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Metabolic Responses to Exercise

PHYSIOLOGICAL RESPONSES TO DOWNHILL WALKING IN OLDER AND YOUNGER INDIVIDUALS

JAMES W. NAVALTA, DARLENE A. SEDLOCK, AND KYUNG-SHIN PARK

Department of Health & Kinesiology, Purdue University, West Lafayette, IN 47907-2046

ABSTRACT

PHYSIOLOGICAL RESPONSES TO DOWNHILL WALKING IN OLDER AND YOUNGER INDIVIDUALS**. James W Navalta, Darlene A Sedlock, Kyung-Shin Park. JEP**online. 2004;7(6):45-51. The purpose of this study was to measure selected cardiovascular and metabolic responses in healthy older and younger individuals during downhill walking. Twenty subjects, ten older [age 64±3 yr (mean±SD)] and ten younger (age 23±3 yr) performed 6 min treadmill walking bouts at 80.4 m/min at grades of 5, 0, -5, -10, -15, and -20 %. Heart rate (HR), systolic (SBP) and diastolic (DBP) blood pressure, rate pressure product (RPP), oxygen uptake (VO_2), pulmonary ventilation (V_E), and rate of perceived exertion (RPE) were determined. Older subjects had significantly greater HR, SBP, RPP, DBP and RPE during uphill, level, and downhill walking compared to younger subjects. Older individuals exhibited similar VO_2 and V_E during downhill walking compared with younger subjects. There was a characteristic curvilinear response observed for HR, SBP, RPP, VO_2, and V_E with progressively steeper negative grades. These measures were highest at 5% grade and lowest between -5% and -10%. Downhill walking at grades between -5% and -10% reduced the cardiovascular and metabolic demand during exercise in older and younger subjects. Downhill walking is an activity that may be particularly beneficial for older individuals who are previously sedentary and at the beginning stages of an exercise training program.

Key Words: Negative grade, Eccentric exercise, Age, Curvilinear response

INTRODUCTION

It is physiologically less stressful for young adults to exercise on a downhill grade than on a level or uphill grade. Pivarnik and Sherman reported significantly lower heart rate (HR) responses at grades of -5 and -10 % than at +5 and +10 % in aerobically trained young men and women during both walking and slow jogging (15). Wanta et al. examined the HR and oxygen uptake (VO_2) responses of ten fit young men to walking at two different speeds (90 and 105 m/min) on a level grade as well as downhill grades that changed in 3 % increments to –18 % (21). Responses were curvilinear, with the lowest value for HR occurring between –6 % and –9 %

grade, and between –9 % and –12 % for VO_2. Robergs et al. measured HR in a group of recreational runners while running on grades of 0, -1.8, -3.6, and -5.4 % at three self-selected speeds (16). Although not analyzed statistically, HR at any given speed became lower with progressively steeper grades. Based on results of these studies, it seems that in young adults HR and VO_2 decrease curvilinearly in response to walking or jogging at progressively greater negative grades.

Activities that enhance physical movement (i.e. increasing walking speed), without producing undue cardiovascular or metabolic stress may be beneficial for older adults to perform and should be identified. Negative grade exercise may be useful in this regard if the physiological responses reported in young healthy adults similarly occur in older individuals. Many activities of daily living use muscle combinations that require the coordinated use of concentric and eccentric contractions. It is well known that eccentric contractions performed by untrained muscle groups leads to acute soreness and a decrement in functional strength (19,20). To overcome these consequences, activities that involve combinations of eccentric and concentric actions should be regularly performed. Walking down stairs, or downhill, are examples of activities which carry a large eccentric bias and that are likely to be performed during the course of a day. To date, studies that have employed downhill exercise have focused primarily on young healthy subjects (15, 16, 21). The purpose of this study was to assess the cardiovascular and metabolic responses of healthy older adults to walking downhill. A group of younger individuals was also tested for comparison.

METHODS

Subjects

Twenty physically active healthy older and younger men and women volunteered to participate in the study. Subjects were not taking any medications that would alter cardiovascular or metabolic function. Older subjects obtained medical clearance before participating in the study. The institutional committee on the use of human research subjects approved the protocol and all subjects provided written informed consent.

