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Original Article

Effects of a Structured 8-week Nordic Walking Exercise Program on Physical Fitness in the Japanese Elderly

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ABSTRACT

Although Nordic Walking (NW) is a fast growing form of exercise in Europe. This study aimed to determine how a supervised NW exercise program affects basic fitness and examine its application as a sports activity for supporting the health of elderly. Forty participants were randomly assigned to the NW group (NW: 66±4 years old) or the control group (CO: 68±4 years old). Functional measurements included the sit-and-reach test, timed-up and go test (TUG), knee extensor strength assessment, and incremental shuttle walking test (ISWT). Throughout the ISWT, the heart rate (HR) of each subject was monitored. Static balance was measured with a force platform under four test conditions: normal standing, with eyes open and closed, semi-tandem, and tandem standing with eyes open. These measurements were taken before and after the 8-week NW program. The NW group exercised 60–90 min/session, 3 times/wk. Results showed that NW training had positive effects on the TUG test, flexibility, and knee extensor strength ($p < 0.05$) assessments. In contrast, knee extensor strength was decreased in the CO group throughout the duration of the study ($p < 0.05$). The NW group walked with significantly lower HRs from level 1 (1.8 km/h) to 5 (4.3 km/h) after training ($p < 0.05$). However, there was no significant difference in HRs for the CO group during the ISWT. There were no significant changes between the groups in any of the four platform tests. In conclusion, the 8-week NW program either improved or maintained flexibility, leg strength, and cardiorespiratory endurance with no measurable changes in static balance.

＜Key-words＞
nordic walking, cardiovascular fitness, static balance, elderly, muscle strength

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I. Introduction

Life expectancy and retirement age are increasing worldwide, Japan being the fastest aging nation (Statistics Bureau, Japan, 2018). Because of this change, maintenance of mobility has become a vital part of a good quality of life and working capacity. In aging neuromuscular control declines (Delbono, 2003) and muscle mass (Nair, 2005) and cardiorespiratory performance decrease (Sanada, Kuchiki, Miyachi, et al., 2007). These factors promote instability in common daily movements thereby increasing the risk of falls. It is a well-known phenomenon that the improvement of mobility and balance prevents falls and fractures (Kannus, Sievänen, Palvanen, et al., 2005).

Nordic Walking (NW) is a popular and fast growing form of exercise in Europe. Previous studies have demonstrated that NW has both short-term and long-term effects on cardiorespiratory performance. Studies by Porcari, Hendrickson, Walter, et al. (1997) and Church, Earnest & Morss (2002) have found that walking using poles resulted in significant increases in VO_2, caloric expenditure, and heart rate (HR) responses in comparison to walking without poles on a treadmill. Conversely, Schiffer, Knicker, Hoffman, et al. (2006) found that NW resulted in fairly small increases in HR and VO2. The pooling technique (e.g. intensity of pooling) seems to be the reason for inter-individual differences and the degree of improvement in oxygen consumption (Church, Earnest & Morss, 2002). The increase is due to increased muscle activity in the upper body muscle groups (Koizumi, Tsujiuchi, Takeda, et al., 2008).

To the best of our knowledge, there are not many published studies available examining the long-term effects of Nordic Walking. Stoughton (1992) studied muscular and aerobic fitness responses before and after 12 weeks of exerstriding and walking training in sedentary women. In their study, the participants were subdivided into three groups: a walking group, a walking group with poles, and a control group. The maximal aerobic power increased significantly in both exercise groups, which was 8 and 19%, respectively, for each group. Muscular endurance improved by 37% in the Exertrider group and by 14% in the walking group. In contrast, Kukkola-Harjula, Hiilloskorpi, Mänttäri, et al. (2007) identified only moderate increases in peak VO_2 (2.5 ml/min/kg) after 13 weeks of training in 50–60-year-old sedentary women.

The results demonstrated that NW is a suitable exercise method for the elderly and NW may improve functional capacity safely and effectively in this population. However, the knowledge of how NW affects aerobic and functional capacity among the elderly is still lacking. Furthermore, randomized controlled studies are also needed with global participation (e.g. Japan). Thus, the aim of this study was to explore the effects of a structured, 8-week NW exercise program on mobility, functional capacity, and physical conditions in elderly Japanese men and women.

