Walking Speed at Self-Selected Exercise Pace Is Lower but Energy Cost Higher in Older Versus Younger Women

Lynnette M. Jones, Debra L. Waters, and Michael Legge

Background: Walking is usually undertaken at a speed that coincides with the lowest metabolic cost. Aging however, alters the speed–cost relationship, as preferred walking speeds decrease and energy costs increase. It is unclear to what extent this relationship is affected when older women undertake walking as an exercise modality. The aim of this study was to compare the energetic cost of walking at a self-selected exercise pace for 30 min in older and younger women.

Methods: The energetic cost of walking was assessed using the energy equivalent of oxygen consumption measured in 18 young (25 to 49 y) and 20 older (50 to 79 y) women who were asked to walk at their “normal” exercise pace on a motorized treadmill for 30 min.

Results: The mass-specific net cost of walking (\(C_w\)) was 15% higher and self-selected walking speed was 23% lower in the older women than in the younger group. When speed was held constant, the \(C_w\) was 0.30 (J · kg\(^{-1}\) · m\(^{-1}\)) higher in the older women.

Conclusions: Preferred exercise pace incurs a higher metabolic cost in older women and needs to be taken into consideration when recommending walking as an exercise modality.

Keywords: physical activity, metabolic costs, females, aging

Walking is a convenient and popular form of aerobic activity and is widely recommended for health and fitness for individuals of all ages. The associated energy costs of this activity are the result of the need to convert chemical energy to the mechanical work of walking. Measurement of oxygen consumption during physical activity allows an assessment of the associated metabolic costs to be made. The mass-specific net cost of walking (\(C_w\)), defined as the energy cost of moving 1 kg of body mass 1 m, and speed is U shaped, with an individual’s walking speed selected to coincide with the lowest metabolic cost. This relationship can be altered by changes in gait patterns as a result of amputation, disease, loading, obesity, gender, and aging.

Self-selected walking speeds decrease with age, while the associated energy costs increase, resulting in an upward shift in the \(C_w\)--speed relationship during aging. The reason for this upward shift in older adults is multifactorial. Determinants of walking speed and metabolic cost in older individuals that have been proposed include the effects of age, alterations in muscle efficiency, step length, height, body composition, and increased cardiorespiratory demands.

Many studies undertaken to evaluate the metabolic cost of walking at self-selected or predetermined walking speeds in older individuals have been undertaken for relatively short periods of time or over relatively short distances. Furthermore, no studies to date have focused on the metabolic costs of walking at a self-selected exercise pace. American College of Sports Medicine (ACSM) physical activity recommendations for adults suggest that moderate-intensity exercise be undertaken 5 d/wk for 30 min/session for adults age 18 to 65 years, although in adults >65 years this recommendation can be obtained by shorter-duration exercise repeated several times per day. It is more difficult to extrapolate \(C_w\) over short periods of time to a continuous “exercise-focused” protocol. Therefore the aim of this study was to compare the energetic cost of walking at a self-selected speed for a 30 min in older and younger women.

Methods

Forty white women were recruited by advertisement to participate in this cross-sectional comparative study, which was approved by the University of Otago Human Ethics Committee. All were regular recreational exercisers, that is, they normally undertook physical activity...
less than 4 d/wk or 150 min/wk. Participants in the younger (YOU) group included women 25 to 49 years of age (n = 20), and women age 50 to 79 years composed the older (OLD) group (n = 20).

Informed written consent was obtained and a medical and exercise screening questionnaire was completed before the first exercise testing session. Exclusion criteria included a history of heart disease, type 2 diabetes, orthopedic problems, current hormone-replacement therapy, regular use of any medications known to affect metabolism (eg, thyroid drugs), significant weight fluctuations (± 5 kg) within the 6 months before participation in the study, any health problem that might have interfered with exercise, or an inability to walk continuously for 30 minutes. Participants were also excluded if they demonstrated a high level of current physical activity, exercising more than 4 d/wk or 150 min/wk.