Protocol

Subjects completed a laboratory session consisting of 6 treadmill walking bouts, each lasting 6 min, with 2 min rest periods between bouts. Walking speed was 80.4 m/min at grades of 5, 0, -5, -10, -15, and -20 % administered in a random order. Subjects were instructed to walk normally and were not allowed to hold the handrails during exercise. HR was measured every minute using telemetry (Polar; Oy, Finland) whereas systolic (SBP) and diastolic (DBP; 5^{th} Korotkoff sound) blood pressures were determined at the end of each bout using auscultatory sphygmomanometry (American Diagnostic Corporation; Newport Beach, CA). Rate pressure product (RPP) was calculated as $RPP = HR*SBP*10^{-3}$.

VO_2 and pulmonary ventilation (V_E) were measured using an automated gas analysis system (Parvo Medics TrueMax 2400; Salt Lake City, UT) that was calibrated prior to each testing session. Metabolic measurements and HR were recorded every minute, with values from minutes 5 and 6 of the bout averaged and used in the analysis. Rating of perceived exertion was obtained from subjects at the end of each exercise bout using the Borg scale (3).

Statistical Analyses

All data are presented as the mean ± SD. Statistical analyses were performed using Statistical Analysis System Institute Inc. version 8.1 software (SAS; Cary, NC). Dependent variables were analyzed using 2-way (age x grade) mixed factorial ANOVA with Tukey post hoc tests used when appropriate. Statistical significance was accepted at $P \leq 0.05$.

Table 1. Subject characteristics.

Variable	*Older*	*Younger*
Age (yr)	64 ± 3*	23 ± 3
Height (cm)	166 ± 9	170 ± 6
Weight (kg)	72 ± 9	71 ± 12
BMI (kg/m^2)	26 ± 3	25 ± 4

Values are the mean±SD. BMI = Body mass index.
* indicates significant difference (P<0.05).

RESULTS

Heart Rate

Participants in the older group were significantly older than those in the younger group, but had similar height, weight and body mass index (Table 1). All subjects were physically active as determined by the Aerobics Center Longitudinal Study Physical Activity Questionnaire (8). Resting HR was not significantly different between age groups (younger=63.7±12.1 beats/min, older=65.4±9.4 beats/min). With graded exercise, significant main effects for age (P=0.01) and grade (P<0.0001) emerged. HR was higher in older subjects (104.3±13.7 beats/min) than younger subjects (97.8±17.1 beats/min) across all exercise bouts. Values corresponded to 66.9±8.2 % (older group) and 49.6±8.5 % (younger group) of age adjusted HRmax (P<0.0001). HR during uphill walking was significantly higher than all other grades except -20% (Figure 1). There was no significant difference in the HR response between level walking and any downhill grade.

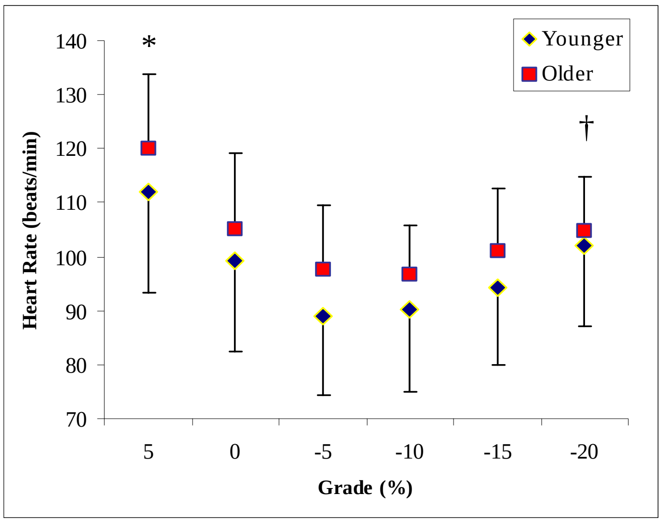

Figure 1. Heart rate during graded treadmill walking at 80.4 m/min.
*** = significantly greater than all grades except -20%;**
† = statistically similar to all grades.

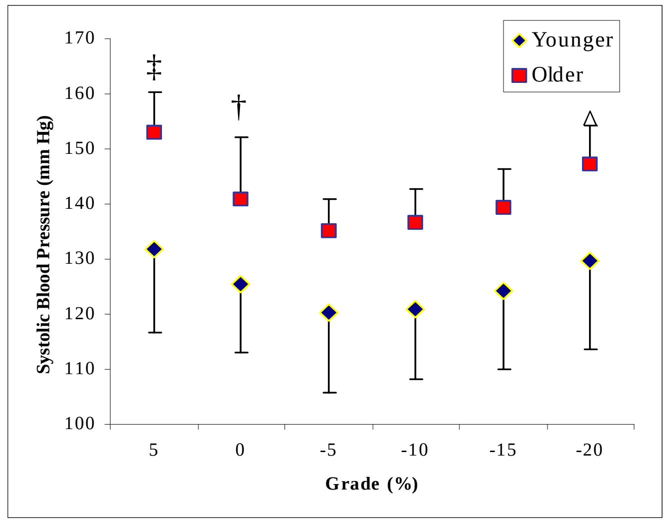

Figure 2. Systolic blood pressure during graded treadmill walking at 80.4 m/min.
‡ = significantly greater than -5, -10, and -15%;
† statistically similar to all grades;
^ similar to all grades except -5%.