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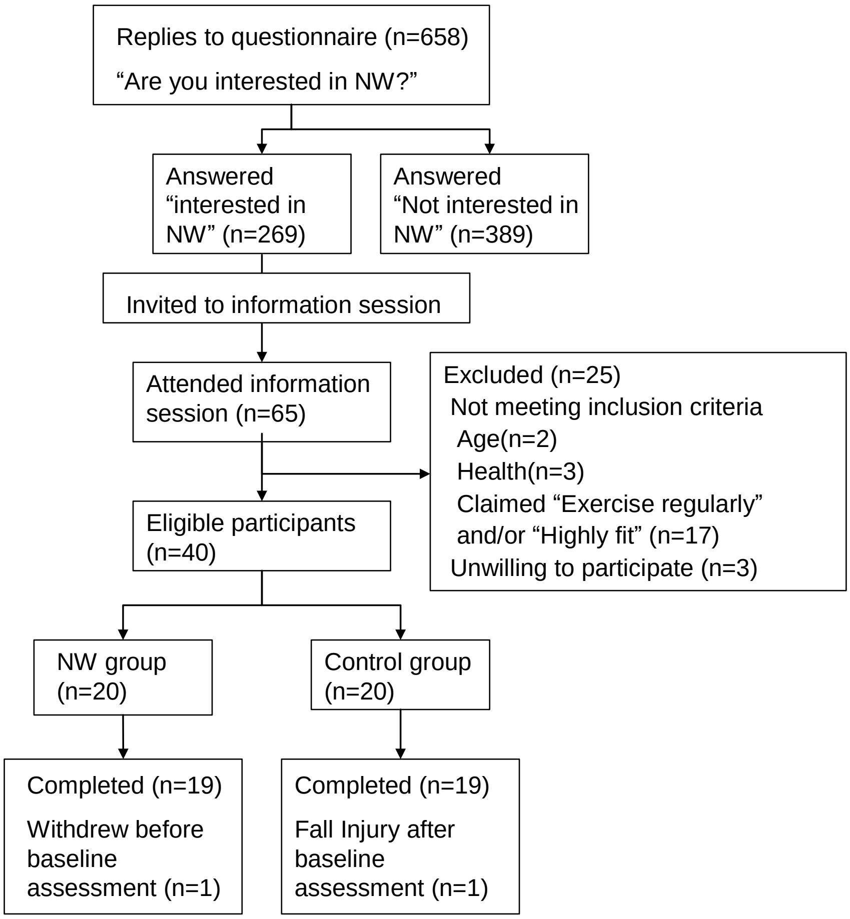
II. Subjects and Methods

1. Subjects and Procedures

Community dwelling elderly were recruited from annual medical checkups in Yamamoto town (Figure 1). A subject group was chosen from an age group ranging in age from 60–70 years. All subjects were able to walk independently (i.e., not dependent on mobility aids) and stand (≥ 1 minute) and walk (≥ 1 km) without any assistance. To prevent potential confounding effects from other exercise programs, volunteers who regularly (≥ 1 day per week) participated in a supervised exercise program were excluded.

The study plan was explained and written informed consent was obtained. Forty subjects were stratified according to age and sex, then the community nurse who was independent of this study randomly assigned the participants to an exercise (n = 20) or control (n = 20) group. Group assignment was revealed following baseline testing. All studies were performed according to a research protocol approved by the Ethical Committee of the Tohoku Fukushi University.



<Figure 1> Flowchart of recruitment and inclusion of study participants.
NW=Nordic walking

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NW poles were provided by Exel Ltd. Each exercise in the NW group was supervised by 2–3 trainers and community volunteers experienced in NW. The trainers were certified as Activity Leaders and/or Basic Instructors by the Japanese Nordic Fitness Association (JNFA). The NW group exercised for about 60 min (5–10 min warm-up, 20 min NW, stretching between sessions, 20 min NW and 5–10 min cool-down), 3 times per week for 8-weeks. Intensity of the NW was based on their rate of perceived exertion (RPE), which did not exceed 13. The walking distance progressed through three stages: the 1st stage, 1.6–2.4 km (1–8 sessions); 2nd stage, 2.4–3.6 km (9–17 sessions), and the 3rd stage, 3.6–4.8 km (18–24 sessions), At the 1st stage of the training program, subjects were provided technical instructions for about 20 minutes after the warm up.