**Anthropometry**

Height, weight, and waist and hip circumferences were recorded before the treadmill walk. Height was determined without shoes using a freestanding stadiometer, and weight was measured with participants wearing their walking attire, also without shoes, using electronic scales (Digi, D1-10, Teraoka Ltd, Tokyo, Japan). A standard fiberglass anthropometric tape was used to measure waist circumference, defined as the narrowest part between the last rib and the anterior superior iliac spine (ASIS), and hip circumference, defined as the widest part between the ASIS and the greater trochanter. Body-mass index (weight [kg]/height [m²]) was used to estimate adiposity, and waist:hip ratios were calculated to describe body-fat distribution.

**Exercise Protocol**

All exercise sessions and maximal exercise testing took place at the School of Physical Education, University of Otago. The study protocol required the participants to complete 30 continuous minutes of treadmill walking. Participants were tested individually and asked to undertake the exercise sessions at their “normal” exercise pace, that is, self-paced exercise. They were asked to maintain their normal diet and activity patterns between the exercise session and the maximal exercise test. The maximal exercise test was undertaken 48 hours after the exercise session had been completed to ensure that the women chose their own exercise pace during the walk. Prior experience or perception of higher-intensity exercise on the treadmill could have influenced the choice of exercise pace made by each woman.

Treadmill walking was undertaken in an exercise physiology laboratory, ambient temperature 26°C, using a Quinton motorized treadmill (Quinton Instrument Co, Series 90 Q65, WA, USA) set at 0% gradient. Breath sampling occurred at rest, for 3 minutes immediately before beginning the treadmill walk; the average of the first 2 minutes was used in the analyses. Thereafter the 30-minute exercise session was divided into five 6-minute blocks for sampling purposes. Breath samples were collected for the final 80 seconds of each block. The Sensormedics metabolic cart samples every 20 seconds, so the initial 20 seconds of data were discarded and the remaining 60 seconds averaged for analytical purposes. Rating of perceived exertion, Borg scale 6 to 20, and heart-rate (HR) values (Polar heart-rate monitor) were collected at the end of each 6-minute block. All women were given the opportunity to increase or decrease treadmill speed at the end of each 6-minute interval to ensure replication of a self-selected exercise pace. Speed was increased or decreased by a technician when requested and any change in speed noted. All women were familiarized with the exercise environment, equipment, and the measurement scales to be used, after the rest period and before sampling began for their exercise session. Throughout the exercise session, participants were verbally reminded to continue exercising at their normal pace.

Energy expenditure (EE) was calculated using the energetic equivalent of 20.1 J/mL−1 O₂, from the indirect calorimetry values collected at rest and at the end of each 6-minute block. Resting EE was calculated from the mean oxygen consumption (VO₂) over the 2-minute sampling period immediately before the exercise session, and the 60 seconds of breath analysis were averaged and used to estimate EE per minute during the exercise session at minutes 6, 12, 18, 24, and 30. The average EE for the treadmill session does not include resting values, so these data represent EE associated with activity only.

To find the mass-specific net Cw, that is, the energy cost of moving 1 kg of body mass 1 m, the energetic equivalent of the average rate of VO₂ at rest and over the 30-minute treadmill walk was calculated using the energetic equivalent of O₂, and expressed in J/s. Only participants with a respiratory-exchange ratio <1.0 were used in these analyses to ensure that aerobic metabolism was the primary metabolic pathway. Two women in the YOU group had respiratory-exchange ratios >1.0 and were excluded from further analyses; thus, the final participant number for the YOU group was 18. The mass-specific net metabolic rate was calculated by subtracting the resting EE from the average EE over the 30-minute TM walk and dividing by body mass (W/kg). Mass-specific net metabolic rate was then divided by the average treadmill speed (m/s) to give the net metabolic cost of walking (Cw, in J · kg⁻¹ · m⁻¹).²²²

Metabolic equivalents were calculated to facilitate direct comparisons of exercise intensity between the self-selected walking pace of our groups and the recent ACSM recommendations defining moderate intensity as activities using 3.0 to 6.0 METs. For the purposes of this estimation, resting metabolic rate was assumed to be 3.5 mL · kg⁻¹ · min⁻¹.
Maximal-Oxygen-Consumption Test

After the completion of the walk, a maximal VO2 exercise (VO2max) test was undertaken on a treadmill using individualized ramp protocols, with predicted VO2max and grade increments calculated from established equations.9 Treadmill speed was determined from the average of velocities chosen during the 30-minute walking exercise session and was held constant throughout the test. After a 2-minute warm-up, grade was increased every minute until volitional fatigue. Grade increments were calculated using predicted VO2max estimated from equations of Cooper and Storer.9

Continuous breath analysis (Sensormedics 2900 metabolic cart, Sensormedics, California, USA) and HR were undertaken throughout the exercise test, and values were recorded at 20-second intervals.

