 19 min·d^{-1} (P = 0.003). MVPA time increased (P < 0.001), which was primarily accounted for by the supervised exercise. Interestingly, daily steps increased more in the moderate-dose than the low-dose group (P = 0.023 for group–time interaction; 33.6% and 19.8% median increase in moderate- and low-dose groups, respectively). Also, there were individual differences in these changes. **Conclusion:** Results indicated that, on average, older women did not reduce time of LPA or MVPA outside the exercise program or increase sedentary time as a result of participating in the exercise program. **Key Words:** LOW-INTENSITY PHYSICAL ACTIVITY, SEDENTARY TIME, STEP COUNTS, CARDIORESPIRATORY FITNESS, BODY WEIGHT, INDIVIDUAL DIFFERENCES, OLDER ADULTS

The beneficial health effects of moderate- to vigorous-intensity physical activity (MVPA) are well recognized. The U.S. Department of Health and Human Services recommends accumulating at least 150 min of MVPA or 75 min of vigorous-intensity PA per week for adults, including older adults, for obtaining substantial health benefits of exercise (1). Although the literature identifies regular PA as an important predictor of successful aging, older adults continue to exhibit the lowest rate for meeting the PA guidelines in comparison with all other adult age-groups (2,3). Studies have prescribed MVPA in a supervised setting to individuals to increase their MVPA levels; however, there is evidence suggesting that exercise participation may lead to compensatory adjustments in nonexercise PA and sedentary time, which may lessen the intended healthful effects of exercise (4–6). Further, these compensatory adjustments are suggested to be more in older women (7).

Despite the vulnerability of older adults, there are a limited number of studies in this age-group that have objectively examined the impact of an exercise intervention on total PA or nonexercise PA. An earlier study in a small group of older men and women found increased total daily PA counts measured by accelerometry after 6 and 12 wk of combined aerobic and resistance training (8). In the Dose Response to Exercise in Women study, step counts in postmenopausal women outside the exercise intervention were not different from baseline levels irrespective of exercise group assignment (4, 8, or 12 kcal·kg^{-1} body weight per week) (9). These studies did not differentiate MVPA or light-intensity PA (LPA) except during the supervised exercise sessions. However, this information is important because MVPA and LPA may offer different degrees of health benefits. The beneficial effects of LPA for mortality were found to be less than MVPA of equal volume (10), although LPA is also beneficially associated with obesity, lipid and glucose metabolism, and mortality (11).

Examining time spent on MVPA and LPA during an exercise intervention is inherently linked to the investigation of sedentary time, which has significant ramifications given the accumulating evidence of an association between sedentary behavior and all-cause mortality, cardiovascular disease, type 2 diabetes, and metabolic syndrome (12–14). Of note, reducing sedentary behavior has been added to the latest PA

Address for correspondence: Xuewen Wang, Ph.D., Department of Exercise Science, University of South Carolina, 921 Assembly St., PHRC 301, Columbia, SC 29208; E-mail: xwang@sc.edu.
Submitted for publication November 2019.
Accepted for publication May 2020.

0195-9131/20/5212-2590/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000002407

guidelines (1). However, older adults not only have the lowest rate for meeting the PA guidelines but also spend an average of 9.4 h (range, 8.5–10.7 h) per day being sedentary (15). Few studies have examined sedentary time in older adults who start participating in an intervention with prescribed MVPA. An analysis of the Lifestyle Interventions and Independence for Elders (LIFE) study showed that participants in the group participating in MVPA had an average of 9 min shorter sedentary time than those in the health education control group (16). On the contrary, a small study did not observe a change in sedentary behavior in older adults participating in a behavioral intervention with a goal to reach 150 min of MVPA each week (17). Thus, it remains unclear whether sedentary time changes in older adults as a result of participating in an exercise program.

These behavioral changes in nonexercise PA and time spent sedentary are highly individual in that differences have been noted among individuals enrolled in the same exercise intervention (18). The variability in these changes has important implications for identifying factors that may potentially contribute to this response. One possible factor is cardiorespiratory fitness, a physiological measure reflecting a combination of genetic potential, behavioral, and functional health of various organ systems (19,20). Another factor is body weight; one prospective study observed baseline body weight to be associated with a decrease in MVPA during a follow-up approximately 6 yr later (21). Therefore, the purpose of this study was to examine the effects of an aerobic exercise training program on time spent on PA at different intensities and being sedentary, and the number of steps in older women, and whether cardiorespiratory fitness and body weight affected any of these changes.

METHODS

Participants

Data used in this study were from the Women's Energy Expenditure in Walking Programs (WEWALK) study, which was a randomized controlled trial designed to examine energy expenditure responses to 16 wk of moderate-intensity walking in older women (22). The study was registered at ClinicalTrials.gov (NCT01722136). The research protocol was approved by the University of South Carolina Institutional Review Board, and all participants provided written informed consent.

The participant inclusion and exclusion criteria were described previously (22). Briefly, participants were older women (age 60–75 yr), nonobese (body mass index = 18–30 $kg \cdot m^{-2}$), self-reported weight being stable (±3%) in the past 3 months, physically inactive (less than 20 min × 3 times per week of structured exercise) in the past 3 months, and nonsmoking in the past year. They did not have self-reported or signs of serious cardiovascular, metabolic, or respiratory diseases, or any other conditions that might affect adherence to the study protocol, affect exercise safety, or may be aggravated by exercise. In addition, participants did not use medications known to affect exercise performance or metabolism.