At the 2nd session and 11th session, 800 m walking time, RPE, and HR (Polar Electro, Kempele, Finland) were recorded to assess the physiological intensity of NW. HR was analyzed during the last 400 m. RPE was assessed immediately after completing 800 m of NW.

For the control group, the community nurses provided phone calls every other week to discuss health-related topics, which were not related to physical exercise. Otherwise, they were asked to continue their usual daily activities. All subjects were asked to refrain from initiating any other new exercise programs, or otherwise consciously changing their activity levels during their participation in the study.

2. Physical Fitness Measurements

After the 8-week NW exercise period, the same measurements were repeated for all subjects. The physical fitness tests included to sit-and-reach test for flexibility, timed-up and go test (TUG) (Podsiadlo & Richardson, 1991) for functional mobility, knee extensor strength for lower extremity strength, and the incremental shuttle walking test (ISWT) (Singh, Morgan, Scott, et al., 1992) for endurance fitness. Flexibility was measured by a sit-and-reach test (Yamamoto, Kawano, Gando, et al., 2009) using a digital flexibility testing device (T.K.K.5112; Takeikiki Co. Ltd, Tokyo, Japan). Isometric knee extensor strength was measured bilaterally using a Musculater GT-50 (OG-giken Co. Ltd., Okayama, Japan). The subjects sat on a specially designed chair secured with straps fastening the trunk and thighs to fix their hip joint at 90 degrees and a knee joint at 70 degrees. The lower leg was tightly strapped to a strain gauge transducer placed just above the ankle. Subjects were asked to exert three-second isometric maximal voluntary contractions against the strain gauge transducer. Two attempts were carried out at three-minute intervals. The real-time force applied to the force transducer was displayed and the peak value was recorded. Peak extension torque was calculated by the multiplication of force with the length of lever arm for each subject. In each of the functional tests, the best of two trials was chosen for analysis.

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In the TUG (Schiffer, Knicker, Hoffman, et al., 2006) assessments, an armchair of comfortable height was used and a distance of 3 m was marked with a line of tape and cone on the floor. The starting position was sitting with hands resting on the arms on their thighs. The participants turned around and walked back to sit down in the chair again. They were instructed to perform the TUG at their normal and maximal speed and they performed one trial before they were timed. The timing of the TUG started when the participant's back came off the back of the chair, and stopped when their buttocks touched the seat of the chair again.

For the ISWT, subjects were instructed to walk between two markers (visible tape on the floor) set 10 m apart in a straight line on the flat surface. Pre-recorded bleeps on a CD were emitted from a CD player. At 1-min intervals the time between each bleep shortened, indicated by a triple bleep, and the number of shuttles increased. The ISWT consisted of a maximum of 12 levels, when subjects failed to achieve the set pace, the number of shuttles they had completed was recorded. Throughout the ISWT, each subject's HR (Polar Electro, Kempele, Finland) was monitored. The test stopped when the subject did not reach the tape at the same time as the bleep by 0.5 m on two consecutive occasions, showed signs of physical injury or distress (as indicated by HR), or no longer wished to continue.

Using the force platform, balance was tested in four different test conditions: (1) normal stand test with eyes open on the balance platform (HUR Labs Oy, Tampere, Finland) with a clearance of 2 cm between the heels, at an angle of 30 degrees between the medial sides of the feet; (2) normal stand test with eyes closed; (3) semi-tandem test with eyes open, the participant placed the heel of one foot along the side of the big toe of the other foot; (4) full tandem test with eyes open, the feet were positioned heel-to-toe along the midline of the platform. The participants performed one trial of each test in the following order (1) to (4) and repeated the trail after a few minutes' rest. We instructed the participants to gaze at a point marker at eye-level at a distance of 2 m and to stand as motionless as possible during all tests. The data sampling rate was set to 50 samples/second, and test duration was 30 seconds for each condition. For data analysis, we used standard posturographic parameters derived from the center-of-pressure (COP), 90% confidence ellipse area (C90A), trace length (TL), sway average velocity (SaV), and standard deviation velocity (StdV). In the analysis of the balance data, the subject's best trial was chosen.

