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Original Article

"Slow walking with turns" increases quadriceps and erector spinae muscle activity

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Abstract. [Purpose] To maintain an independent lifestyle, older adults should improve muscle strength and mass, or aerobic capacity. A new exercise pattern, called slow walking with turns, which incorporates turning as an extra load additional to walking. The purpose of this study was to measure oxygen consumption during exercise and muscle activity while turning. [Subjects and Methods] Recreationally active volunteers participated. The participants performed 20 turns per minute while walking back and forth over distances of 1.5 to 3.5 m. We measured oxygen consumption, heart rate, and rating of perceived exertion and performed electromyography during the exercise. [Results] The metabolic equivalents of the exercise were 4.0 ± 0.4 to 6.3 ± 4.0 Mets. Activity was significantly greater in the vastus medialis, vastus lateralis, and erector spinae during the turn phase of slow walking with turns than during the stance phase of treadmill walking. [Conclusion] These findings suggest that slow walking with turns may help to preserve the muscle strength and mass of the trunk and lower limbs that are needed to maintain an independent lifestyle. Slow walking can be performed easily by older people, and in slow walking with turns, the exercise intensity can be adjusted as required for each individual.
Key words: EMG, Mets, Turn

INTRODUCTION

Age-related changes in skeletal muscle result in loss of muscle mass and weakness. This leads to a decrease in daily physical activity in older adults, and can result in poor health and a need for professional care. Muscle loss and weakness cause serious health problems, such as decreased strength and aerobic capacity[1]. The World Health Organization (WHO) ranked lack of physical activity as the fourth leading cause of mortality worldwide[2]. According to WHO recommendations, older adults should aim to maintain or increase their daily amount of moderately or vigorously intense physical activity[3]. Many older people, particularly those 65 years of age or older, who are interested in enhancing their health do perform some kind of exercise training[4]; however, the chosen exercise often has a low intensity level (e.g., walking). This is not strenuous enough to effectively improve either muscle strength and mass or aerobic capacity[5–8]. Moderately intense exercise more effectively provides training benefits.

Hatamoto et al.[9] showed that turning during sports increased the energy cost of running and that the magnitude of the increase depended on both the turn frequency and running velocity. In this study, we examined a new exercise pattern called slow walking with turns (SWT), which incorporates turns to increase the work load of walking. We have already shown that SWT increases the exercise intensity relative to normal walking at the same velocity and hypothesized that the reason for this increase was extra muscle contraction resulting from the turns. The walking velocity and turn frequency is easily adjusted

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to provide an exercise intensity of 3 to 10 metabolic equivalents (Mets) over a 3-m distance, and it is thus easy to prescribe an exercise program tailored to individual needs[10]. In the current study, the SWT (tempo, turn frequency, and method of turning) was adjusted to reduce individual differences and make it easy to perform even for older people. The purpose of this study was to confirm the exercise intensity of SWT and examine the muscle activity during turns.

SUBJECTS AND METHODS

Eight recreationally active volunteers participated in order to confirm the exercise intensity of SWT. The participants' mean age was 24.9 (standard deviation (SD), 5.0) years, mean stature was 1.66 (0.10) m, and mean mass was 58.0 (6.8) kg. None of the participants had any injury that might have influenced their athletic performance. All participants performed SWT over five fixed distances and treadmill walking (TW) at five different velocities in random order. Oxygen consumption (VO_2), rating of perceived exertion (RPE), and heart rate (HR) were measured during each exercise.

During SWT, the participants walked back and forth over several fixed distances and performed 20 turns per minute. The distances were 1.5, 2.0, 2.5, 3.0, and 3.5 m; the average velocities for walking back and forth were 2.7, 3.6, 4.5, 5.4, and 6.3 km/h; and the cadence was 180 steps per minute. The participants took six steps for each distance during walking and three steps per turn. The TW velocities were set at 2.7, 3.6, 4.5, 5.4, and 6.3 km/h, which were the same velocities as during the walking portion of the SWT. The cadence was not controlled for TW in order to reproduce usual walking. All sessions consisted of 4 minutes of exercise at each velocity with 1 minute of rest between different velocities (Fig. 1). Step cadence during SWT was controlled using rhythmical music. When participants could not maintain the cadence, the trials were stopped and restarted.