Exercise Training

Women were randomized to one of two moderate-intensity walking training protocols at low or moderate doses (target exercise energy expenditure of 33.6 and 58.8 $kJ \cdot kg^{-1}$ body weight weekly, respectively). Both groups were instructed to attend three supervised exercise sessions per week located in the Clinical Exercise Research Center at the University of South Carolina. The target intensity of the exercise was 50%–55% of each woman's heart rate reserve, calculated as [(peak heart rate − resting heart rate) × intensity (50%–55%) + resting heart rate], with resting heart rate and peak heart rate obtained before and during the graded exercise test (see below). Exercise energy expenditure was estimated based on walking duration at each speed and grade, and body weight using a standardized formula by the American College of Sports Medicine (23). Exercise progressively increased for both groups from a low-intensity and low weekly dose until the assigned exercise intensity and dosage were reached. The low- and moderate-dose groups reached the target exercise within 5 and 8 wk, respectively. Each exercise session began with a 3-min warm-up and ended with a 3-min cooldown. Women wore heart rate monitors (FT1; Polar Electro, Lake Success, NY) throughout each exercise session to monitor heart rate.

Tests and Measurements

Height and body weight were measured at baseline before randomization, weekly during exercise intervention, and at the end of intervention. Measurements were obtained while women were in standard scrubs and without shoes or outer garments.

Graded exercise test. A graded exercise test was performed at baseline and upon completion of the exercise training program for determination of cardiorespiratory fitness. The test at baseline was also used to exclude women with cardiopulmonary limitations to exercise. A maximum of 10 min of walking on the treadmill before the test was allowed for participants to familiarize themselves with the instrumentation. After a brief rest, women walked at a self-selected speed with the grade of treadmill increasing by 2% every 2 min throughout the test. Gas analysis was performed by a metabolic measurement system (TrueOne 2400; Parvo Medics, Salt Lake City, UT), and a 12-lead electrocardiogram was monitored by a standard system (Quinton Q-Stress®; Cardiac Science, Bothell, WA) continuously during the entire test. Blood pressure was measured during each 2-min stage. A valid peak volume of oxygen consumption ($\dot{V}O_{2peak}$) was obtained when at least two of the following criteria were met: 1) plateau in $\dot{V}O_2$ (a change <2 $mL \cdot kg^{-1} \cdot min^{-1}$) with increasing work rate, 2) heart rate surpasses >90% of age-predicted maximum heart rate (220 − age), 3) respiratory exchange ratio ≥1.10, and 4) a rate of perceived exertion ≥17 on the Borg exertion scale.

PA. The SenseWear Mini Armband (BodyMedia Inc., Pittsburgh, PA) was used to measure PA and sedentary time at baseline, midintervention, and end intervention. Women

APPLIED SCIENCES

were instructed to wear the monitor all the time for 14 d during each phase except during water activities. Previous research indicated acceptable agreement between energy expenditure assessed by the SenseWear monitor with the doubly labeled water method (24–26) and with indirect calorimetry for sedentary behavior and LPA (27). The monitor is a portable, multisensor device worn on the upper left arm that incorporates triaxial accelerometry with measures of heat flux, galvanic skin response, skin temperature, and near-body ambient temperature. Data were analyzed using the software provided by the manufacturer (SenseWear Professional 8.0, BodyMedia, Inc.). Specifically, the algorithm combines data collected from the monitor's sensors with individual information (age, sex, height, weight, smoking, and handedness) to give estimates of energy expenditure for each minute of wear time, which are then converted to metabolic equivalents (METs). The SenseWear software classifies activity as either "awake" or "asleep." Therefore, the time spent being sedentary was calculated by subtracting time designated as "asleep" from time with METs ranging from 1.0 to ≤1.5. The software does not provide information about body posture. For example, standing still and sitting are both classified as being sedentary. Time spent on PA was classified by intensity according to the estimated MET level when the participant was awake, based on the following criteria: light, 1.5 to ≤3.0 METs; moderate, 3.0 to ≤6.0 METs; and vigorous, >6.0 METs. Because of participants engaging in very low amounts of time on vigorous activities, moderate and vigorous intensities were combined as MVPA. In addition, the MVPA time outside the exercise program was calculated by subtracting the daily average time spent in the supervised exercise sessions during the period the SenseWear monitor was worn, for each individual at mid- and end intervention. The SenseWear monitor also provides an estimate of total number of steps. Data from women with at least 5 d including at least one weekend day of ≥90% of 24 h (21.6 h) of wear time on each of the days were considered valid.

Statistical Analysis

Descriptive statistics, including mean and SD and proportions, were calculated. Differences between randomized exercise groups at baseline were determined using *t*-tests or chi-square tests, as appropriate. A repeated-measure analysis, including a group–time interaction, was performed using a mixed-effects model with a random intercept, which allowed for various baseline values among individuals. When the group–time interaction was not statistically significant, further analyses were conducted with the two groups combined. As appropriate, follow-up analyses were conducted to determine at which time points (baseline, midintervention, or end intervention) the outcome of interest were different. Separate models were run for each variable of interest, including body weight, $\dot{V}O_{2peak}$, sedentary time, and PA measures.

Additional analyses were performed to adjust for body weight and $\dot{V}O_{2peak}$ in the models testing sedentary time and PA measures. These were conducted in two ways. One was to adjust for body weight and $\dot{V}O_{2peak}$ as time-varying variables, and the other was to adjust for weight and $\dot{V}O_{2peak}$ at baseline and their respective changes from baseline to end intervention. In separate models, we examined whether baseline body weight and $\dot{V}O_{2peak}$ moderated the changes in sedentary time and PA by including those variables along with their individual interactions with time (baseline weight by time and $\dot{V}O_{2peak}$ by time). Exploratory analyses were conducted to follow up significant interactions. Analyses were conducted using the SAS software (SAS Institute, Cary, NC). Statistical significance was defined as a P value <0.05. Bonferroni adjustments were used to account for multiple comparisons as appropriate.