3. Statistical analysis

Data were analyzed using the SPSS statistical software package, version 14.0 (SPSS Inc., Chicago, USA). Comparisons between the two groups were performed using either the Mann-Whitney test or the chi-squire test for nonparametric variables and the independent samples t-test for parametric variables. The training parametric data were

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analyzed by repeated-measures ANOVA with post-hoc test. All data with a $p < 0.05$ confidence level were considered statistically significant.

III. Results

1. Subject Characteristics

One participant from the NW group did not complete the study, and the subject's baseline data were excluded. Attendance at training sessions for the NW group was 90%. There were no statistically significant differences between the NW and control group characteristics at baseline (Tables 1 & 2). No training-related injuries were reported in the NW group.

<Table 1> Characteristics of participants in the Nordic Walking group and the Control group

	NW			CO			
Variable	Mean		SD	Mean		SD	*P*-value
No. participants (Male/Female)	19 (5/14)			19 (5/14)			NS
Age (yr)	66.7	±	4.5	68.0	±	4.6	NS
Height (cm)	152.6	±	6.9	155.3	±	7.4	NS
Weight (kg)	60.4	±	9.7	58.0	±	8.1	NS
BMI (kg・m^{-2})	25.9	±	3.8	24.1	±	2.9	NS
SBP (mmHg)	148	±	20	140	±	17	NS
DBP (mmHg)	86	±	13	82	±	11	NS
HR (bpm)	83	±	14	84	±	13	NS
Hypertension	9			6			NS
Diabetes	3			4			NS
Dyslipidemia	7			6			NS
Heart disease	3			3			NS
Osteoporosis	1			1			NS
Musculoskeletal pain	8			14			NS

Values are expressed as mean and SD. The last column shows the significance values (p) of the differences. Abbreviations: NW=Nordic walking group, CO=Control group, SD=standard deviation, BMI=Body Mass Index, SBP=Systolic Blood Pressure, DBP=Diastolic Blood Pressure, HR=heart rate

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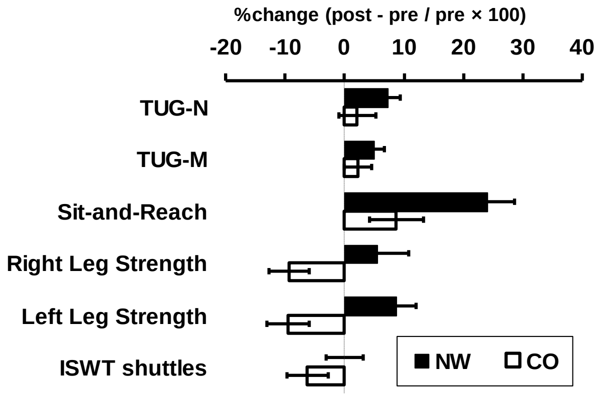
<Table 2> Summary of results-physical fitness tests at baseline in the Nordic Walking group (NW) and the Control group (CO).

Variables		NW Mean		SD	CO Mean		SD	P-value
TUG-N	Sec	8.4	±	0.9	8.1	±	1.1	NS
TUG-M	Sec	6.4	±	0.8	6.1	±	1.1	NS
Sit-and-reach	Cm	27.7	±	7.2	31.3	±	9.0	NS
Leg strength	Right, Nm	80.8	±	23.9	97.5	±	39.2	NS
	Right, Nm/kg	1.34	±	0.37	1.57	±	0.52	NS
	Left, Nm	89.2	±	29.0	110.0	±	36.2	NS
	Left, Nm/kg	1.50	±	0.47	1.69	±	0.48	NS
ISWT	No. of shuttles	45.1	±	10.6	50.2	±	12.3	NS

Values are expressed as mean and SD. The last column shows the significance values (p) of the differences. Abbreviations: TUG-N=timed-up-and go test at normal walking speed, TUG-M=timed-up and go test at maximal walking speed, ISWT=incremental shuttle walking test.

