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Effect of Pole Weight on Nordic Walking

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Abstract**—**The purpose of study was to investigate the effect of varying pole weights on energy expenditure, upper limb and lower limb muscle activity as Electromyogram during Nordic walking (NW). Four healthy men [age = 22.5 (±1.0) years, body mass = 61.4 (±3.6) kg, height = 170.3 (±4.3) cm] and three healthy women [age = 22.7 (±2.9) years, body mass = 53.0 (±1.7) kg, height = 156.7 (±4.5) cm] participated in the experiments after informed consent. Seven healthy subjects were tested on the treadmill, walking, walking (W) with Nordic Poles (NW) and walking with 1kg weight Nordic Poles (NW+1). Walking speed was 6 km per hours in all trials. Eight EMG activities were recorded by bipolar surface methods in biceps brachii, triceps brachii, trapezius, deltoideus, tibialis anterior, medial gastrocnemius, rectus femoris and biceps femoris muscles. And heart rate (HR), oxygen uptake ($\dot{V}O_2$), and rate of perceived exertion (RPE) were measured. The level of significance was set at a = 0.05, with $p < 0.05$ regarded as statistically significant. Our results confirmed that use of NW poles increased HR at a given upper arm muscle activity but decreased lower limb EMGs in comparison with W. Moreover NW was able to increase more step lengths with hip joint extension during NW rather than W. Also, EMG revealed higher activation of upper limb for almost all NW and 1kgNW tests plus added masses compared to W ($p < 0.05$). Therefore, it was thought either of NW and 1kgNW were to have benefit as a physical exercise for safe, feasible, and readily training for a wide range of aged people in the quality of daily life. However, there was no significant effected in leg muscles activity by using 1kgNW except for upper arm muscle activity during Nordic pole walking.

Keywords**—**Nordic walking, electromyogram, heart rate.

I. INTRODUCTION

PHYSICAL inactivity is a major factor for developing illness in humans. Regular participation in aerobic endurance sport seems to be an appropriate stimulus to maintain or enhance physical fitness and health. NW is an established discipline among endurance sports, which is widely used in health and leisure time sports. Over the past decade, NW has gained in popularity as a healthy activity in sports. For example, in aging societies of Japan, it is important to maintain the physical function for the elderly people. NW is a suitable discipline to gain health benefits from regular participation in endurance sports [1]. NW is suitable form of aerobic exercise because of reducing lower limb load by poles [2]. Moreover, NW is considered as a useful exercise for improving health in lack of physical exercise. It was reported that NW is low risk treatment exercise therapy compared to normal walking for preventing postural threat. W is good exercise for the whole body because of upper arm and lower segments muscle activity. Moreover, NW induced greater exercise intensity compared to normal walking [3]. Even though it is accepted that NW increases the metabolic and cardiovascular demands compared to W [4], the extent and cause for the increase is still controversial. NW is easily acquired a skill as a safe of endurance exercise training for a wide range of people. NW proved to be simple and feasible form of physical activity that can be done by everybody, everywhere, and at almost any time.

The data from previous study reported that $\dot{V}O_2$ was approximately 20% higher during NW than during W [5]. Schiffer et al. [6] reported that $\dot{V}O_2$, HR and blood lactate concentration were significantly higher with NW than without pole W at speeds above 1.8 m/s. In 1997, NW was provided additional training benefit to walkers with the use of handheld weights [4]. Thus, NW clearly increases heart rate and muscle activities, induces higher work intensity than W. However, NW was performed pole to ground contact, resulting in possible load reduction to the lower extremities. The causes have been speculated to lie in higher muscular activation during arm swing. One decisive movement pattern of NW compared to running and walking is the enforcement of a pronounced arm swing, which in turn increases the muscular work of the upper extremities. Therefore, lower limb muscle loads can be expected to have higher influence on energy expenditure than during running and walking where additional loads can diminish the range of the arm swing by NW pole. However, the magnitude of physiological responses in EMG activities at different walking speeds during NW versus W remains unclear, because of the wide variety of experimental conditions used in previous studies. It was indicated that NW induced a smaller knee joint movement during the stance phase compared to W. Thus, it was suggested that this human physiological response may be to reduce the load on the knees joint in NW [7]. There was similarity with the use of hiking poles during downhill walking for reduced knee joint moment. Moreover, to determine whether NW alleviated the load on the lower extremities, it is important to compare integrated EMG (iEMG) readings of the lower extremities between NW and W at various walking speeds.