A total of 69 women completed the study and had valid SenseWear data at baseline. Among these women, valid SenseWear data were not available for four women at midintervention and four different women at end intervention. Therefore, the primary data analysis was performed and reported on the 61 women who had complete SenseWear data at all three time points. Additional analyses were performed, including the eight women with SenseWear data at two of the three time points. Results were similar to those without these women; therefore, these results were not reported.

RESULTS

Participant Characteristics

Participant characteristics are included in Table 1 by assignment group. These women were older (age = 65.5 ± 4.3 yr, mean ± SD in this manuscript), nonobese (body mass index = 25.6 ± 3.6 $kg \cdot m^{-2}$), and mainly White (85.2%). There were no differences between the two groups in age, race and ethnicity distribution, height, weight, or $\dot{V}O_{2peak}$.

Women attended 47.0 ± 6.9 sessions, and those in the low-dose and moderate-dose groups walked 109 ± 11 min and 160 ± 19 $min \cdot wk^{-1}$ in our research center, respectively. The adherence to prescribed exercise dose (expressed as actual/prescribed ratio) was 104.6% ± 8.6% and 99.1% ± 7.9% for the two groups, respectively. Valid SenseWear data were available from 12.1 ± 2.0 d, 11.9 ± 2.3 d, and 11.6 ± 2.3 d at baseline, midintervention, and end intervention, respectively. The wear time for valid days ranged between 21.65 and 24 h with an average of 23.60 $h \cdot d^{-1}$.

Changes in body weight and cardiorespiratory fitness with exercise training. The two exercise groups had similar changes in body weight with exercise training (P for group–time interaction = 0.879). In the entire sample, body weight significantly reduced over time (P = 0.007) with weight at baseline being higher than at end intervention (P = 0.002), but both were not different from midintervention (P = 0.025 and 0.392 for comparison with baseline and end-intervention weight, respectively; P < 0.017 signifies statistical significance with Bonferroni adjustments). The average change in body weight over the entire period (values at end intervention minus at baseline) was −0.7 ± 2.1 kg. The lowest value, the lower quartile, the median, the higher

APPLIED SCIENCES

TABLE 1. Participant characteristics by assignment group.

	Low Dose (n = 32)						Moderate Dose (n = 29)					
	Mean ± SD	Min	Q1	Median	Q3	Max	Mean ± SD	Min	Q1	Median	Q3	Max
Age, yr	65.7 ± 4.7	60.1	61.6	64.5	68.2	75.0	65.2 ± 4.0	59.4	62.0	64.6	66.9	74.1
Non-White, n (%)	4 (12.5%)	–	–	–	–	–	5 (17.2%)	–	–	–	–	–
Height, cm	162.2 ± 6.4	149.1	158.8	162.4	166.4	172.9	163.0 ± 5.5	153.2	160.5	162.2	166.2	173.7
Weight, kg												
Baseline	67.3 ± 10.3	43.6	60.5	66.9	74.6	85.4	67.3 ± 9.0	47.0	61.4	66.1	75.1	84.6
Midintervention	66.7 ± 10.2	43.5	59.7	66.9	73.2	85.3	67.0 ± 8.7	48.3	61.9	66.3	75.6	79.4
End intervention	66.6 ± 10.3	42.7	60.0	66.3	73.3	85.4	66.7 ± 9.0	47.7	61.6	65.7	75.1	79.3
$\dot{V}O_{2peak}$, $mL \cdot kg^{-1} \cdot min^{-1}$												
Baseline	20.0 ± 3.7	13.7	17.5	19.8	22.2	28.2	20.1 ± 3.8	13.5	17.3	19.5	22.3	28.8
End intervention	20.7 ± 4.4	12.9	17.6	21.1	23.0	28.7	22.3 ± 5.0	14.0	20.0	21.6	24.0	35.2

Min, minimum; Q1, lower quartile; Q3, higher quartile; max, maximum.

quartile, and the highest value of weight change were −6.4, −1.7, −0.6, 0.7 and 4.9 kg, respectively. $\dot{V}O_{2peak}$ did not change differently from baseline to end intervention between the two groups (P = 0.054 for group–time interaction), and it increased significantly in the combined sample (P < 0.001) by 1.44 ± 3.0 $mL \cdot kg^{-1} \cdot min^{-1}$. The lowest value, the lower quartile, the median, the higher quartile, and the highest value for $\dot{V}O_{2peak}$ changes were −5.8, −0.2, 0.9, 3.2, and 8.8 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively. Both weight and $\dot{V}O_{2peak}$ change values were normally distributed around their mean, and the most extreme value was <2.7 SD and <2.5 SD away from the mean weight and $\dot{V}O_{2peak}$ changes, respectively.

Changes in sedentary time and PA with exercise training. The time spent being sedentary, on LPA, and on MVPA and the number of daily steps are included in Table 2 by group. At baseline, the two groups were similar in each of the time variables and number of daily steps (all P values >0.430). The two groups did not differ in the changes in the time being sedentary, or time spent on LPA, MVPA, or total PA across the exercise training (all P values for group–time interaction >0.580). Therefore, the two groups were combined to examine the main effect of exercise training on these time variables.