2. Changes observed

Although body weight in the NW was unchanged after the training period, there was a slight but significant increase in the control group (**p** < 0.05). During the 2nd and 11th training sessions, the average HR during the 800 m NW increased from 122±17 bpm (2nd session) to 130±16 bpm (11th training session) at a self-selected comfortable speed. The average walking speed was significantly (**p** < 0.05) faster at the 11th training session (1.46±0.14 m/s) compared to the 2nd session (1.58±0.15 m/s), whereas their RPE was similar for all sessions (2nd: 12.3±1.7 vs. 11th: 11.6 ±1.3).



<Figure 2> Percentage of change in physical fitness scores from baseline to 8 weeks after the Nordic Walking exercise (NW) and control treatment (CO).
TUG-N: timed-up-and go test at normal walking speed.
TUG-M: timed-up and go test at maximal walking speed.
ISWT: incremental shuttle walking test.

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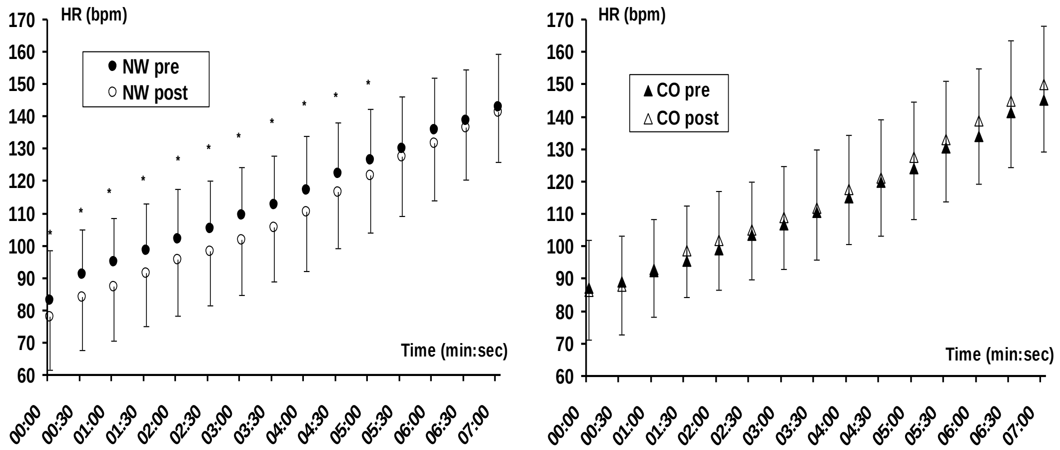
Figure 2 shows the results of the physical fitness test. In the NW group, training had positive effects ($p < 0.05$) on the TUG, flexibility, and knee extension strength (left leg). In contrast, bilateral knee extension strength was decreased in the control group during the same period ($p < 0.05$). There were no statistically significant differences between the first and second ISWT in the number of shuttles completed in the NW group (baseline: 45.1±10.6 shuttles vs. post NW: 44.4±9.7 shuttles). However, the control group performed fewer shuttles in the second test compared to the first test (baseline: 50.2±12.3 shuttles vs. post-Control: 47.1±9.8 shuttles). All subjects achieved more than level 6 (walking speed at level 6: 82 m/min). During the ISWT, the NW group walked with significantly lower HRs from level 1–5 after the 8-week training period ($p < 0.05$). However, there was no difference in HRs in the control group (Figure 3).



<Figure 3> Heart rate (HR) response during the incremental shuttle walk test for the Nordic walking (NW: left graph) and control (CO: right graph) groups at baseline (Pre) and 8 weeks after the intervention period (Post).

The symbols and error bars express mean ± SD. *$p < 0.05$ pre- vs. post-intervention period within the group.

In the force platform measurements (Table 3), all subjects were able to perform four standing positions for 30 s periods. As expected, average higher values were observed for most variables in the tandem stance. TL and SaV were significantly different between the groups in the normal standing condition with only eyes open ($p < 0.05$), however, there were no statistically significant changes between the groups in any of four balance tests.

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<Table 3> Mean and standard deviation (SD) of balance variables on the force platform in the Nordic walking group (NW) and the control group (CO).