All participants completed a familiarization session prior to the actual trial session. The experiments were conducted in an indoor facility with hard flooring, and the participants were instructed to wear the same indoor sports shoes for all trials. Turning consisted of three steps, a deceleration step, a change of direction step, and an acceleration step out of the turn. The turning technique was adapted from the cross-step turn, and participants turned towards the striding foot during the deceleration step. The participants practiced the cross-step turn technique until they could repeat it consistently. All participants were instructed to avoid food, caffeine, tobacco products, and alcohol for 3 hours prior to the exercise sessions.

During the exercise, the participants wore a face mask to collect exhaled gas, which was measured at 12-second intervals using an mass spectrometer (ARCO 2000; ARCO System, Chiba, Japan). The mean VO_2 of the last minute of each stage was used in the data analysis. The HR (Polar CE0537 HR monitor; Polar Electro, Kempele, Finland) was measured just before the end of each 4-minute stage, and subjective exercise intensity was assessed using the Borg RPE scale[11]. Measured VO_2 was converted into Mets (1 Met=3.5 ml/kg/min). All measurements are expressed as means ± standard deviation.

Second, the participants for measurement of muscle activity were six healthy men with a mean age of 25.0 (4.4) years, mean stature of 1.74 (0.05) m, and mean mass of 68.3 (5.0) kg. The participants performed SWT and TW in random order. The SWT protocol was the same as above-mentioned, except the walking distances were 1.5, 2.0, and 2.5 m. The TW velocities were 2.7, 3.6, and 4.5 km/h; these were chosen to be the same as the walking velocities during SWT. The activity of 11 muscles during SWT, TW, and isometric maximum voluntary contractions (MVC) was measured using electromyography (EMG) (LP-WS1221; Logical Product Corp., Fukuoka, Japan) to compare muscle activity during the stance phase of TW
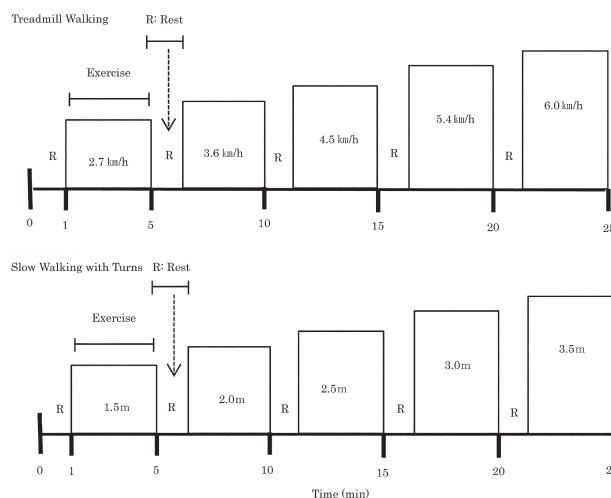
Fig. 1. Exercise protocols for TW and SWT
Each stage lasted 4 minutes, with a 1-minute rest between stages. SWT involved shuttle walking for a short distance, including 20 turns per minute. The distance in each stage was 1.5, 2.0, 2.5, 3.0 and 3.5 m.

and the turning phase of SWT.

The 11 muscles selected for EMG were the rectus abdominis (RA), erector spinae (ES), gluteus maximus (Gmax), gluteus medius (Gmed), hip adductor (HA), vastus lateralis (VL), rectus femoris (RF), vastus medialis (VM), biceps femoris (BF), tibialis anterior (TA) and soleus (Sol). All measurements were taken on the right side using wireless EMG sensors attached over the muscle belly. A foot sensor was attached to the right heel. Before application of the sensors, the skin area was shaved, cleaned with alcohol, and abraded with coarse tape to reduce skin impedance and ensure good adhesion of the sensors.

The MVC was measured using a manual method. In this method, the researcher manually fixed the posture of the participant, applying resistance against the direction of MVC. The participant then exerted an isometric MVC against the resistance while EMG was performed on the muscle being tested. The MVC for each muscle was measured as follows:

RA: The participant lay in a supine position with his knees positioned at 90° flexion and ankles restrained by an assistant. He then raised his shoulders and exerted enough force to further elevate their upper body while the researcher applied resistance against the direction of force.

