Energy expenditure and comfort during Nordic Walking with different pole lengths

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ABSTRACT

Energy expenditure and comfort for Nordic Walking with self-selected and 7.5 cm shorter poles as well as ordinary walking were measured during uphill (12˚), downhill (12˚) and horizontally. Twelve (11 female and 1 male) Nordic Walking practitioners participated (mean±SEM: 171.5±1.5 cm, 67.0±2.7 kg, 50.6±2.4 years, and maximal oxygen uptake of 43.4±2.8 ml kg^{-1} min^{-1}). Energy expenditure was calculated from oxygen uptake and comfort was self-rated. Differences in physiological responses between the three locomotion types at each slope were first analyzed by a one-way ANOVA. In case of significance, Student's paired-samples two-tailed *t*-test was applied twice, to test for differences between the two pole lengths as well as between Nordic Walking (with self-selected pole length) and ordinary walking. The corresponding differences in comfort were evaluated by a Wilcoxon matched pairs test. The relative exercise intensity during Nordic Walking with self-selected pole length ranged between ~44% and ~87% of the maximal oxygen uptake across the different slopes. For comparison, it ranged between ~29% and ~80% during ordinary walking. Uphill Nordic Walking with short poles compared to poles of self-selected length caused 3% greater energy expenditure. Notwithstanding, comfort was similar. Horizontally and downhill, energy expenditure and comfort were similar between pole lengths. Compared with ordinary walking, Nordic Walking required as much as 67% greater energy expenditure. Comfort was similar for ordinary and Nordic Walking for each slope. In conclusion, shorter poles caused greater energy expenditure during uphill Nordic Walking while comfort was similar to poles of self-selected length. The substantially enhanced energy expenditure of Nordic Walking compared to previous studies reflects the vigorous technique used here.

INTRODUCTION

Nordic Walking is an outdoor non-competitive fitness activity in which the practitioners perform brisk walking with specially designed poles. The activity is characterized by diagonal locomotion using longer steps than during ordinary walking (12), and a forceful foot take-off that is facilitated by use of the poles. Nordic Walking, as a fitness activity, has existed for around 10 years (1) but has been used by cross-country skiers as summer training for many decades. Throughout this last decade, the activity's popularity has grown considerably with a population of Nordic Walkers at the end of the year 2005 estimated to be more than 5 million (2) and more than 7 million at the beginning of 2008 (3).

A variety of special features of Nordic Walking might have contributed to the popularity of the activity. For example, the relative exercise intensity is reported to be submaximal, around 45% of the maximal rate of oxygen uptake (20), and thus gentle and manageable for many as long as Nordic Walking is performed on level ground. At the same time, however, more vigorous bouts over short distances, for example on steep slopes, can be included by fit and experienced practitioners of Nordic Walking [(9), p. 65-72]. It is also anecdotally claimed by practitioners that a comfortable feeling of locomotion rhythm is even stronger during Nordic Walking than during ordinary walking because of the greater arm involvement. Finally, it is an attractive feature of Nordic Walking that average rate of oxygen uptake, which reflects energy expenditure and might be thought of as "productivity" during a fitness activity, is reported to be up to 23% higher than during ordinary walking at fixed velocities (8, 20, 21, 23). Notably, the greater energy expenditure of Nordic Walking has been reported to be obtained without increasing the rate of perceived exertion (8, 21, 22).

The lengths of poles used in Nordic Walking are self-selected by practitioners on the basis of practical experience rather than scientific research (1). Earlier, a widely used pole length was 70% of the body height [(14), p. 30]. Presently, however, a shorter pole length (around 68% of the body height) is widely recommended [(2) and (9), p. 32-34,]. This length results in an elbow angle around 90 degrees when the pole and upper arm are held vertically and the pole is planted in front of the individual, while standing on a horizontal surface. Many Nordic Walking groups now agree that 68% of the body height is a comfortable pole length to be recommended for Nordic Walking on level ground. Still, Nordic Walking may also be performed in hilly terrain where a pole length of 68% of the body height is not necessarily favorable. It is thus abundantly clear that objective measures of metabolic responses and subjective measures of comfort remain to be compared across different pole lengths on different terrain to elucidate if Nordic Walking is influenced by modifying the pole length.