Statistical Analysis

Group mean ± standard error of the mean (SEM) was used to describe the data. Shapiro–Wilk testing of all variables was undertaken to ensure normal distribution of data; all data were found to be normally distributed. Independent t tests were performed to determine differences in physiological parameters between the YOU and OLD groups. To control for self-selected treadmill speed, analysis of covariance (ANCOVA) was used to examine the influence of group (YOU or OLD) on the net energetic cost of walking (J · kg−1 · m−1). A stepwise multiple-regression analysis was undertaken using combined group data (n = 38) to determine the predictor(s) of treadmill speed selection (m/s). Independent variables entered into the model were age, height, weight, and VO2max (expressed as mL · kg−1 · min−1). Pearson product–moment-correlation coefficient testing was undertaken to investigate the relationships between the independent variables and walking speed. Statistical Package for the Social Sciences (SPSS) was used for all statistical analyses (SPSS Inc, v 14.0, Chicago, IL). Significance was set at P < .05.

Results

Demographic and baseline physiological data (mean ± SEM) are presented in (Table 1). Maximum HR and VO2, measured from the treadmill exercise test were significantly higher (P < .05) in the YOU group than the OLD group (Table 1).

The self-selected treadmill speed was significantly greater for the younger women than for the older group (5.3 ± 0.19 vs 4.1 ± 0.24 km/h, respectively P < .001). Net Cw was also significantly higher in the OLD group than the YOU group (P < .05; Table 2). Mean VO2, HR, MET values, and rating of perceived exertion were not significantly different between the groups (P < .05; Table 2).

<table>
<thead>
<tr>
<th>Table 1 Demographic and Baseline Physiological Data for Younger (YOU) and Older (OLD) Groups (Mean ± SEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YOU</strong> (n = 18)</td>
</tr>
<tr>
<td>Age (y)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
</tr>
<tr>
<td>VO2max (L/min)</td>
</tr>
<tr>
<td>VO2max (mL · kg−1 · min−1)</td>
</tr>
<tr>
<td>HRmax (bpm)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body-mass index; HR, heart rate; bpm = beats per minute.

<table>
<thead>
<tr>
<th>Table 2 Physiological Data From the Treadmill-Walking (TM) Exercise Session for the Younger (YOU) and Older (OLD) Groups (Mean ± SEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YOU</strong> (n = 18)</td>
</tr>
<tr>
<td>Mean TM speed (m/s)</td>
</tr>
<tr>
<td>Net Cw (J · kg−1 · m−1)</td>
</tr>
<tr>
<td>Mean VO2 (mL · kg−1 · min−1)</td>
</tr>
<tr>
<td>Mean HR (bpm)</td>
</tr>
<tr>
<td>METs</td>
</tr>
<tr>
<td>Mean RPE</td>
</tr>
</tbody>
</table>

Abbreviations: Cw, energetic cost of walking; HR, heart rate; METs, metabolic equivalents; RPE, rating of perceived exertion. * P < .05. ** P < .01.

A 1-way ANCOVA was conducted to investigate the cost of walking at similar speeds between the 2 groups. Correlations between the cost of walking and self-selected treadmill speed were small and nonsignificant (r2 = .10, P = .16 vs r2 = .01, P = .59) for the YOU and OLD groups, respectively. There was no significant difference found in the slopes of the regression lines (P = .53), thereby demonstrating homogeneity, but a significant difference in the net cost of walking was observed at the y-intercept by 0.30 J · kg−1 · m−1, P = .006 (Figure 1).

When the independent variables of age, height, weight, and relative VO2 were entered into the regression model, only VO2, expressed relative to body mass, remained a significant predictor of self-selected walking pace in this group of women. This variable accounted for 61% of the variance in walking speed (β coefficient = 0.78, P = .0005). Age was significantly (P < .05) inversely associated with walking speed, whereas height
Jones, Waters, and Legge evaluated using subjective instruction of “slow, normal, or fast” walking pace or by using predetermined speed on a treadmill. To our knowledge, this is the first article to address the metabolic costs of self-selected walking pace as an exercise modality.