Systolic Blood Pressure

Significant main effects for age (P<0.0001) and grade (P=0.0005) emerged. SBP of older participants (142.1±9.6 mm Hg) was greater than younger participants (125.4±14.2 mm Hg) during all bouts of walking, however, resting SBP was significantly higher in older (126.6 ± 10.4 mm Hg) compared to younger subjects (113.8±9.2 mm Hg). When the change in SBP from resting values was analyzed there was no significant difference between older and younger subjects, i.e. the change in SBP was similar between age groups with exercise. With regard to grade, SBP during uphill walking was similar to that observed during the level and -20 % bouts (Figure 2). There was no significant difference in the SBP response between level walking versus any downhill grade.

Diastolic Blood Pressure

There was a significant age effect for diastolic blood pressure during positive, level and negative grade walking (P<0.0001). DBP of older subjects (78.6±6.6 mm Hg) was significantly higher than younger subjects during exercise (63.4±7.3 mm Hg), with resting values significantly different between age groups (older=79±4.7 mm Hg, younger=68±9.2 mm Hg; P<0.0001). When the change in DBP from resting values was analyzed, the difference between age groups remained with younger individuals exhibiting a greater change with exercise (-4.65 ± 5.9) than older individuals (-0.43±4.1; P<0.0001).

Rate Pressure Product

Significant main effects were observed for age (P<0.0001) and grade (P<0.0001). Older participants (14.9±2.7) exhibited greater RPP across all bouts of walking than younger participants (12.4±3.2). However, resting RPP was significantly higher in older (8.2±1.0) versus younger individuals (7.3±1.6), therefore the change in RPP from rest to exercise was analyzed. Analysis revealed that older individuals exhibited a greater change in RPP with exercise (6.7±2.3) than younger individuals (5.1±2.5) (P<0.0001). RPP at 5% grade was significantly higher than all other grades except -20 % (Figure 3). RPP during level and all downhill grades were similar.

Oxygen consumption

No significant age effect for VO_2 was noted, however, there was a significant grade effect (P < 0.0001). Since there was no age effect observed, data are collapsed across age and the main effect for grade was analyzed. As shown in figure 4, VO_2 during the uphill bout was significantly higher than all other grades. VO_2 was similar when walking on a level grade and at -20%, but significantly higher than all other downhill grades.

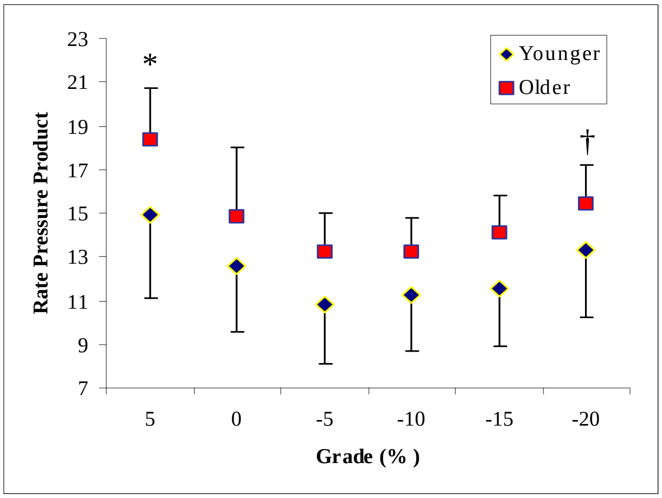

Figure 3. Rate pressure product during treadmill walking at 80.4 m/min.
*** = significantly greater than all grades except -20%;**
† = statistically similar to all grades.