NW is generally believed to reduce the lower limb EMG activity. However, oxygen consumption significantly increased. The results of previous study's walking speed were different from lowest at 1.65 ms^{-1} [3], highest speed at 1.86 ms^{-1} [5], respectively. respectively. The reasons for the differences between the previous study results were attributed to different study designs, outdoor versus treadmill exercise, different

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walking speeds and the NW skill of walking style and training status of the subjects. However, there was no data unifying condition of walking for according to increasing the $\dot{V}O_2$ by NW. The purpose of this study was to investigate the effect of NW the pole weight on arm and shoulder muscle activation patterns and energy expenditure at a same walking speed.

II. METHODS

Subjects

Three females and four males with an average age, body mass and height of 22.6 ± 1.81 years, 57.8 ± 5.2 kg and 1.64 ± 0.08 m, respectively, participated in this study. All participants received Nordic walk training sessions by an instructor who ensured that they were able to maintain a consistent NW technique for experimental protocols and thus familiar with the Nordic pole walking. Also, none of the subjects had any medical history in cardiovascular, musculoskeletal, or neurological conditions before the beginning of the experimental protocol and gave their written consent in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 1983. The study was approved by the local Ethics Committee. Food intake was standardized 2 days before the experiment and it was not allowed to perform high intensity physical activity.

Experimental Procedure and Protocols

All participants carried out three tests for 5 minutes walking on treadmill walking at 6 km/h. Experimental settings were following conditions:

- W: Walking without poles
- NW: Nordic Walking with normal poles (API-202A, 240 g/pole, Kizaki Co. Ltd, Japan)
- NW+1: Nordic Walking with loaded pole (custom-build, 1 kg/pole, Kizaki Co. Ltd, Japan)

The order of the performed test was randomized with interpose enough rest periods. To determine the pole length for NW and NW+1, each subject's height was multiplied from 0.62 to 0.63.

Measurement and Analysis

HR was recorded continuously, with a digital heart rate monitoring system (Polar S610i, Polar Electro, Finnland).

VO_2 was continuously measured with metabolic measurement system by electronic variable sampling by analyzing of expired gas monitoring system (VO2000, Medical Graphics Corporation, USA). Before every data collection, the device was confirmed as calibrate according to the manufacture's description. After each experimental protocol, the participants were asked for their RPE on a scale from 6 to 20 (9: very light, 15: hard, 17: very hard, 19: very very hard) [8].

Surface electromyographic (EMG) activity from 8 places; trapezius muscle, deltoid muscle, triceps brachii muscle, biceps brachii muscle, rectus femoris muscle, biceps femoris muscle, tibialis anterior muscle and medial gastrocnemius muscle of the right side of the body, was recorded using silver chloride surface bipolar electrode (F-105M, Nihon Kohden., Japan) and amplified directly behind the detection (DL-1000, S&ME, Japan). The electrodes were placed longitudinally over the muscle nelly with an interelectrode distance of 30 mm. Care was taken that the interelectrode resistance was below 3 kΩ by shaving and cleansing the skin with 70% alcohol swab. The electrode position was carefully marked on the skin to ensure the same electrode position in each test throughout the whole experiment. The EMG signal was stored simultaneously with own transmitted device memory before stored on a computer hard disk, which included a 12-bit A/D converter with a sampling frequency of 1 kHz. Integrated EMG is the best method to measure total muscular effort. IEMG is the important for quantitative EMG activity during walking. All experiment data were calculated under absolute values of EMG time series. IEMG was obtained by calculating the summation of the absolute value of EMG signal.

Statistics

Data for each dependent variable (VO2, HR, RPE and iEMG) were expressed as mean ± SD. Repeated measures ANOVA were used to determine significance of comparison of W, NW and NW+1 during 5 minutes walking. The statistical evaluation was performed with the SAS University Edition (SAS Institute, USA). If significant differences were identified using ANOVA, post hoc comparison using paired t-tests with a Bonferroni adjustment were used to identify the specific effects of pole conditions. The significance level for all analysis was set at $P < 0.05$.

III. RESULTS

W, NW and NW+1 resulted in increased tendency, 8.71 ± 2.19, 10.0 ± 1.69, 10.71 ± 2.76, respectively. There was no significant difference among the average of RPE (Fig. 1). RPE ranged from 7 to 15. The answered 15 of RPE in NW+1 condition were two female participants. Similarly, HR during NW and NW+1 was increased tendency than during W.

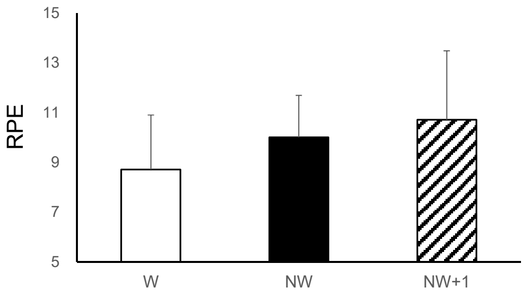

Fig. 1 RPE after each 5 minutes experimental protocol, walking (W), NW with normal poles and NW with additional pole weight of 1.0 kg/pole (NW+1) at a constant speed of 6 km/h ($1.7\ ms^{-1}$)

There were statistically significant differences in the outcome measures HR (Fig. 2). HR (Fig. 2) for NW and NW+1 were higher than for W at $1.7\ m\ s^{-1}$ ($P < 0.01$). It was illustrated average of last 30 seconds in each experimental protocol. However, there was no significantly difference between NW and NW+1 in HR.