ES: The participant lay face down with his hands on the back of his head and raised his upper body (trunk extension). The researcher applied resistance to prevent shoulder elevation.

Gmax: The participant lay face down with his knee flexed to 90° and extended his hip joint. The researcher applied resistance to prevent thigh elevation.

Gmed: The participant lay on his side with the test leg uppermost and abducted his mildly extended hip joint. The researcher applied resistance to prevent thigh elevation.

HA: The participant lay on his side with the test leg down and resting on the bed. The upper leg was abducted to 25° and supported by the experimenter. The researcher then applied resistance while the participant attempted to elevate (adduct) the test leg.

VL, RF, and VM: The participant sat on a chair with back support. His trunk was secured with a belt and his feet did not touch the floor. His hip and knee joints were fixed at 90° angles by fastening a belt around his lower legs. He then extended his knees against the resistance of the belt to allow for measurement of the MVC.

BF: The participant lay face down on the floor with his lower legs held in an upright position perpendicular to the floor, knees flexed at 90° and hips flexed at 0°. He then tried to further flex his knees against resistance applied by the researcher.

TA and Sol: The participant sat horizontally on a tilt table with his knees fixed to the table and his ankles in a neutral position (0° dorsi/plantar flexion) and his feet fastened to a foot cradle with a belt. He then made maximal attempts to dorsiflex and plantar flex his ankle against the resistance of the belt.

The MVCs were exerted for 5 seconds per trial. Two trials were conducted for each muscle, with a rest of 2 minutes or more between trials. The EMG sampling frequency was 1,000 Hz. After the trials, the EMG data were downloaded onto personal computer (VAIO; Sony, Tokyo, Japan). The EMG data were full-wave rectified, and the integrated EMGs data were averaged during MVC over 1 second including the point at which the torque was maximal.

EMG values of SWT and TW were measured continuously for 60 seconds. The muscle activities during the stance phase of TW and the turn phase of SWT were calculated by integrating the EMG value in the reaction time of the foot sensor. Each EMG level was averaged for five times of turns in SWT and five steps in TW. The EMG data in SWT were adopted from five turns at the beginning of the exercise. In TW, the measurement was started after walking had become stable, and the data were adopted from first five steps. The averaged integrated EMG data during the actions were quantified and normalized as the values relative to those during MVC (i.e., %MVC). All statistical analyses were conducted using SPSS software (v21; IBM Corporation, Armonk, NY, USA). Differences between SWT and TW were assessed using t-tests in Experiment 1 and one-way analysis of variance in Experiment 2. Differences were considered significant when $p < 0.05$.

This study was approved by the Ethical Committee of Fukuoka University, Fukuoka, Japan (number 10-02-02), and informed consent was obtained from all participants. This study followed the guidelines of the World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects, as well as the Ethical Guidelines for Epidemiological Research outlined by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare, Japan.

RESULTS

Oxygen consumption during the last minute of each stage remained in a steady state with no difference between the 3rd and 4th minute from the start of the exercise. The results of Mets, HR and RPE were shown in Table 1. The Mets of SWT were significantly higher than those of TW at a velocity corresponding to walking of SWT ($p < 0.01$). The difference in Mets between SWT and TW appeared to be larger at slower speeds, but not significantly. The HR and RPE values were measured just before the end of each stage. There was no significant difference in HR and RPE except for the HR at distances of 3.6 and 4.5 km/h ($p < 0.05$), despite the significantly higher exercise intensity in the SWT.

Muscle activity was significantly greater in the ES, VL and VM during the turn phase of SWT relative to the stance phase of TW at all stages (Table 2). The activity of the ES, VL, and VM during the turn phase of SWT was about twice the activity level during the stance phase of TW. Further, the activity of Gmax and BF at 1.5 m and HA at 2.5 m during the turn phase of SWT was significantly greater than during the stance phase of TW. Increases in walking velocity in TW did not increase the activity levels of any of the assessed muscles.