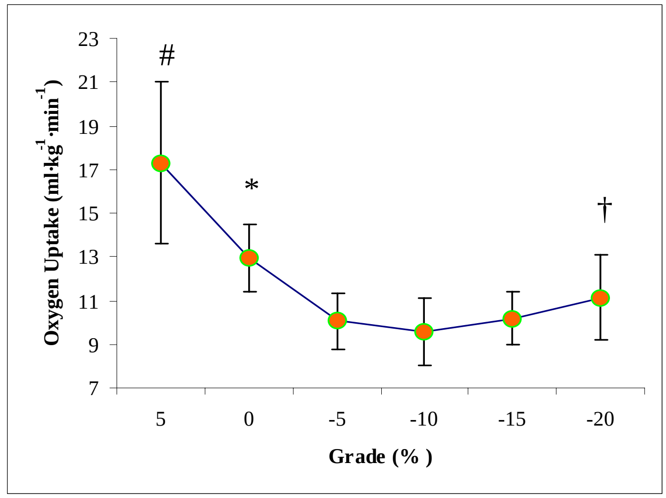

Figure 4. Oxygen uptake during graded treadmill walking bouts at 80.4 m/min.
 # = significantly greater than all other grades;
*** = significantly greater than all other grades except +5 and -20%;**

Pulmonary Ventilation

The only significant effect for V_E was grade (P<0.0001). Since there was no age effect observed, data are collapsed across age and the main effect for grade was analyzed. V_E was significantly greater while walking uphill than at any other grade (Figure 5). Walking on the level and at all downhill grades elicited statistically similar values for V_E.

Rating of perceived exertion

Significant main effects were observed for both age (P=0.04) and grade (P<0.0001). Older subjects perceived the exercise session to be more effortful than younger subjects (10.07±0.71 vs. 9.33±0.62). With reference to grade, walking at 0% and -5% were perceived to require significantly lower effort than walking at 5% and -20% (Figure 6).

DISCUSSION

The original findings of this study center on the cardiovascular and metabolic responses to downhill walking in older individuals compared with younger individuals. Older participants had higher cardiovascular responses and perception of effort, but similar metabolic and ventilatory responses to positive, level, and negative grade walking than younger participants.

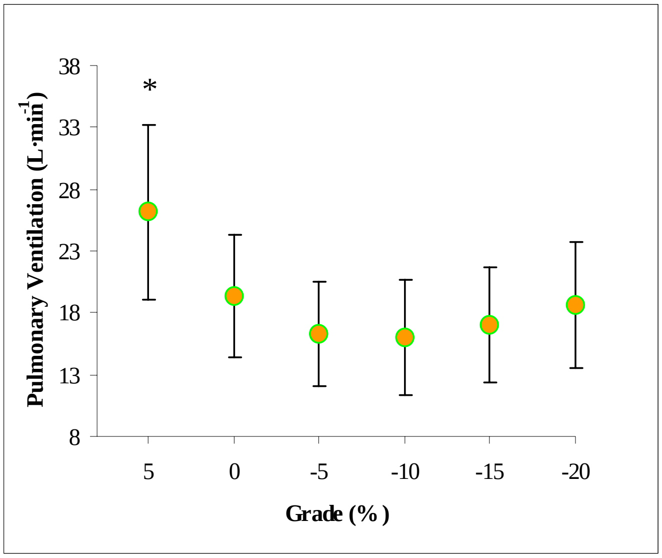

Figure 5. Pulmonary ventilation of during graded treadmill walking at 80.4 m/min.
*** = significantly greater than all other grades.**

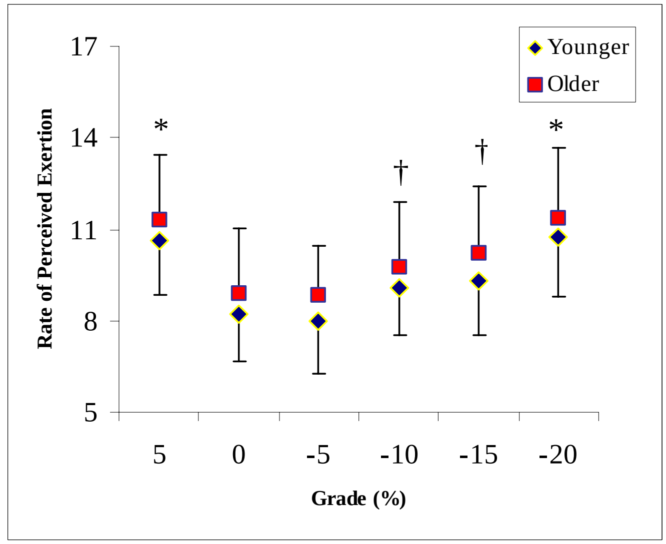

Figure 6. Perceived exertion during graded treadmill walking
at 80.4 m/min.
*** = significantly greater than 0 and -5%;**
† = statistically similar to all grades.