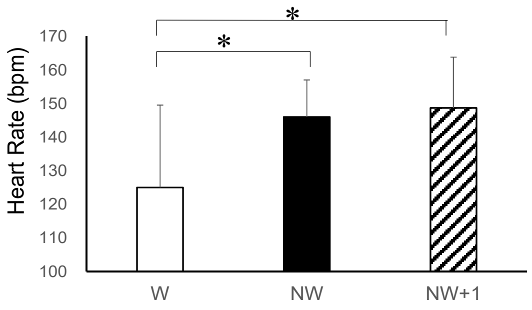

Fig. 2 HR of average resulted walking (W), NW with normal poles and NW with additional pole weight of 1.0 kg/pole (NW+1) at a constant speed of 6 km/h (1.7 ms^{-1}) during last 30 seconds period

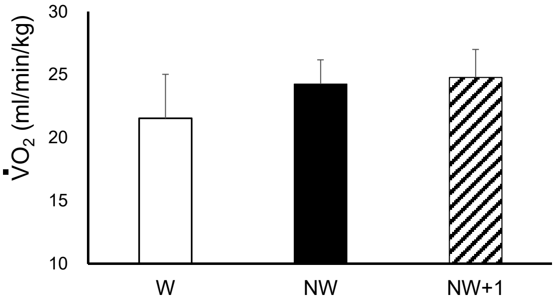

Fig. 3 $\dot{V}O_2$ during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

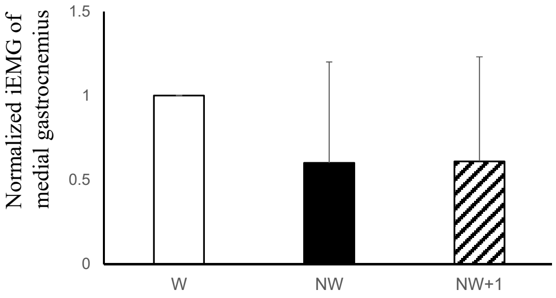

Fig. 4 Normalized iEMG of medial gastrocnemius by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

Fig. 3 showed that there was no significant difference about $\dot{V}O_2$ in any walking conditions among W, NW and NW+1. The overall effects of poles versus no pole were compared by iEMG from rectified EMG data (Figs. 4-9). There was no significant difference between NW and NW+1 in medial gastrocnemius muscle activity (Fig. 4). In comparison with W, both NW and NW+1 showed lower EMG activity. Fig. 5 indicated that there was no significant difference in iEMG of tibialis anterior. However, there was no significant difference in lower muscles. Biceps femoris muscles showed different response in comparison with lower limb muscles. In biceps femoris, there was decreased muscle activity in NW, the other NW+1 was the same as W conditions. Rectus femoris muscle showed decreased muscle activity in NW and NW+1 than W. However, there was no significant difference in leg muscles activity during W, NW and NW+1.

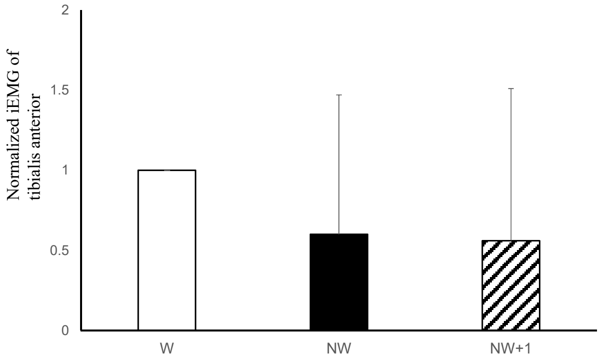

Fig. 5 Normalized iEMG of tibialis anterior by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

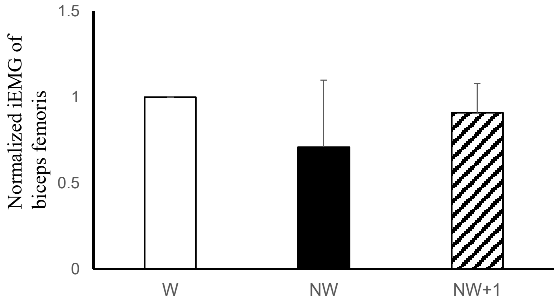

Fig. 6 Normalized iEMG of biceps femoris by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