Time being sedentary significantly reduced (P = 0.001), and LPA, MVPA, and total PA time significantly increased (P = 0.007, <0.001, and <0.001, respectively); however, time of MVPA outside the exercise program did not change over time (P = 0.126). Time being sedentary was not different between baseline and midintervention (P = 0.129), but it was significantly longer at baseline and midintervention than at end intervention by approximately 23 (P = 0.029) and 39 $min \cdot d^{-1}$ (P < 0.001) (from mixed-effects model), respectively. Similarly, LPA time was not different between baseline and midintervention (P = 0.623), but it was shorter at baseline and midintervention in comparison with end intervention by approximately 16 (P = 0.013) and 19 $min \cdot d^{-1}$ (P = 0.003), respectively. MVPA showed a different pattern of change than sedentary time and LPA. MVPA at baseline was shorter than at mid- and end intervention by approximately 25 and 20 $min \cdot d^{-1}$, respectively (P < 0.001 for both). There was no difference between mid- and end intervention (P = 0.112). Similarly, total PA time increased by approximately 28 $min \cdot d^{-1}$ from baseline to midintervention (P = 0.001), and 39 $min \cdot d^{-1}$ from baseline to end intervention (P < 0.001), but no difference from mid- to end intervention (P = 0.199).

Interestingly, the number of daily steps changed differently between the two groups (P for group–time interaction = 0.023). Follow-up analyses showed that the only difference between the two groups was between baseline and end intervention (P for group–time interaction = 0.006). Both groups increased daily steps (P = 0.001 and <0.001, respectively, for the low- and moderate-dose groups), but the degrees of changes were different (increased by 1053 steps and 2227 steps, or a median increase of 19.8% and 33.6%, respectively, in low- and moderate-dose groups). Daily steps increased from baseline to midintervention similarly in the two groups (P < 0.001 in both low- and moderate-dose groups; P for group–time interaction = 0.200) and did not change in either group from mid- to end intervention (P = 0.121 and 0.847 in low- and moderate-dose groups, respectively; P for group–time interaction = 0.125).

Influence of body weight and cardiorespiratory fitness. $\dot{V}O_{2peak}$ was measured at baseline and end intervention; thus, models adjusting for $\dot{V}O_{2peak}$ and body weight did not include midintervention. When body weight and $\dot{V}O_{2peak}$ at baseline and their respective changes over time were adjusted for in the models, sedentary time remained decreased, and MVPA time, total PA time, and daily steps remained increased, although these changes seem to be of

TABLE 2. Average daily sedentary time and PA at baseline, midintervention, and end intervention, by assignment group.

Variable	Baseline	Midintervention	End Intervention
Sedentary time, $min \cdot d^{-1}$			
Low dose	708 ± 122	683 ± 122	667 ± 116
Moderate dose	686 ± 108	680 ± 99	648 ± 95
Light PA, $min \cdot d^{-1}$			
Low dose	272 ± 115	278 ± 101	289 ± 100
Moderate dose	263 ± 81	264 ± 73	285 ± 82
Total MVPA, $min \cdot d^{-1}$			
Low dose	41 ± 30	64 ± 33	58 ± 36
Moderate dose	47 ± 32	74 ± 35	69 ± 33
MVPA outside the prescribed exercise, $min \cdot d^{-1}$			
Low dose	41 ± 30	48 ± 33	46 ± 34
Moderate dose	47 ± 32	53 ± 35	51 ± 33
Total PA, $min \cdot d^{-1}$			
Low dose	313 ± 140	342 ± 121	347 ± 121
Moderate dose	310 ± 104	338 ± 94	354 ± 114
Steps, numbers per day			
Low dose	6618 ± 2537	8165 ± 2865	7671 ± 2592
Moderate dose	6536 ± 2735	8710 ± 2771	8763 ± 2772

Data are presented as mean ± SD.

smaller degrees compared with without adjustment. LPA and MVPA outside exercise program no longer changed from baseline to end intervention (Table 3). When body weight and $\dot{V}O_{2peak}$ were adjusted for as time-varying variables in the models, similar results were found (data not shown).

As shown in Table 3, baseline weight was positively associated with sedentary time, negatively associated with LPA time, but was not associated with MVPA or total PA time, or steps. For example, for each kilogram of greater baseline weight, LPA was 3.1 min less, holding all other variables in the model constant. Changes in weight were negatively associated with MVPA outside exercise program and total PA time. Baseline $\dot{V}O_{2peak}$ was negatively associated with sedentary time and positively associated with time spent in LPA, MVPA, and total PA and number of daily steps. Changes in $\dot{V}O_{2peak}$ were not associated with sedentary time or any PA variables.

Separate models, including baseline weight, $\dot{V}O_{2peak}$, and their interactions with time, were used to examine potential moderating effects of baseline weight and $\dot{V}O_{2peak}$. LPA time was the only outcome that did not show a significant weight–time (P = 0.237) or $\dot{V}O_{2peak}$–time (P = 0.069) interaction. A significant baseline weight–time interaction was found for MVPA (total and outside exercise program) and total PA time, as well as number of steps (P = 0.005, 0.005, 0.032, 0.004, respectively). These results indicated differential changes in the outcomes across different baseline weights. To follow up these significant interactions, we categorized into subgroups of similar sample size using quartiles of baseline weight considering the limited sample size. Changes in MVPA and total PA time and number of steps within each quartile were subsequently determined (Table 4). The outcomes significantly changed in some but not other quartiles, and the overall trend was that within higher quartiles of baseline weight; MVPA and total PA time and daily steps were more likely to increase.