Intuitively, a fixed pole length may not be equally effective across all terrain. For example, when velocity decreases as a result of changing from horizontal to uphill walking, both step length and step rate decrease (18, 24). For the arms to be able to follow the shorter and slower steps during uphill Nordic Walking may call for a shorter arm trajectory and pole thrust. With a fixed pole length this might be enabled by lifting the shoulders and flexing the elbows more and shifting the arm trajectory more forward relative to the torso and hip so that the pole thrust is ended before the hand passes the hip. However, all these adjustments conflict with the recommended Nordic Walking technique [(9), p. 45-56 and (14), p. 36-41], might limit the arm involvement, and might compromise a Nordic walker's "productivity" and comfort. Alternatively, shortening the pole could perhaps counteract these seemingly unfavorable consequences of using a pole of self-selected length.

In the present study we measured energy expenditure and self-rated comfort during uphill, horizontal, and downhill Nordic Walking with different pole lengths as well as during ordinary walking. We specifically tested the hypothesis that a shorter pole length would result in greater energy expenditure compared to a self-selected pole length during uphill Nordic Walking. Further, that this would occur without compromising the self-rated comfort. In addition, for comparison, we evaluated the energy expenditure and comfort with the two pole lengths during downhill and horizontal Nordic Walking. Finally, we tested the hypothesis that energy expenditure during Nordic Walking is higher than during ordinary walking, to assure that the present participants in this key aspect were comparable to previously studied Nordic Walkers. Further, that the enhanced energy expenditure occurs contemporary with similar self-rated comfort.

METHODS

Experimental approach to the problem

The applied laboratory test conditions were designed to match, as closely as possible, the normal locomotion conditions experienced by the participants when walking or performing Nordic Walking outdoors. For example, the motorized treadmill was custom built and considerably larger than a traditional treadmill. This allowed a great movement space for the participants, even when performing Nordic Walking with poles. Also, the lengths of the participants own poles were tested as one of the pole lengths rather than testing some fixed length that could have been decided by the researchers. The length of the short poles was based on a combination of our theoretical understanding, pilot studies, and the practitioners' practical experiences. We predicted that 7.5 cm was a reasonable pole shortening that could result in

relevant physiological changes without harming the core of the Nordic Walking technique. In addition, locomotion velocities were self-selected, which is also the case outdoors. Still, velocity was, of course, maintained constant for each participant, at each slope, to be able to compare physiological responses and self-rated comfort between locomotion types and between pole lengths. The applied slopes were representative of slopes occurring during sections of a course that the participants completed regularly with their Nordic Walking group. It was beyond the purpose of the present study to compare physiological responses and self-rated comfort between slopes. Therefore, the order of slopes was not randomized.

Subjects

Twelve (11 female and 1 male) healthy and recreationally active individuals (mean±SEM: 171.5±1.5 cm, 67.0±2.7 kg, 50.6±2.4 years) participated in the study. The body height varied from 164 cm to 183 cm. The participants were volunteers among members of a local Nordic Walking group. All participants were very familiar with Nordic Walking as they had participated in this fitness activity for 2.8±0.5 years on a regular basis of approximately 2 times per week. The least experienced had participated for 0.5 year (minimum requirement) while the most experienced had participated for 6 years. There was no requirement for age or gender. All participants were examined by a medical doctor for excluding criteria of hypertension and cardiovascular diseases, as well as for other possible complications that could cause testing to be a risk for the participants. None of the participants were excluded. Written informed consent was obtained from the participants. The study conformed to the standards set by the *Declaration of Helsinki* and the procedures were approved by the regional committee of Southern Norway, within the National Committees for Research Ethics in Norway.