Haveman-Nies et al.15 reported a 27% lower self-selected walking speed in older women than their younger counterparts, with total EE 22% higher when walking at either a self-selected or fixed speed. Malatesta et al.19 found preferred walking speed to be approximately 15% slower in the oldest group of adults (80 years), with oxygen cost per distance walked approximately 22% higher than those age 25 years. Waters et al.29 reported that normal walking speed was approximately 10% slower in older (60 to 80 years) than younger (20 to 59 years) adults, although gross oxygen cost at this speed was similar. However, when expressed per distance walked, oxygen costs were 8% higher in the older group. Similarly, when treadmill speeds are fixed, energy costs are also higher for older individuals. Walking at speeds over a range of 0.7 to 1.8 m/s, average metabolic costs of walking have been reported as being 31%22 and 20%25 higher in older adults than in younger adults. In the current study, self-selected walking speed at exercise pace was approximately 23% lower in our OLD group than in the YOU group, and the average net Cw was 15% higher. Our results are similar to those found by Haveman-Nies et al.15 and Malatesta et al.19 for “normal” walking pace, and our finding of a similar gross rate of VO2 between the 2 groups, despite significantly slower walking speeds selected by the older women, concur with those of Waters et al.29

Table 3 Pearson Correlation Coefficients Between Predictor Variables and Self-Selected Walking Speed (N = 38)

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Walking speed (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>−.61**</td>
</tr>
<tr>
<td>Height</td>
<td>.39*</td>
</tr>
<tr>
<td>Weight</td>
<td>−.96</td>
</tr>
<tr>
<td>VO2max (mL · kg−1 · min−1)</td>
<td>.78**</td>
</tr>
</tbody>
</table>

* P < .05, ** P < .01.

and relative maximal VO2 were positively related with walking speed (Table 3).

**Discussion**

We investigated the net energetic cost of walking at a self-selected pace for 30 minutes in 2 groups of women. The main findings in this study were that older women incurred a higher metabolic cost while walking at a slower pace than younger women and that their level of fitness was the greatest predictor of self-selected speed. Furthermore, when walking speed is held constant, the net energetic cost of walking remains higher in the older group than the younger group of women.

It has been suggested that all individuals have an ideal, or habitual, walking speed, and it is at this speed that EE is lowest.30 However, walking speed decreases with age and the metabolic costs increase.8,16,19-21 Walking speeds and the associated energy costs have been evaluated using subjective instruction of “slow, normal, or fast” walking pace or by using predetermined speed on a treadmill. To our knowledge, this is the first article to address the metabolic costs of self-selected walking pace as an exercise modality.

Haveman-Nies et al.15 reported a 27% lower self-selected walking speed in older women than their younger counterparts, with total EE 22% higher when walking at either a self-selected or fixed speed. Malatesta et al.19 found preferred walking speed to be approximately 15% slower in the oldest group of adults (80 years), with oxygen cost per distance walked approximately 22% higher than those age 25 years. Waters et al.29 reported that normal walking speed was approximately 10% slower in older (60 to 80 years) than younger (20 to 59 years) adults, although gross oxygen cost at this speed was similar. However, when expressed per distance walked, oxygen costs were 8% higher in the older group. Similarly, when treadmill speeds are fixed, energy costs are also higher for older individuals. Walking at speeds over a range of 0.7 to 1.8 m/s, average metabolic costs of walking have been reported as being 31%22 and 20%25 higher in older adults than in younger adults. In the current study, self-selected walking speed at exercise pace was approximately 23% lower in our OLD group than in the YOU group, and the average net Cw was 15% higher. Our results are similar to those found by Haveman-Nies et al.15 and Malatesta et al.19 for “normal” walking pace, and our finding of a similar gross rate of VO2 between the 2 groups, despite significantly slower walking speeds selected by the older women, concur with those of Waters et al.29
Furthermore, the relationship between rate of energy consumption and speed in our women falls within the range of normative data for adults age 20 to 80 years produced by Waters et al. The discrepancies among studies investigating speed and metabolic costs of walking are likely to be attributable to methodological differences. Participant age groups vary, which might distort speed-related results because the most rapid decline in walking speed occurs at age 62. Gender might also have an effect, because gait speed and stride length and frequency have been shown to differ between males and females. The modality used to assess gait speed might also explain part of the differences. Some studies used subjective instruction to assess walking over a range of speeds on level ground or a treadmill, and others used fixed speeds while participants walked on a treadmill. Furthermore, VO2 values that have not been corrected for resting VO2 might underestimate the metabolic costs attributable to locomotion.