HR and RPP responses of the participants in the present study during downhill walking are consistent with what has been previously reported for more conventional exercise activities (e.g., level or uphill walking, cycling). For example, longitudinal (17), and cross-sectional studies on men (4,5,22) and women (23) have consistently reported significantly higher HR in older versus younger participants. The RPP, or double product, is directly related to myocardial VO_2 (7, 11) and is elevated to a greater extent in older than younger individuals during various modes of submaximal exercise (4,13). Our results also agree with those of other researchers who found higher SBP during submaximal exercise in older versus younger individuals (5,6,17). However after controlling for resting differences between age groups, we observed SBP to change similarly with exercise.

The VO_2 response to positive work or submaximal uphill exercise has previously been shown to be similar with aging in both longitudinal (2,17,18) and cross-sectional studies (10,23). The results of the present study provide evidence that the similarity in VO_2 during submaximal treadmill exercise between age groups includes downhill walking at grades as steep as -20 %. In addition, no difference in pulmonary ventilation was noted between our older and younger subjects who walked uphill, on the level, and at several downhill grades. Similar results have been found in subjects who have performed submaximal cycle ergometry (1, 14). However, other researchers have found different ventilatory responses with aging. Patrick et al. found no difference in the submaximal V_E response in a cross-sectional comparison of men of different ages who performed an incremental load cycle test, however, men in the older group were then tested annually for seven years and at final testing had significantly greater V_E when compared to initial values from the younger group (14). Age differences in V_E have been noted in other longitudinal studies of males performing submaximal treadmill exercise (17,18), as well as cross-sectional studies involving treadmill (5,10) and cycle exercise (9). These differences might be attributed to older subjects performing work at greater percentages of VO_2max than younger subjects or when at a younger age. Even though it is likely that the older subjects in the present study were exercising at a higher percentage of their VO_2max than the younger subjects, the lack of an age difference in V_E could be due to the nature of downhill walking, which seems to reduce metabolic and pulmonary responses.

Unlike the change from level to uphill work where an increase in grade results in a linear increase in cardiovascular and metabolic measures, these variables exhibit a curvilinear response during downhill walking. The curvilinearity of the response may be explained by the effect of gravity associated with this mode of exercise. Gravitational force increasingly assists with the work of performing the activity as the negative slope becomes steeper, thus reducing the physiologic work required of the body. Physiologic work continues to decrease as the negative grade becomes greater until the point at which the body is required to generate braking forces due to the steepness of the slope. Further increases in the negative grade then increase physiological work, reflective of the greater braking requirements.

Specialized treadmills with a negative slope capacity are now being manufactured. Thus, it becomes important to characterize physiological responses to negative grade work in order to understand the consequences of predominantly eccentric exercise. Based on observations in the present study, downhill walking at slight negative grades may be efficacious with regards to cardiovascular and metabolic responses within certain contexts. For example, downhill walking is an activity with the ability to enhance physical movement without placing undue cardiovascular or metabolic stress on an individual. In other words, an individual can walk at a faster speed on a negative slope than on the level or uphill and still have lower cardiovascular and metabolic responses. This could be important for persons initiating an exercise or rehabilitation program with limitations on the level of stress that can be tolerated. Since it can feel awkward to walk at a very slow speed, downhill walking could be employed at a pace that might be more comfortable and without any added cardiovascular and metabolic stress. It should be noted that certain studies have employed negative grade exercise with the intent of inducing muscle soreness and damage (19,20), and there exists the probability that these side effects will occur in previously sedentary individuals who incorporate downhill walking into a beginning exercise program. However, research on repeated bouts of eccentric exercise has determined a protective effect from a single bout of eccentric exercise that persists for up to six months (12).

In conclusion, metabolic responses of healthy older men and women are similar to younger individuals during downhill walking. Age differences in some cardiovascular responses are due, at least in part, to higher resting values in older individuals. Additionally, walking at negative grades reduces cardiovascular and metabolic responses in a curvilinear manner, with lowest values observed between -5% and -10%. With regards to cardiovascular and metabolic stress, these findings indicate that incorporating downhill walking into exercise programs might be a safe alternative form of exercise for younger and older men and women.

Address for correspondence: James W. Navalta; Department of Health, Kinesiology, and Recreation; Southern Arkansas University, Box 9166, Magnolia, AR 71753-9166; E-mail: jwnavalta@saumag.edu

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