Procedures

Each participant reported to the laboratory three times. On the first test day, the

participant was carefully familiarized with ordinary walking and Nordic Walking on a 3x4 m

custom-built treadmill (Rodby Innovation AB, Hagby, Sweden). It was carefully emphasized to

the participant that the self-selected locomotion techniques should be as representative as

possible of the techniques that the participant used during outdoor ordinary walking and Nordic

Walking. A part of the participant's familiarization was to select velocities during 12° (~21.3%)

uphill, horizontal, and 12° downhill Nordic Walking on the treadmill. The velocities should be

considered comfortable and comparable to the velocities that would have been chosen during

outdoor Nordic Walking. The three self-selected velocities were noted and used in the

subsequent testing during 12° uphill, horizontal, and 12° downhill conditions. Thus for each

participant, treadmill velocity was maintained the same, for all three locomotion types, at a

given slope condition. The length of the participant's own Nordic Walking poles was measured

from the top of the grip to the tip of the spike and represented the participant's self-selected pole

length. Subsequent testing was performed using this self-selected pole length and 7.5 cm shorter

poles. Adjustable, CT5 high performance Nordic Walking poles (Swix, Lillehammer, Norway)

were used for testing. The mass of each pole was 240 g. To be able to compare the present pole

lengths with pole lengths reported in previous studies it should be noted that four cm separated

the top of the grip and the point of insertion of the strap on the CT5 high performance Nordic

Walking poles. The familiarization was followed by a 10-min rest period. Subsequently, three

types of locomotion were performed during each of the downhill, horizontal, and uphill

conditions. First, 5-min bouts of ordinary walking, Nordic Walking with self-selected pole

lengths, and Nordic Walking with short pole lengths were performed downhill without pauses in a counterbalanced order. After a 6-min rest period in which the participants were allowed to drink water, the same three types of locomotion were again performed without pauses and in a counterbalanced order but this time horizontally. Finally, after another 6-min rest period, the three types of locomotion mentioned above were repeated, again in counterbalanced order, but this time uphill. This order of locomotion bouts allowed us, for each slope, to compare physiological responses and comfort scores between the two pole lengths during Nordic Walking as well as with ordinary walking. Pulmonary gas exchange was measured during the last 3-4 min of each bout and comfort was self-rated by the participant at the end of each bout. Participants were not informed about the hypotheses and when they used which pole length.

On the second test day, the participant was familiarized with the test of maximal rate of oxygen uptake. As a part of the familiarization, it was determined whether the participant in this test preferred to walk at a set velocity and gradually increasing slope, or run at a set slope and gradually increasing velocity.

On the third test day the maximal rate of oxygen uptake was measured in a progressive test on a motorized Woodway ELG 2 treadmill (Woodway GmbH, Weil am Rhein, Germany). First, 10 min of voluntary warm up was performed. Then, the participants started walking or running at a set grade and velocity. After each minute, the velocity was increased by 1 km h^{-1} or the slope was increased by 1 degree. The test was terminated when the participant signaled that locomotion could not be sustained. A blood sample was taken from a fingertip 3 min after termination of the test for analysis of lactate concentration.

Measurements and data analysis

Heart rate was measured (only on the third test day) with a Polar S710 heart rate monitor (Polar Electro Oy, Kempele, Finland). Participants breathed through a two-way respiratory valve (Model 2700, Hans Rudolph Inc., Kansas City, MO, USA) and pulmonary gas exchange was measured with a Jaeger Oxycon Champion (Eric Jaeger Gmbh, Hoechberg, Germany) online over 30-s periods and expressed under standard conditions of temperature ($0°C$), pressure (760 mm Hg), and dry (no water vapor)(STPD). Before measurements, the gas analyzers were calibrated against certified gases of known concentrations, and the ventilation sensors were calibrated with a 3-l syringe. Verification was performed after testing. For the submaximal measurements on the first test day, the median of the three last measurements of rate of oxygen uptake (and corresponding variables) were selected for further analysis in line with a previous published procedure that has shown to be capable of detecting small differences in oxygen uptake and energy expenditure (11). For the maximal measurements of pulmonary gas exchange and ventilation on the third test day, the maximal values were selected for further analysis. Rate of pulmonary ventilation is reported at body temperature and ambient barometric pressure, saturated with water vapor (BTPS). Respiratory exchange ratio was calculated as the rate of carbon dioxide output divided by the rate of oxygen uptake. Rate of energy expenditure, expressed in watts, was calculated for the submaximal locomotion from the gross rate of oxygen uptake and the corresponding respiratory exchange ratio using previously published tables (10). Metabolic equivalent (MET) intensities were calculated where 1 MET was defined as a standard resting metabolic rate of 4.184 kJ kg^{-1} h^{-1} obtained during quiet sitting (4). Blood lactate concentration was measured using an YSI Model 1500 Sport analyzer (YSI Inc., Yellow Springs, OH, USA).