Similarly, significant $\dot{V}O_{2peak}$–time interaction was found for sedentary time, total PA, and number of daily steps (P = 0.004, 0.035, and 0.039, respectively). Within each quartile of baseline $\dot{V}O_{2peak}$, changes in sedentary time, total PA, and daily steps are also shown in Table 4. Sedentary time decreased and total PA time increased in the second and highest quartile, but not in the lowest or the third quartiles. Daily steps increased in all quartiles but differed in magnitude.

Distribution of individual changes in sedentary and PA time. The changes from baseline to end intervention in time being sedentary and LPA, MVPA, and total PA time were calculated for each woman. Figure 1 shows the distribution of time changes and the percentage of women in each successive range of distribution for sedentary, LPA, MVPA, and MVPA time outside the exercise program. The majority of

TABLE 3. Mixed-effects models examining changes in sedentary time and PA with covariates of weight and cardiorespiratory fitness at baseline and change during intervention.

Dependent Variable	Independent Variable	Regression Coefficient	SE	*P*
Sedentary time, min·d^{-1}	End intervention	−29.7	12.4	0.020
	Baseline weight, kg	2.8	1.2	0.027
	Weight change, kg	6.0	4.3	0.164
	Baseline $\dot{V}O_{2peak}$, mL·kg^{-1}·min^{-1}	−11.4	3.1	<0.001
	$\dot{V}O_{2peak}$ change, mL·kg^{-1}·min^{-1}	−3.9	3.0	0.201
Light PA, min·d^{-1}	End intervention	13.2	7.3	0.075
	Baseline weight, kg	−3.1	1.1	0.008
	Weight change, kg	−4.2	2.8	0.140
	Baseline $\dot{V}O_{2peak}$, mL·kg^{-1}·min^{-1}	6.6	2.9	0.025
	$\dot{V}O_{2peak}$ change, mL·kg^{-1}·min^{-1}	2.1	2.0	0.291
Total MVPA, min·d^{-1}	End intervention	15.5	4.0	<0.001
	Baseline weight, kg	−0.16	0.35	0.653
	Weight change, kg	−3.1	1.6	0.066
	Baseline $\dot{V}O_{2peak}$, mL·kg^{-1}·min^{-1}	4.0	0.91	<0.001
	$\dot{V}O_{2peak}$ change, mL·kg^{-1}·min^{-1}	1.4	1.2	0.222
MVPA outside prescribed exercise, min·d^{-1}	End intervention	0.84	3.9	0.828
	Baseline weight, kg	−0.12	0.35	0.731
	Weight change, kg	−3.2	1.6	0.048
	Baseline $\dot{V}O_{2peak}$, mL·kg^{-1}·min^{-1}	3.9	0.90	<0.001
	$\dot{V}O_{2peak}$ change, mL·kg^{-1}·min^{-1}	1.1	1.1	0.325
	End intervention	28.5	9.1	0.003
Total PA, min·d^{-1}	Baseline weight, kg	−2.6	1.4	0.057
	Weight change, kg	−7.4	3.5	0.039
	Baseline $\dot{V}O_{2peak}$, mL·kg^{-1}·min^{-1}	11.5	3.5	0.002
	$\dot{V}O_{2peak}$ change, mL·kg^{-1}·min^{-1}	3.6	2.5	0.151
Steps per day	End intervention	1366	251	<0.001
	Baseline weight, kg	36.8	32.6	0.263
	Weight change, kg	−82.5	100.8	0.416
	Baseline $\dot{V}O_{2peak}$, mL·kg^{-1}·min^{-1}	288.9	83.6	0.001
	$\dot{V}O_{2peak}$ change, mL·kg^{-1}·min^{-1}	132.0	71.8	0.071

Baseline is the reference time point. The regression coefficient for end intervention is the difference between end intervention and baseline in the mean of each outcome, sedentary time, or PA, adjusting for other variables in the model. The regression coefficients for baseline weight, weight change, baseline $\dot{V}O_{2peak}$, and $\dot{V}O_{2peak}$ change are their respective regression slopes against each outcome variable, adjusting for other variables in the model.

TABLE 4. Changes in sedentary time and PA within each quartile categorized based on baseline body weight or baseline cardiorespiratory fitness.

Dependent Variable	Independent Variable	Regression Coefficient	SE	*P*
Quartiles of baseline weight (low to high)				
Total MVPA, min·d^{-1}	Quartile 1 (lowest)	11.7	6.8	0.108
	Quartile 2	15.6	9.1	0.110
	Quartile 3	20.2	4.3	<0.001
	Quartile 4 (highest)	31.0	8.4	0.003
MVPA outside prescribed exercise, min·d^{-1}	Quartile 1 (lowest)	−3.1	7.0	0.662
	Quartile 2	0.3	8.6	0.972
	Quartile 3	3.9	4.1	0.362
	Quartile 4 (highest)	17.3	8.1	0.050
Total PA, min·d^{-1}	Quartile 1 (lowest)	31.1	20.6	0.153
	Quartile 2	22.8	14.5	0.138
	Quartile 3	30.6	13.3	0.038
	Quartile 4 (highest)	71.2	18.5	0.002
Steps per day	Quartile 1 (lowest)	1146	554	0.058
	Quartile 2	1339	445	0.009
	Quartile 3	1608	404	0.001
	Quartile 4 (highest)	2370	491	<0.001
Quartiles of baseline $\dot{V}O_{2peak}$ (low to high)				
Sedentary time, min·d^{-1}	Quartile 1 (lowest)	4.8	33.3	0.888
	Quartile 2	−35.4	14.6	0.030
	Quartile 3	−39.2	19.1	0.061
	Quartile 4 (highest)	−84.6	18.5	<0.001
Total PA, min·d^{-1}	Quartile 1 (lowest)	15.4	12.5	0.237
	Quartile 2	46.4	13.6	0.005
	Quartile 3	30.2	28.6	0.310
	Quartile 4 (highest)	61.1	17.9	0.004
Steps, numbers per day	Quartile 1 (lowest)	1166	293	0.001
	Quartile 2	1726	463	0.003
	Quartile 3	1483	610	0.030
	Quartile 4 (highest)	2042	480	<0.001