COP movement variable		TL (mm)		C90A (mm²)		StdV (mm/s)		SaV (mm/s)	
(1) Eyes open		Mean	SE	Mean	SE	Mean	SE	Mean	SE
CO	Pre	325.1	17.6	266.4	35.1	6.3	0.3	10.8	0.6
	Post	365.7*	20.3	286.1	45.1	6.8	0.6	12.2*	0.7
NW	Pre	341.9	22.4	242.7	35.0	6.1	0.4	11.4	0.7
	Post	347.1	22.1	236.0	27.1	6.0	0.3	11.6	0.7
(2) Eyes closed									
CO	Pre	450.1	28.1	393.0	60.3	8.7	0.6	15.0	0.9
	Post	445.0	25.2	381.4	69.1	8.2	0.6	14.8	0.8
NW	Pre	450.9	33.0	319.5	38.2	8.0	0.5	15.0	1.1
	Post	476.3	26.8	362.9	50.1	8.3	0.5	15.9	0.9
(3) Semi-tandem									
CO	Pre	494.6	25.4	386.5	53.7	9.0	0.5	16.5	0.8
	Post	467.2	20.9	365.6	56.8	8.7	0.4	15.6	0.7
NW	Pre	491.4	31.7	283.6	32.2	8.5	0.5	16.4	1.1
	Post	499.6	37.3	336.1	39.1	8.7	0.6	16.7	1.2
(4) Tandem									
CO	Pre	595.1	31.3	337.0	27.9	10.7	0.5	19.8	1.0
	Post	652.4	37.4	385.2	49.7	11.7	0.6	21.7	1.2
NW	Pre	650.2	53.6	304.7	31.5	10.8	0.7	21.7	1.8
	Post	672.7	55.7	387.6	83.4	11.1	0.6	22.4	1.9

Outcome variables were: TL = trace length, C90 Area = area of the 90% confidence ellipse, StdV = Standard deviation velocity, SaV = sway average velocity. *$p < 0.05$ pre- vs post-intervention period within group.

IV. Discussion

This study indicates that 8 weeks of the NW program either improved or maintained functional mobility, flexibility, and leg strength with measurable changes in static balance as assessed by the balance platform. As training progressed, NW became a relatively high intensity activity for the elderly.

In older adults, NW or walking with poles seems to have had potential benefits with reduced load to the lower extremities at a controlled walking speed (Strutzenberger, Rasp, Schwameder, 2007) as well as enhanced cardiorespiratory fitness (Stoughton, 1992) Kukkonen−Harjula, Hiilloskorpi, Mänttäri, et al., 2007). However, a recent study showed the lack of a loading effect. Despite its popularity, few studies have assessed the training effects on functional capacity and balance in the elderly. Improvement of the TUG and flexibility produced better results.

Recently, Kukkonen−Harjula, Hiilloskorpi, Mänttäri, et al. (2007) reported that improvement of peak VO_2 was modest (from 26.0 to 28.4 ml/kg/min) in middle-aged (54±3 years old) sedentary women in response to 13 weeks of training, four times per week for 40 minutes per day. They also reported that normal walking, rather than NW improved leg strength assessed by the one leg squat test. Unfortunately, information regarding walking speed, distance, or training environment during the training period was not

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reported in the previous study (Kukkonen−Harjula, Hiilloskorpi, Mänttäri, et al., 2007). We found that NW speed was also significantly faster after the 11th session of training. In addition, isometric knee extensor strength improved after the NW training.

To assess endurance capacity for the elderly in the present study, we used the ISWT. Oxygen uptake has been correlated with distance walked during ISWT in post-myocardial infarction patients and in healthy adults (Woolf-May & Ferrett, 2008). A training effect was observed in the NW group evidence by a decrease in exercise HR at a given submaximal walking speed. After training, however, the number of shuttles achieved at the ISWT did not increase in the NW group. In contrast, there was slight but statistically significant decrease in the number of shuttles in the control group. Although walking with a pole assists subjects to walk faster and widen step length, the shorter heights (range 152–155 cm) of the subjects might have limited their ability to keep up with the speed at higher stages of the ISWT.