Comfort was self-rated by the participant on three scales referring to arms and shoulders, legs, and whole body, respectively. Each scale consisted of numbers from 1 to 10 where 1 corresponded to "very, very uncomfortable" and 10 corresponded to "very, very comfortable". The present scales were inspired by scales that have previously been used to study comfort of running shoes (17) and bicycle seats (13).

Statistical Analyses

Differences in physiological responses between the three locomotion types at each slope were first analyzed by a one-way ANOVA. In case of significance, Student's paired-samples two-tailed *t*-test was applied twice, to test for differences between the two pole lengths as well as between Nordic Walking (with self-selected pole length) and ordinary walking. The corresponding differences in comfort were evaluated by a Wilcoxon matched pairs test since these data were not normally distributed. Statistics were calculated in Excel 2003 (Microsoft Corporation, WA, USA) and SPSS 14.0 (SPSS Inc., Chicago, IL, USA). Data are presented as mean±SEM, unless otherwise indicated. $P<0.05$ was considered statistically significant.

RESULTS

Participants' maximal rate of oxygen uptake was 2.86 ± 0.17 l min^{-1}. Supplementary data from the test of fitness status are presented in Table 1. For personal reasons, one participant did not want to engage in this test. Consequently, $N=11$ for results of maximal oxygen uptake as well as for the reported relative exercise intensities during submaximal locomotion.

The length of the participants' own poles, which is referred to as the "self-selected pole length", was 115.9 ± 1.2 cm corresponding to $67.6\pm0.6\%$ of the body height. The self-selected

pole length varied from 109.5 cm to 126.5 cm. For comparison, the short pole length was 108.5±1.2 cm corresponding to 63.3±0.6% of the body height. The self-selected velocities for locomotion during uphill, horizontal, and downhill conditions were 1.13±0.04, 1.65±0.06, and 1.50±0.04 m s^{-1}, respectively.

During uphill Nordic Walking, the rates of oxygen uptake and energy expenditure as well as MET values were 3.0±1.1%, 3.2±1.0%, and 3.2±1.0%, higher (P=0.03, P=0.01, and P=0.01, respectively) with the short poles compared to the poles of self-selected length (Table 2 and Figure 1). For comparison, no differences were observed between the pole lengths during horizontal and downhill Nordic Walking (Table 2 and Figure 1). None of the comfort scores were different between the pole lengths during Nordic Walking at any of the slopes (P=0.059-0.931)(Table 3 and Figure 2).

The rate of oxygen uptake was 8.3±2.5%, 65.2±11.5%, and 54.7±12.5% higher (P=0.004, P<0.001, and P<0.001 respectively) during Nordic Walking with self-selected pole length than during ordinary walking for uphill, horizontal, and downhill conditions, respectively (Table 2). In accordance with this, the rate of energy expenditure and MET values were 9.0±2.9%, 67.2±11.7%, and 54.2±12.4% higher (P=0.007, P<0.001, and P<0.001 respectively) during Nordic Walking at uphill, horizontal, and downhill conditions, respectively (Figure 1 and Table 2). None of the comfort scores were different between Nordic Walking with the poles of self-selected length and ordinary walking at any of the slopes (P=0.088-0.959)(Table 3 and Figure 2).

The relative exercise intensity during Nordic Walking with self-selected pole length ranged between ~44% and ~87% of the maximal oxygen uptake across the different slopes. For

comparison, it ranged between ~29% and ~80% during ordinary walking. For all values and differences between pole lengths and locomotion types, the reader is referred to Table 2.