Baseline is the reference time point. The regression coefficient is the difference between end intervention and baseline in the mean of each outcome.

women (78.7%) reduced their sedentary time, and more women (60.7%) increased LPA time than those who reduced (39.3%). For MVPA time, 82.0% of women increased; however, once time spent in the exercise program was removed from MVPA, the distribution shifted to only 54.1% of women having an increase. Twenty-eight women (45.9%)

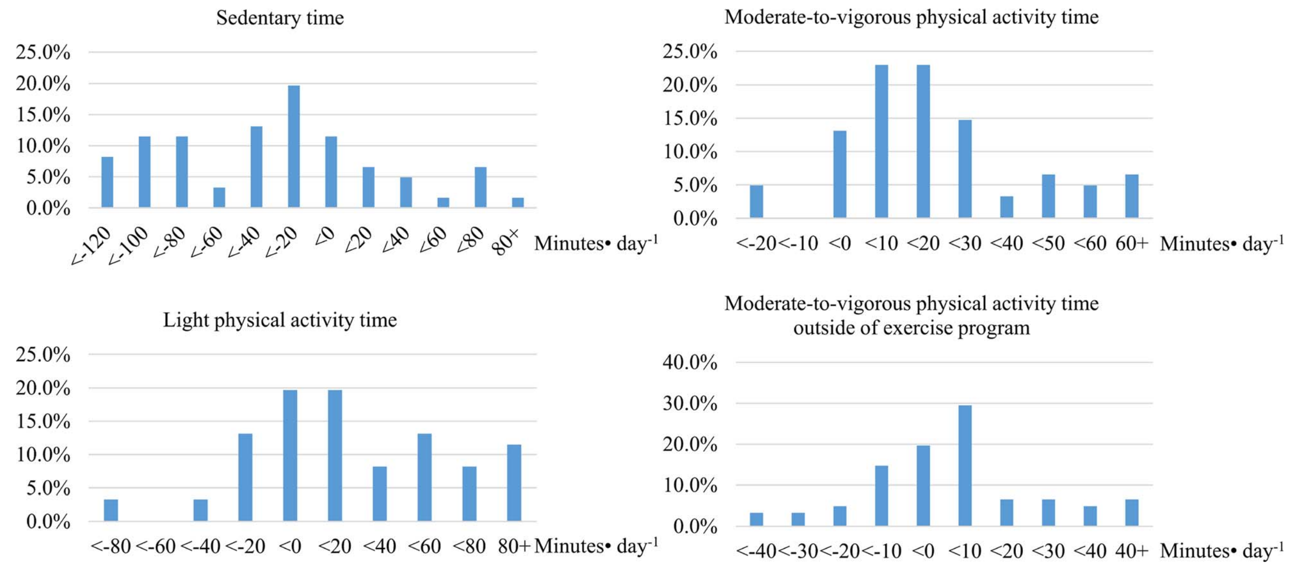

FIGURE 1—Percentage of women in each successive range of time changes of sedentary and PA. Changes were calculated using values at end intervention minus at baseline. Each column represents the percentage of women in the range of time that is less than the labeled value and greater than the previous labeled value.

reduced sedentary time and increased both LPA and MVPA time (no compensatory changes in sedentary or PA time), and three women (4.9%) increased sedentary time and reduced both LPA and MVPA time (had compensatory changes in all three).

DISCUSSION

This is one of the few studies that have objectively determined time being sedentary and time spent on PA by intensity, and number of daily steps, in older women who participated in moderate-intensity aerobic exercise training. Our primary results are that sedentary time reduced, time spent on LPA, MVPA, and total PA, and number of daily steps increased from baseline to end intervention in these older women. We also showed individual differences in the changes, and that weight and cardiorespiratory fitness could affect these changes.

As with many previous exercise trials, the center-based moderate-intensity exercise training was monitored in our study (22). The increase in MVPA time was primarily accounted for by the center-based exercise sessions. The exercise training reached the full target volumes at moderate-intensity by midintervention; as such, MVPA time did not further increase from mid- to end intervention. Women also did not have changes in the time of MVPA outside the center-based exercise program.

There was an increase in LPA time, which primarily occurred after midintervention. The literature suggests that greater LPA has a stronger influence on mortality among those performing the least MVPA (10). Considering that the time many of our participants spent on MVPA was below or just meeting the PA guidelines, the increase in LPA time is encouraging. The fact that the increase in LPA time primarily occurred after midintervention may be because women were still adapting, physiologically and behaviorally, to the increasing exercise dosage in the first few weeks. In line with this, a review of studies examining the effect of exercise training on nonexercise PA suggested that compensatory changes in nonexercise PA would decrease over time as fitness level increases and lifestyle changes develop (7).