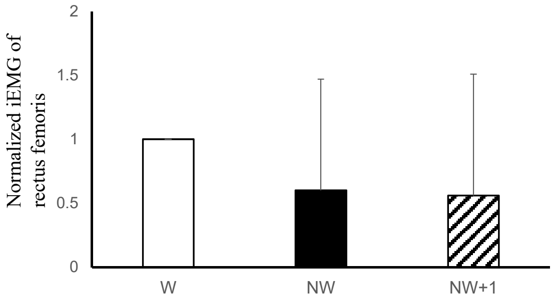

Fig. 7 Normalized iEMG of rectus femoris by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

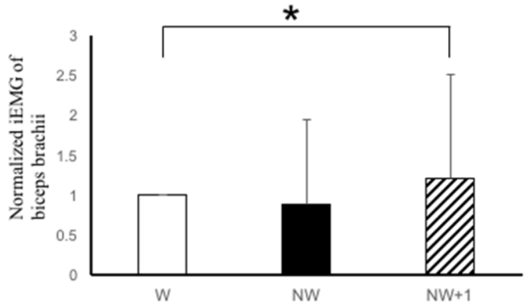

Fig. 8 Normalized iEMG of biceps brachii by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

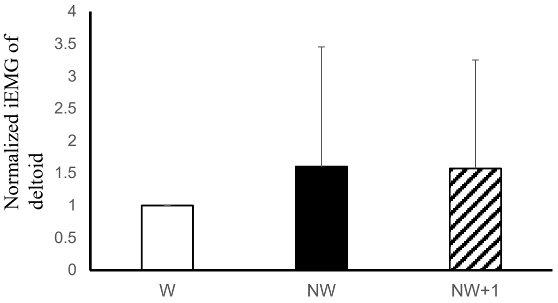

Fig. 9 Normalized iEMG of deltoid by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

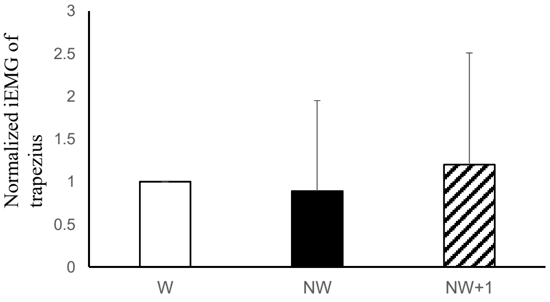

Fig. 10 Normalized iEMG of trapezius by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

There was a significant difference between W and NW+1 in biceps brachii muscle activity (Fig. 8). IEMG of trapezius muscle increased at NW+1 was higher compared with NW and W and no significant differences occurred between W, NW and NW+1. However, there was no significant difference in deltoid muscle (Fig. 9), trapezius muscle (Fig. 10), triceps brachii muscle (Fig. 11).

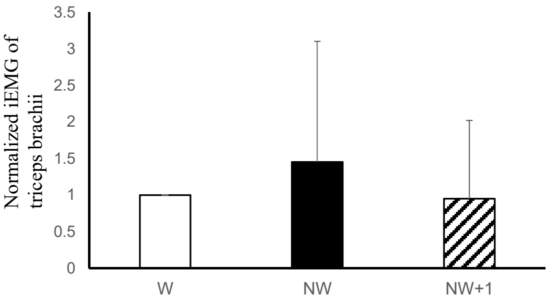

Fig. 11 Normalized iEMG of triceps brachii by each participant's W during W, NW, NW+1 at a constant speed 1.7 ms^{-1}

IV. DISCUSSION

The purpose of this study was to investigate the physiological response of NW and NW+1. We hypothesized that NW + 1Kg weight pole would show larger physiological responses as walking methods and therefore could be alternative exercise modality. The data obtained in the present study indicate lower iEMG for NW than in W. Our results revealed higher HR for NW than for W up to speed levels of 1.7 m s^{-1} and were in good agreement with other studies [6], [7]. There were no differences between the locomotion modes at 1.7 m s^{-1} between $\dot{V}O_2$ and RPE. On the other hand, HR for NW was significantly higher. Furthermore, energy expenditure as estimated by $\dot{V}O_2$ was not significantly influenced by the use of NW poles. Figs. 1 and 3 illustrated that NW was to be easily acceptable human movement exercise than W. The essential physiological difference between NW and W is the use of upper-body muscles. The present study findings could be mainly explained by the recruitment of upper-body musculature due to a greater shoulder swing and back and arm muscles involvement. However, this study demonstrated that there was no effect to increase the physical intensity by the weight pole. Our findings suggest that, within the same walking speed, exercise time, the use of NW poles provides a means to increase exercise intensity in HR. In conclusion, NW could be a means of increasing physical activity and improving human health. Thus, NW could be considered as a physical activity with an important public health application.

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