DISCUSSION

The primary findings of this study were that SWT training increased VO_2 and the activity of the quadriceps and ES muscles relative to TW at the same velocity.

VO_2 was greater during SWT than during TW at the same velocity. The addition of turns caused more muscle contraction due to the acceleration and deceleration associated with the change of direction. We previously reported that VO_2 was increased by turns[10], and our current results confirm the results of our previous study. A turn involves deceleration, a change of direction, and acceleration, and this can be difficult for older adults who often suffer from balance disorders. Therefore, in this study we divided the turn phase into three separate steps (acceleration, change of direction, and deceleration) to make SWT a simpler and easier exercise. This prolonged the turn time and reduced the walking distance per hour; however, the oxygen consumption during SWT was still significantly higher than during TW at the same velocity. Because of this, performing SWT at the fastest natural walking pace resulted in an exercise intensity of up to 6 Mets.

The physical activity of older people is significantly lower than the recommended amount[12], which results in decreased aerobic capacity, muscle mass and muscle strength, further reducing the amount of physical activity[1]. Because muscle weakness and loss are associated with physical disability[13–15], older adults must perform adequate physical activity to maintain or improve aerobic capacity and muscle mass and strength.

Walking is the exercise of choice for many older people. The popularity of walking is due to its safety and simplicity, the fact that it does not generally cause hemodynamic stress and the lack of requirement for special equipment. However, it is known that walking training (excluding race walking) has little effect on aerobic capacity or muscle strength and volume[5–8]. The regular walking speed of older adults is reportedly slow[16, 17], and thus walking is not a sufficiently intense exercise to result in aerobic or strength improvements. The walking speed of most older people is less than 3 Mets. However, the exercise intensity required to maintain and improve physical fitness in older adults is 3.0 to 6.0 Mets[18]. Adding turns while walking, as in SWT, increases the exercise intensity from light to moderate. Furthermore, because SWT did not result in significant increases in HR or RPE relative to TW in the present study, many older people should be able to perform SWT easily and safely.

Table 1. Mets, RPE and HR for SWT and TW

	TW					SWT				
	2.7 km/h	3.6 km/h	4.5 km/h	5.4 km/h	6.3 km/h	1.5 m	2.0 m	2.5 m	3.0 m	3.5 m
Mets	2.6 ± 0.2	3.0 ± 0.2	3.5 ± 0.2	4.2 ± 0.3	5.2 ± 0.2	4.0 ± 0.4***	4.4 ± 0.5***	4.8 ± 0.4***	5.3 ± 0.6**	6.3 ± 0.6**
RPE	7.8 ± 1.0	8.1 ± 1.0	9.3 ± 0.9	10.4 ± 0.7	11.6 ± 0.7	8.5 ± 1.6	9.0 ± 1.5	9.4 ± 1.5	10.5 ± 1.3	11.6 ± 1.1
HR	84 ± 16	89 ± 14	93 ± 12	102 ± 8	112 ± 10	89 ± 15	98 ± 17*	102 ± 18*	107 ± 22	119 ± 19

Mean ± SD

Distances of 1.5, 2.0, 2.5, 3.0 and 3.5 m during SWT correspond to average walking velocities of 2.7, 3.6, 4.5, 5.4, and 6.3 km/h, respectively.

*$p<0.05$, **$p<0.01$ and ***$p<0.001$, comparison between SWT and TW at a velocity corresponding to walking of SWT.

Table 2. % MVC at the turn phase in SWT and the stance phase in TW of each muscle

	TW			SWT		
	2.7 km/h	3.6 km/h	4.5 km/h	1.5 m	2.0 m	2.5 m
RA	6.8	6.8	7.2	8.7	9.0	9.5
ES	5.5	6.2	7.5	14.5**	17.7**	15.5*
Gmax	5.5	7.2	10.1	8.5*	9.3	9.3
Gmed	10.7	10.6	11.3	11.5	12.7	12.6
HA	10.9	10.8	11.3	13.0	13.2	13.9*
VL	7.2	9.4	10.9	13.5**	13.5**	13.7**
RF	9.3	9.4	10.6	10.4	11.0	11.5
VM	4.7	5.0	5.7	10.3**	9.9**	10.9**
BF	11.3	12.3	12.4	15.9*	16.6	18.0
TA	10.0	11.8	13.7	14.2	13.3	13.6
Sol	13.3	15.5	17.5	17.6	20.3	21.9

*$p<0.05$, **$p<0.01$, comparison of muscle activity levels for SWT and TW at a velocity corresponding to walking of SWT.