Reciprocally, sedentary time decreased by an average of 39 min·d^{-1} from baseline to end intervention. In the LIFE study, the PA intervention group also decreased sedentary time 6 months after being in the intervention group; however, the decrease in comparison with the health education control group was small (group difference, 9 min) (16). The PA intervention involved a combination of center-based and home-based activities of moderate-intensity walking. The change in MVPA time was not reported in this analysis, but another analysis of the LIFE study reported participants in the PA intervention participated in 213 min·wk^{-1} of MVPA with an average increase of 15 min·wk^{-1} from baseline to after 6 months (28). The health education control group, however, had an average decrease of MVPA by 25 min, resulting in a 40-min·wk^{-1} difference between the two groups. In another study, older adults were randomized to a Get Active group or a Sit Less group receiving consultations with a goal to increase MVPA or reduce sedentary time, respectively (17). The Get Active group increased MVPA by an average of 67 min·wk^{-1}, but neither group decreased sedentary time assessed by the SenseWear monitor. In our study, MVPA increased by a larger degree (an average of 20 min·d^{-1}) compared with these two studies in older adults (16,17), which may have contributed to the larger decrease in sedentary time over time.

Our data demonstrated individual differences in responses to exercise training in these older women. The majority of women reduced their sedentary time, and more than half increased LPA and MVPA time. In a previous study in postmenopausal women who participated in 13 wk of moderate-intensity walking, about 56% of them increased whereas the rest reduced MVPA time (29). However, in our study, slightly more than half of the sample had at least one undesirable change (increased sedentary time and/or reduced LPA and/or MVPA). We attempted to examine whether body weight and cardiorespiratory fitness, the two factors that are believed to be associated with sedentary behavior and PA participation, contribute to these individual differences.

Our results supported a moderating role of body weight and cardiorespiratory fitness in their responses to exercise intervention. It appeared women with higher weight (note all women were nonobese) at baseline were more likely to increase PA time than those in the lower weight categories. The findings for cardiorespiratory fitness were not very straightforward in that women in the second and fourth (highest) quartile of $\dot{V}O_{2peak}$ were more likely to reduce sedentary time and increase total PA time, which may be because the $\dot{V}O_{2peak}$ is a function of both absolute peak oxygen consumption and body weight. A possible explanation is that women who have optimal fitness level and weight may be better able to engage in more activities and be less sedentary outside the center-based exercise training.

On the other hand, the disappearance of significant changes in LPA time and MVPA time outside the exercise program and the attenuated changes in sedentary time, MVPA, and total PA time after adjusting for weight and cardiorespiratory fitness (either baseline and change values or time varying) suggest that body weight and cardiorespiratory fitness account for, at least in part, the changes in sedentary and PA variables. In our study, body weight and cardiorespiratory fitness both changed with small degrees at the mean level with variations among individuals. These physiological characteristics can be the result of habitual behavioral factors, including sedentary behavior and PA participation. They may also change as a result of the intervention and affect the changes in the behavioral factors in response to an intervention. These associations are therefore intricate and may be affected by genetic, metabolic, and endocrine factors.

Another interesting finding of our study was that the increase in daily steps from baseline to end intervention in the moderate-dose group was almost twofolds of that in the low-dose group. In the Dose Response to Exercise in Women study, step counts outside the exercise intervention were not different between the three exercise training groups of varying energy expenditures (4, 8, and 12 kcal·kg^{-1} body weight per week) among postmenopausal women, but the step counts during exercise sessions were different as expected (9). In our study, the monitor was not removed during exercise sessions; thus, the step counts included PA of any intensity during and outside the exercise program. Considering that changes in both LPA and MVPA time were not statistically different between the two groups, their different changes in number of steps indicate that step counts and PA time do not always agree in terms of statistical inferences. Thus, step counts and PA time represent different goals that can be used to prescribe PA that may lead to different results.

Strengths of this study include supervised exercise intervention, objectively determined PA and sedentary time, and long wear time each day and the number of days women wearing the SenseWear device. The following limitations should be considered when interpreting our findings. First, our participants were nonobese, and thus these findings may not be generalized to obese individuals. Second, our data were obtained when women were still participating in the center-based exercise program. Whether there were changes in sedentary time and PA participation after they stopped the exercise program were not determined. Third, there was not a no-exercise control group, which limited our ability to exclude other reasons that may influence the findings. In addition, it should be noted that these results cannot be directly compared with studies examining changes in PA energy expenditure during exercise interventions because of the various amounts of energy cost associated with the range of PA. A review on this topic highlights the complexity of this issue (4).

In conclusion, sedentary time reduced, and time spent on LPA, MVPA, and total PA and number of daily steps increased during exercise training in this group of older women. The increased MVPA was primarily due to the center-based exercise program. The encouraging findings of this study are that these older women did not reduce time on LPA or MVPA outside the exercise program and did not increase sedentary time as a result of participating in the exercise program. However, there were individual differences in these changes. Body weight and cardiorespiratory fitness partly mediated the changes, and their baseline levels also moderated the responses to exercise training.

This work was supported by the National Institute on Aging of the National Institutes of Health under award number R00AG031297. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

The authors thank the research staff for their dedicated work and participants for participating in the study.

SNB receives book royalties (~$1,000 per year) from Human Kinetics; has served on the Scientific/Medical Advisory Boards for Technogym, Santech, Cancer Fit Steps for Life, Sports Surgery Clinic Dublin, and Clarity; and has received honoraria for lectures and consultations from various scientific, educational, and lay groups. During the past 5-yr period, he has received research grants from the National Institutes of Health, Body Media, and The Coca Cola Company.