We also demonstrated that when walking speed is held constant, the cost of walking was increased by 0.30 J·kg⁻¹·m⁻¹ in the older women. This would equate to the expenditure of an additional 111.3 kJ in 1 hour of walking at the same pace as the YOU group. Although this level of EE appears small, in older individuals who might be undernourished, the increased energy requirements for exercise might further deplete existing limited energy reserves.

Older individuals are being encouraged to undertake regular physical activity; however, the impact of increased daily exercise energy expenditure on activities of daily living (ADL) has not been fully appreciated. In a free-living situation, Harris et al., using a telemetry-based system, calculated that older individuals walk approximately 6.5 miles (10.4 km) per day, 3 miles (5 km) per day less than younger individuals, and, in agreement with the results of the current study, EE per mile walked at the same speed was higher in the older group. In addition to a reduction in total distance walked at a higher energy cost, Harris et al. observed a decline in daily nonexercise movement, standing time, and movement accelerations in the older individuals, although total EE did not differ between the young and old individuals. Thus, it could be proposed that some compensatory behaviors are undertaken by older individuals to limit EE of ADL throughout the day. Careful attention to nutritional intake and recovery strategies should be incorporated when programming exercise for older individuals. Failure to do so might result in an even greater reduction in movement associated with ADL.

Cardiorespiratory demands are increased in older adults walking at their preferred speed, evidenced by the higher relative fractions of VO2max and ventilatory threshold compared with younger individuals. In the current study, although differences were not significant, the older women were walking at a slightly higher percentage of their maximum aerobic capacity than the younger group, 47% versus 44%, respectively. This compares well with a study by Malatesta et al., who found preferred walking speed in a group of 65-year-old adults to be undertaken at 43% VO2max; however, the women in our study were asked to walk at their “normal exercise pace,” and thus the working fraction might have been expected to be somewhat higher. Despite this, the self-selected exercise pace in both groups satisfied the recent ACSM physical activity definition of “moderate intensity” (3.0 to 6.0 METs), which is recommended for cardiovascular maintenance in healthy adults age 18 to 65 years.

A consistent finding in previous studies is that walking speed declines with age. Reasons proposed for this have been attributed to age-related changes in physiological function and biomechanical efficiency. We found associations between self-selected exercise pace and age, height, and maximal VO2, that concur with those previously reported. In agreement with studies by others, we found maximal VO2, expressed relative to body weight, to be the primary determinant of walking speed when our groups were combined, accounting for 61% of the variance. Malatesta et al. reported 48% of the variance in walking speed in adults age 65 to 80 years to be explained by the fraction of VO2 corresponding to the ventilatory threshold at preferred walking speed. Given the numerous studies that have reported a decrease in walking speed with advancing age, it is somewhat surprising that, as with our study, Malatesta et al. and Cunningham et al. also did not find age to be an independent factor in determining preferred walking speed. In both studies, and in ours, the lack of an independent age effect on walking speed might be explained by the strength of association with the use of more stringent statistical procedures. Simple correlational analyses in all studies reveal significant negative associations between age and aerobic fitness and walking speed; however, age effects are lost in multiple-regression analysis. It is also notable that the self-selected speed of walking for exercise in our 2 groups of women coincided with the normal, or preferred, walking speed of individuals in similar age categories reported elsewhere.

In summary, this study demonstrated that the relative energetic costs of walking at a self-selected exercise pace for 30 minutes are significantly higher in older women than younger women. Furthermore, preferred walking speed is determined by the individual’s maximal aerobic-fitness level. Some effort should be made to assess initial fitness levels in older women and the higher relative energy costs of walking kept in mind to ensure that an exercise plan is safe and effective for that individual.

Acknowledgments

Funding was provided by a University of Otago research grant. We would like to thank Vicky Phillips and Kate Parrott, who collected the data for this study.
References