DISCUSSION

Two findings in the present study were particularly notable. First, the rate of energy expenditure was on average 3% higher during uphill Nordic Walking with short poles compared to poles of self-selected length. This higher "productivity" with short poles occurred without a compromise in comfort. For comparison, rate of energy expenditure and comfort were not different between pole lengths during horizontal and downhill Nordic Walking. Second, the rate of energy expenditure was on average 67% higher during horizontal Nordic Walking compared to ordinary walking. This is a markedly larger difference than previously reported. For comparison, smaller excess rates of energy expenditure for Nordic Walking were found during uphill and downhill slopes.

It could be argued that because of the apparent modest magnitude of 3% higher "productivity" with short compared to self-selected poles during uphill Nordic Walking, there is no physiological or clinical relevance for using shorter poles. For some practitioners it would be difficult to show a health influencing benefit if an adjusted pole length were used. However, from a more general public health perspective, even an apparent modest difference of 3% in rate of energy expenditure during a physical activity should be taken seriously, especially when it can be obtained without compromising comfort. It seems that the particular physical activity of Nordic Walking has an exceptional potential to be exploited in the effort to counteract physical inactivity of populations. In this context, it is of note that Nordic Walking is specifically referred to in a paper that presents evidence and discusses principles for prescribing exercise therapy in

the treatment of metabolic syndrome-related disorders, heart and pulmonary diseases, as well as muscle, bone and joint diseases (19).

In the present study we did not attempt to study mechanisms by which pole length could influence energy expenditure. It can therefore only be speculated why the rate of energy expenditure was greater with the short poles during uphill Nordic Walking. Possible reasons include more work done to move the body center of mass (7) using a "bouncier" technique when performing Nordic Walking with short poles. It is also possible that during Nordic Walking with short poles, less exchange occurred between potential energy and kinetic energy as well as between mechanical energy stored in the muscle's elastic elements and potential energy and kinetic energy (6, 16). Finally, it is possible that greater force was applied on the shorter poles or that force was developed more rapidly which would increase energy expenditure (5). Future kinematic and kinetic studies of movement of the body center of mass and the body segments, as well as of pole forces during Nordic Walking could elucidate these explanations.

The second notable finding of the present study was that the excess energy expenditure obtained during horizontal Nordic Walking compared to ordinary walking was considerably larger than previously reported. A likely reason for this derives from teaching differences which can easily be detected visually. This is particularly obvious between groups that have had different instructors but even between practitioners who have had the same instructor. The present participants had been instructed by the former female world class distance runner, Ingrid Kristiansen, who is now an active promoter of Nordic Walking. The "Ingrid Kristiansen technique", in comparison with other Nordic Walking techniques, could be characterized as vigorous. Particularly long steps are taken that apparently result in a considerable horizontal movement of the body center of mass, long muscle stretch-shorten cycles, and long pole thrusts.

These are all aspects that could contribute to the substantially greater energy expenditure for Nordic Walking compared to ordinary walking, as observed in the present study (6, 7, 16). For detailed description of the "Ingrid Kristiansen technique", the reader is referred to a lavishly illustrated book that has been published in Norwegian, Danish, Swedish, and Finnish (14).

The present investigation of the difference in energy expenditure between Nordic Walking and ordinary walking on steep uphill and downhill conditions is the first of its kind. It was observed that slope modifies the differences of energy expenditure between Nordic Walking and ordinary walking. Still, the overall picture was that energy expenditure was generally greater during Nordic Walking compared to ordinary walking as previously reported (8, 20, 21, 23). While uphill and downhill Nordic Walking involves greater energy expenditure than ordinary walking at the same speed, the difference for level ground is greater than for either slope condition.

Self-rated comfort during Nordic Walking was generally high in the present study, which agrees with previous findings of low rates of perceived exertion during Nordic Walking. For example, the rate of perceived exertion has been reported to be around 12, on the 15-point Borg scale (6 up to 20), corresponding to between "fairly light" and "somewhat hard" (20). What is particularly notable is that this moderate perception of effort with Nordic Walking occurs despite high energy expenditure. At least a part of the explanation for this could have to do with the fact that energy expenditure is largely a result of the total work performed. Since upper and lower body are both involved in Nordic Walking, the load on each active muscle group is perhaps smaller during this activity than when the same energy expenditure is reached during for example cycling, which primarily involves the legs while not the upper body. In line with this, and if both comfort and substantial energy expenditure are considered advantageous

for fitness locomotion, work of the upper and lower body is better distributed during Nordic Walking compared to ordinary walking.