The results of the present study do not constitute endorsement by the American College of Sports Medicine. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

REFERENCES

1. U.S. Department of Health and Human Services. *Physical Activity Guidelines for Americans*. Washington (DC): U.S. Department of Health and Human Services; 2018.
2. Baker J, Meisner BA, Logan AJ, Kungl AM, Weir P. Physical activity and successful aging in Canadian older adults. *J Aging Phys Act*. 2009;17(2):223–35.
3. Du Y, Liu B, Sun Y, Snetselaar LG, Wallace RB, Bao W. Trends in adherence to the physical activity guidelines for Americans for aerobic activity and time spent on sedentary behavior among US adults, 2007 to 2016. *JAMA Netw Open*. 2019;2(7):e197597.
4. Melanson EL. The effect of exercise on non-exercise physical activity and sedentary behavior in adults. *Obes Rev*. 2017;18:40–9.
5. Westerterp KR. Exercise, energy expenditure and energy balance, as measured with doubly labelled water. *Proc Nutr Soc*. 2018;77(1):4–10.
6. Matthews CE, Keadle SK, Saint-Maurice PF, et al. Use of time and energy on exercise, prolonged TV viewing, and work days. *Am J Prev Med*. 2018;55(3):e61–9.
7. Fedewa MV, Hathaway ED, Williams TD, Schmidt MD. Effect of exercise training on non-exercise physical activity: a systematic review and meta-analysis of randomized controlled trials. *Sports Med*. 2017;47(6):1171–82.
8. Meijer EP, Westerterp KR, Verstappen FT. Effect of exercise training on physical activity and substrate utilization in the elderly. *Int J Sports Med*. 2000;21(7):499–504.
9. Jordan AN, Jurca GM, Locke CT, Church TS, Blair SN. Pedometer indices for weekly physical activity recommendations in postmenopausal women. *Med Sci Sports Exerc*. 2005;37(9):1627–32.
10. Saint-Maurice PF, Troiano RP, Berrigan D, Kraus WE, Matthews CE. Volume of light versus moderate-to-vigorous physical activity: similar benefits for all-cause mortality? *J Am Heart Assoc*. 2018;7(7):e008815.
11. Füzéki E, Engeroff T, Banzer W. Health benefits of light-intensity physical activity: a systematic review of accelerometer data of the National Health and Nutrition Examination Survey (NHANES). *Sports Med*. 2017;47(9):1769–93.
12. de Rezende LF, Rey-Lopez JP, Matsudo VK, do Carmo Luiz O. Sedentary behavior and health outcomes among older adults: a systematic review. *BMC Public Health*. 2014;14:333.
13. Seguin R, Buchner DM, Liu J, et al. Sedentary behavior and mortality in older women: the Women's Health Initiative. *Am J Prev Med*. 2014;46(2):122–35.
14. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet*. 2016;388(10051):1302–10.
15. Harvey JA, Chastin SF, Skelton DA. How sedentary are older people? A systematic review of the amount of sedentary behavior. *J Aging Phys Act*. 2015;23(3):471–87.
16. Wanigatunga AA, Ambrosius WT, Rejeski WJ, et al. Association between structured physical activity and sedentary time in older adults. *JAMA*. 2017;318(3):297–9.
17. Gibbs BB, Brach JS, Byard T, et al. Reducing sedentary behavior versus increasing moderate-to-vigorous intensity physical activity in older adults. *J Aging Health*. 2017;29(2):247–67.
18. Kozey-Keadle S, Staudenmayer J, Libertine A, et al. Changes in sedentary time and physical activity in response to an exercise training and/or lifestyle intervention. *J Phys Act Health*. 2014;11(7):1324–33.
19. Carnethon MR, Evans NS, Church TS, et al. Joint associations of physical activity and aerobic fitness on the development of incident hypertension. *Hypertension*. 2010;56(1):49–55.

20. Rivera-Torres S, Fahey TD, Rivera MA. Adherence to exercise programs in older adults: informative report. *Gerontol Geriatr Med*. 2019;5:2333721418823604–4.
21. Ekelund U, Kolle E, Steene-Johannessen J, Dalene KE, Nilsen AKO, Hansen BH. Objectively measured sedentary time and physical activity and associations with body weight gain: does body weight determine a decline in moderate and vigorous intensity physical activity? *Int J Obes (Lond)*. 2017;41(12):1769–74.
22. Wang X, Bowyer KP, Porter RR, Breneman CB, Custer SS. Energy expenditure responses to exercise training in older women. *Physiol Rep*. 2017;5(15):e13360.
23. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. Philadelphia (PA): Lippincott Williams & Wilkins; 2010.
24. Mackey DC, Manini TM, Schoeller DA, et al. Validation of an armband to measure daily energy expenditure in older adults. *J Gerontol A Biol Sci Med Sci*. 2011;66(10):1108–13.
25. Johannsen DL, Calabro MA, Stewart J, Franke W, Rood JC, Welk GJ. Accuracy of armband monitors for measuring daily energy expenditure in healthy adults. *Med Sci Sports Exerc*. 2010;42(11):2134–40.
26. St-Onge M, Mignault D, Allison DB, Rabasa-Lhoret R. Evaluation of a portable device to measure daily energy expenditure in free-living adults. *Am J Clin Nutr*. 2007;85(3):742–9.
27. Reece JD, Barry V, Fuller DK, Caputo J. Validation of the SenseWear armband as a measure of sedentary behavior and light activity. *J Phys Act Health*. 2015;12(9):1229–37.
28. Pahor M, Guralnik JM, Ambrosius WT, et al. Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. *JAMA*. 2014;311(23):2387–96.
29. Di Blasio A, Ripari P, Bucci I, et al. Walking training in postmenopause: effects on both spontaneous physical activity and training-induced body adaptations. *Menopause*. 2012;19:23–32.

APPLIED SCIENCES