Therefore, with a proper poling technique, NW increases the length of steps and promotes walking at a higher speed than walking at normal speed with a reduced subjective perception of fatigue and increased safety of walking with poles (Church, Earnest & Morss, 2002; van Eijkeren FJM, Reijmers RSJ, Kleinveld, et al., 2008) in the elderly. Based on the peak HR during the ISWT, we assessed the individual's training intensity by expressing the 800-m walk HR as a percent of HR reserve (%HRR) at the 2nd and 11th sessions. Although, the RPEs were similar between the sessions (2nd: 12.3±1.7 vs. 11th: 11.6 ±1.3), their walking speed improved significantly from the 2nd to the 11th session. In addition, the %HRR values also increased from 68±15% during the 2nd session to 77±17% during the 11th session. According to the American College of Sports Medicine guidelines, exercise at an intensity equivalent to 60–84% of HRR is considered "hard" or "vigorous" (Woledge, Birtles & Newham, 2005). NW is often viewed favorably as exercise in terms of energy expenditure. However, with regard to the safety of this type of exercise among the elderly, precautions should be taken given the discrepancy between subjective feeling of intensity (RPE) and the physiological basis of intensity (i.e., %HRR). Traditionally, moderate (40–59 %HRR) intensity activities are preferred among older adults, especially for those with chronic diseases. Schiffer, Knicker, Hoffman, et al. (2006) reported that both HR and oxygen consumption responses were similar for NW and jogging at both 6.4 km/h and 7.5 km/h. They also found that based on lactate concentrations, training recommendations derived from walking tests would underestimate NW loads when training intensity was determined using monitoring of HR. Moreover, an increase in walking speed led to a more dynamic walking pattern and simultaneously led to increased ground force in the first part of the stance phase (Strutzenberger, Rasp & Schwameder, 2007) while the load on the knee joint may also increase (Thapa, Gideon, Brockman et al., 1996). Therefore, when introducing NW to previously sedentary elderly individuals, an initial physical activity assessment is

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essential and should include monitoring of exercise intensity using a HR monitor or pulse counting to improve safety.

Our findings provide further evidence for walking and NW as effective forms of exercise that help to maintain or improve endurance capacity. Previous studies, using maximum oxygen treadmill testing in walking programs of greater than 12-week duration, found increases in fitness ranging from 8–30% (Paillard, Lafont, Costes-Salon, et al., 2003; Hardman & Hudson, 1994). In agreement our results, Kukkonen-Harjula et al. (Kukkonen−Harjula, Hiilloskorpi, Mänttäri, et al., 2007) also reported that 13 weeks of NW attenuated the submaximal cardiovascular response and enhanced the peak VO_2 level as much as normal walking.

Eight weeks of NW did not affect balance variables. Walking is an unstable activity and lateral sway during walking is increased in older adults (Woledge, Birtles & Newham, 2005). An increased in COP movement in the force platform balance test was seen in older individuals (Thapa, Gideon, Brockman, et al, 1996; Maki, Holliday & Topper AK, 1994; Era, Schroll, Ytting, et al., 1996) and some prospective studies showed that increased COP movement correlated with risk of falls (Bergland, Jarnlo & Laake, 2003; Bergland & Wyller, 2004; Stela, Smitb, Pluijma et al., 2003). With increasing age, step width increased and step length and stride velocity decreased (Winter, 1991). In agreement with the results of a previous study (Era, Sainio, Koskinen, et al, 2006), tandem stands are challenging for elderly. Tandem standing, in particular, requires muscle strength and endurance to maintain the posture against a narrowed base of support in the medio-lateral direction (Jonsson, Seiger & Hirschfeld, 2005). Reduction of foot impact and support from the poles while walking may be responsible for the lack of changes in the balance variables assessed by the balance platform tests. Furthermore, our subjects were relatively healthy, and their balance was very good even before intervention (Era, Sainio, Koskinen, et al, 2006). Previous studies have shown that both in healthy and active older individuals falls were more often associated with the demands of the activity they engaged in (Hill, Schwarz, Flicker et al., 1999; Bath & Morgan, 1999). Therefore, the engagement in previous physical and sports activities might have contributed to the lack of change observed in the static balance test in our study. Further studies need to assess the impact of prolonged (i.e. 3 months or more [Howe, Rochester, Neil, et al., 2011]) of NW exercise on both static and dynamic balance controls in this population.

In conclusion, a structured 8-week NW exercise program achieved good results in maintaining functional mobility in elderly Japanese men and women. Static balance assessed by the balance platform, however, did not change during the intervention period.

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