We focused on muscle activity during the turn phase of SWT and compared it with the muscle activity during the stance phase of TW. The activity levels of the ES, VL, and VM were significantly greater while turning during SWT than during TW. This indicates that it is possible to increase the stimulation provided by regular walking by adding turns. Performing SWT instead of TW or simple straight walking may increase the strength of the knee and trunk extensors and muscle mass in the thigh and back.

Only a few studies have examined the effect of aerobic training on muscle strength and mass in older adults. Several cross-sectional studies have reported no significant differences between the leg strength and power of chronically aerobically trained and sedentary older people[19, 20]. Longitudinal studies have shown no effect of regular walking training on leg strength and muscle mass[5–8]. The few studies that have shown positive effects of exercise on the mass and strength of the thigh muscles used brisk walking, jogging at 85% HR reserve[21], or interval training at 70% to 85% VO_2 peak[6, 22] as exercises. Cycling at 70% VO_2 max or 80% HR reserve has been shown to increase quadriceps muscle strength and power and thigh muscle volume[23, 24]. Aerobic exercise can increase muscle strength and mass depending on the intensity, frequency, and duration of the exercise. Importantly, to facilitate the development of a training habit, it is better that exercisers do not feel fatigue. Muscle strength significantly decreases when training is stopped; if training is resumed, its muscle strengthening effects are then less than they were previously[24]. Therefore, training should consist of exercises that are easy to continue. However, no studies have examined the effects of moderate endurance training (except for the bench step exercise[25]) on muscle strength.

The muscle activity of the VM during the turn phase of SWT was twice that seen during regular walking. Gazendam and Hof[26] reported the EMG profile during walking and jogging at 4.5 to 8.1 km/h; the EMG amplitude of the VM during the turn phase of SWT at 2.5 to 4.5 km/h in the current study was equal to what they reported during jogging at 8.1 km/h and brisk walking at 5.2 km/h. Thus, muscle activity that occurs while turning during SWT is equal to or greater than that seen during brisk walking or jogging. Because brisk walking and jogging have been confirmed to increase the muscle mass and strength of the thigh, our results suggest that SWT may also increase muscle mass and strength. Additionally, in a study comparing running and soccer in young and middle-aged subjects, the VL cross-sectional area and knee extensor strength were increased only by soccer[27, 28]. Training consisting of varying intensities and motions, such as SWT, has the potential to result in muscle hypertrophy and strength gains. At present, the research on muscle hypertrophy and strength gains caused by aerobic exercise has been limited to the lower limbs; further studies clarifying the effects of aerobic exercise on the muscles of other regions of the body, including the trunk, are needed.

The purpose of this study was to investigate whether SWT is useful for older people; however, we chose, young people as subjects. The characteristics of walking in older people are a decreased: stride caused by a reduced range of motion of the hip and ankle, a lower walking speed cause by the decreased stride, and extension of the two-leg supporting moment. However, walking adjusted to 180 strides per minute is unlikely to be affected by the characteristics, showing an operation pattern similar to that of young people[29]. In future work we will examine the effects of SWT on the physical function of the older adults in terms of increased aerobic capacity, prevention of muscle ageing, and improvement in balance.

Our findings suggest that SWT may help to preserve the muscle strength and mass of the trunk and lower limbs that is needed to maintain an independent lifestyle. Even slow walking can be performed easily by older people, and the exercise intensity can be adjusted as required for each individual. Furthermore, SWT requires the participant to have greater control of their center of gravity during lateral, sagittal, and up and down movements than during regular walking. Complex exercise training consisting of strength, balance, and walking training for older adults has been expected to effectively prevent falls[30]. SWT is done over short distances (maximum of 3.5 m), which allows its performance in a small indoor space and eliminates the need for supervision or equipment. SWT can be introduced to many older adults as a home exercise.

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