Another finding of the present study, which is being reported here for the first time, is that comfort was similar between the different pole lengths. This implies that during uphill Nordic Walking, a shorter pole length could be used to obtain a beneficial increase in "productivity" without affecting comfort negatively. It also implies that during horizontal Nordic Walking, the pole length could be changed to vary the movement and thereby the load on the musculoskeletal system, without compromising comfort. Loading the cardiovascular system and expending energy during varying movements and thereby varying musculoskeletal load is generally considered a central aspect of healthy physical activity.

Finally, comfort was found to be similar between Nordic Walking and ordinary walking as previously observed in reports of perceived exertion [(8, 21, 22), with one exception, (20)]. The subjects were actively engaged in Nordic Walking before the study. It is thus likely that they have positive impressions about it. This could bias the comfort ratings during Nordic Walking compared to ordinary walking since the comfort ratings are based on perceptions. With a majority of findings supporting a similar comfort or perceived exertion during Nordic Walking and ordinary walking, we believe the healthy benefits of increased demand on the cardiovascular system during Nordic Walking compared to ordinary walking can be obtained without negative perceptions.

Instead of the presently self-selected pole lengths, pre-determined pole lengths could have been used which perhaps would have shifted results. If for example, the difference between the two pole lengths had been larger as a result of using a length of 70% of body height as earlier recommended [(14), p. 30] and studied [e.g. (15)] instead of the self-selected length, it is

possible that the differences in energy expenditure between pole lengths would have been greater. However, the test conditions were designed to match as closely as possible the normal poling situation chosen by the participants.

A further consequence of this applied approach was that walking velocities were self-selected which gave up some control of the experimental conditions. Still, the average self-selected velocity during horizontal locomotion was 1.65 m s^{-1} (5.9 km h^{-1}) which is identical to the velocity that was self-selected in another study (8) and well within 1.5 to 1.7 m s^{-1} that currently represents the range of reported self-selected velocities (12, 20, 25). Furthermore, since each participant maintained the same velocity during a given slope condition, regardless of locomotion type, locomotion types could be compared using paired statistical tests.

It is possible that the finding of no difference in comfort between the two pole lengths as well as between Nordic Walking and ordinary walking could represent a Type II error due to the substantial range of comfort scores recorded. One could argue however that even if the differences had reached statistical significance, the small absolute differences would have little practical importance.

In conclusion, experienced practitioners of Nordic Walking increased their rate of energy expenditure by 3% during uphill Nordic Walking by using poles that were 7.5 cm shorter than their self-selected poles. Notably, the greater rate of energy expenditure with shorter poles was obtained without changes in the self-rated comfort. For horizontal and downhill conditions, rate of energy expenditure and comfort were similar between pole lengths. Compared with ordinary walking, rate of energy expenditure was as much as 67% higher during Nordic Walking while being similarly comfortable.

PRACTICAL APPLICATIONS

Aerobic training effects of Nordic Walking can be enhanced by using shorter poles. During uphill Nordic Walking, a 3% increase in energy expenditure was obtained with shorter poles which was not associated with a change in comfort. From another perspective, a Nordic Walker is able to adjust the exercise intensity somewhat during uphill sections by adjusting pole length. This may be exploited when Nordic Walking is performed in groups of practitioners that advance in a body throughout a course. Otherwise, under such circumstances, energy expenditure is more or less fixed for participants in the group because of the fixed major energy expenditure determinants of velocity and slope. Nordic Walking has considerable potential as a fitness activity which can be highly recommended for the general public. With uphill Nordic Walking, the participants exercised at more than 80% of their maximum aerobic power while reporting high comfort. It is particularly noteworthy from a public health perspective that Nordic Walking compared to other forms of physical activity is comfortable and gentle for the musculoskeletal system for many people, even when performed at intensities that result in a large cardiovascular load. To illustrate this, one could swim butterfly or run at 10.8 km h^{-1} to obtain a cardiovascular load of 11 MET (4), which was reached during uphill Nordic Walking. To obtain 8 MET, which was reached during horizontal Nordic Walking, one could play a basketball game or run at 8 km h^{-1} (4). These comparison activities are perhaps more technically demanding and/or less gentle for the musculoskeletal system than is Nordic Walking.

ACKNOWLEDGMENTS

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Tables

Table 1. Results from the test of the participants' maximal rate of oxygen uptake. N=11. Data are mean±SEM

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Maximal oxygen uptake (mL kg^{-1} min^{-1})	Respiratory exchange ratio	Pulmonary ventilation (L min^{-1})	Heart rate (beats min^{-1})	Blood lactate concentration (mmol L^{-1})
43.4±2.8	1.08±0.01	102.5±5.5	179±3	6.1±0.3

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Table 2. Physiological responses at the different slopes and locomotion types. N=12 (except, N=11 for % of maximal rate of oxygen uptake).

Data are mean±SEM.

	Oxygen uptake (L min^{-1})	% of maximal oxygen uptake (%)	Pulmonary ventilation (L min^{-1})	Respiratory exchange ratio	MET
Downhill					
Ordinary walking	0.80±0.04	29.1±2.1	26±1	0.83±0.03	3.5±0.1
NW (self-selected pole length)	1.19±0.06[a]	43.7±2.4[a]	37±2[b]	0.80±0.02	5.3±0.4[b]
NW (short pole length)	1.21±0.07	43.9±2.1	36±3	0.79±0.02	5.3±0.4
Horizontal					
Ordinary walking	1.11±0.07	40.0±2.5	31±2	0.80±0.02	4.8±0.3
NW (self-selected pole length)	1.80±0.14[a]	64.7±3.4[a]	53±5[a]	0.85±0.02[c]	8.0±0.7[a]
NW (short pole length)	1.81±0.13	64.5±3.5	52±4	0.85±0.02	8.1±0.7
Uphill					
Ordinary walking	2.24±0.11	80.3±2.7	64±4	0.89±0.01	10.0±0.4
NW (self-selected pole length)	2.42±0.11[b]	86.8±2.2[b]	77±4[c]	0.93±0.02	10.9±0.5[c]
NW (short pole length)	2.49±0.12[c]	89.2±2.3[c]	78±4	0.93±0.01	11.2±0.6[c]

NW=Nordic Walking

[a]Higher than the value above ($P<0.001$)

[b]Higher than the value above ($P<0.01$)

[c]Higher than the value above ($P<0.05$)

Table 3. Self-rated comfort at the different slopes and locomotion types. Comfort range is 1-10, with 1 corresponding to "very, very uncomfortable" and 10 corresponding to "very, very comfortable". *N*=12. Data are mean (min-max).

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	Comfort	
	Arms and shoulders	Legs
Downhill		
Ordinary walking	9.6 (8-10)	8.9 (6-10)
NW (self-selected pole length)	9.1 (6-10)	8.5 (5-10)
NW (short pole length)	9.1 (7-10)	8.3 (5-10)
Horizontal		
Ordinary walking	9.8 (8-10)	9.6 (8-10)
NW (self-selected pole length)	8.8 (6-10)	9.3 (7-10)
NW (short pole length)	8.8 (5-10)	8.8 (5-10)
Uphill		
Ordinary walking	9.1 (7-10)	7.3 (3-9)
NW (self-selected pole length)	8.2 (5-10)	7.8 (5-10)
NW (short pole length)	8.3 (5-10)	7.4 (5-10)

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NW=Nordic Walking

Figure captions

Figure 1

Rate of energy expenditure at the different locomotion types and slopes. Data points represent means. Error bars represent SEM. NW=Nordic Walking.

*Lower than during Nordic Walking with self-selected pole length at the same slope (P<0.01).

#Higher than during Nordic Walking with self-selected pole length at the same slope (P=0.01).

Figure 2

Self-rated whole body comfort at the different locomotion types and slopes. Minimum and maximum values are indicated in the parentheses. NW=Nordic Walking.
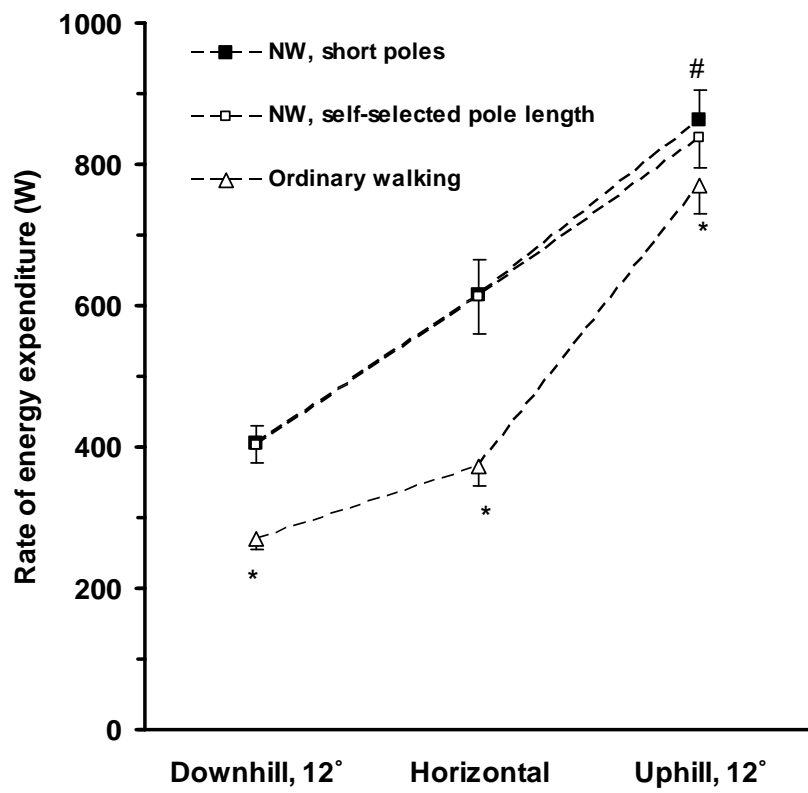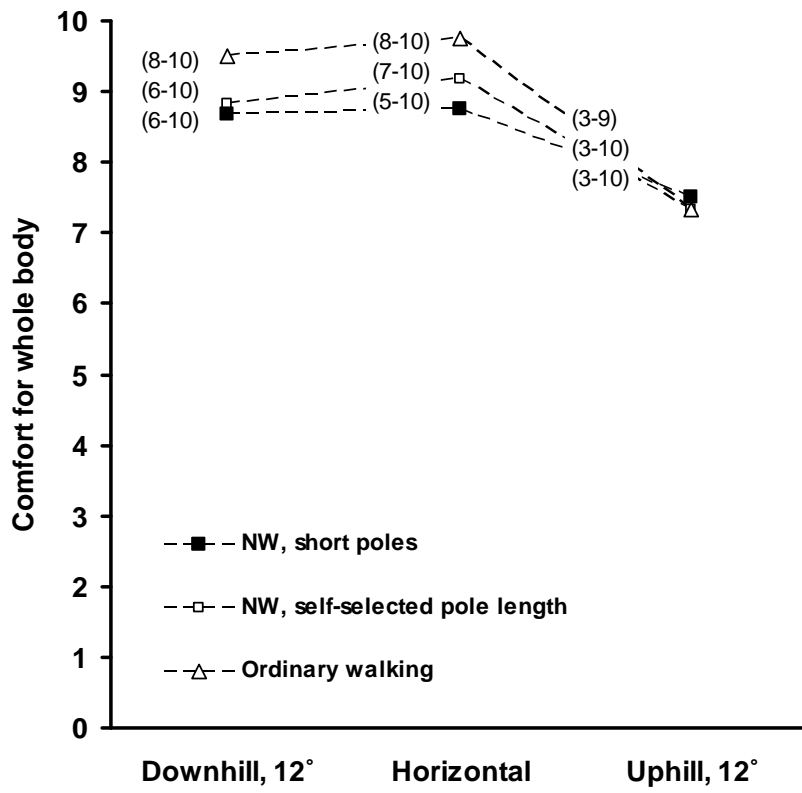
Fig. 1

Fig. 2