

EFFECT OF WALKING SPEED AND POLE LENGTH ON KINEMATICS AND DYNAMICS IN NORDIC WALKING

Gerda Strutzenberger¹, Bettina Rasp², Hermann Schwameder¹

¹ Institute of Sport and Sport Science, University of Karlsruhe, Germany

² Department of Sport Science and Kinesiology, University of Salzburg, Austria

Nordic walking has become a wide established leisure sport in middle and northern Europe. Although cardiopulmonary benefits are well documented, reported load reductions on the lower extremities seem to be overestimated. The influence of Nordic walking speed on the gait parameters has not been researched sufficiently. The recommendations of the optimal length for Nordic walking poles vary and merely the effect of different lengths on the biomechanics of the technique has been studied. Thus, the aim of this study was to analyze the effects of Nordic walking speed and pole length on kinematic and dynamic parameters in 16 Nordic walking skilled subjects. An increase of walking speed causes a more dynamic walking pattern and leads to an increase of the ground reaction forces in the first part of the stance phase and a decrease in the middle part of the stance phase. Only fine and non-systematic changes in kinematics and ground reaction forces were observed when using poles with different pole lengths.

KEYWORDS: Nordic walking, ground reaction force, pole length.

INTRODUCTION:

Nordic walking has become a popular leisure sport in middle and northern Europe and is associated with reduced loading on the lower extremities (Schwameder & Ring-Dimitriou, 2005) along with additional cardiopulmonary benefit(s)? (Rodgers et al., 1995; Porcari et al., 1997; Church et al., 2002). Recently published studies have compared the lower extremity joint loading in Nordic walking as well as regular walking with differing results (e.g. Schwameder & Ring-Dimitriou, 2005; Jöllenbeck et al., 2006; Kleindienst et al., 2006). Joint loading can be controlled by the walking speed which has been documented for level walking (e.g. Voloshin et al. 2000; Winter, 1991) and graded walking (Schwameder et al., 2005). Studies on Nordic walking included different Nordic walking speeds, however systematic comparison between the different Nordic walking velocities was not made. Thus, the first part of this study was to examine the effect of walking speed on the kinematics and dynamics in Nordic walking. The second issue covers the effect of the pole-length on biomechanical parameters in Nordic walking, which has been neglected in past studies investigated. This issue is essential since recommendations for the optimal pole length vary between 0.66 up to 0.7 times body height. Sabo (2005) claimed that poles that are too long may alter the Nordic walking technique. Additionally, commercially available Nordic walking poles differ in lengths of 5 cm increments. Therefore, the second aim of this study was to examine the influence of the pole length on the kinematics and dynamics in Nordic walking at an individually chosen speed.

METHODS:

Data Collection: 9 female and 7 male Nordic walking skilled subjects (age: \bar{x} 30.8 yrs) participated in the study. Kinematic data was collected using a setup of 8 Vicon cameras (240 Hz). 41 reflective markers were placed on the participants by means of the Plug-in-Gait Marker Set (Vicon). Three additional markers were placed on each Nordic walking pole and two markers were added on each forearm since the strap-system of the poles interfered with the standard wrist markers. A full body model was applied to determine joint centres and segment angles. Ground reaction forces of the right foot were obtained by stepping on an AMTI force platform (1200 Hz) which was embedded in the middle of the 20 m walkway. Nordic walking speed was controlled by photo cells located 1.5 m in front of and behind the force platform. Deviations of 0.05 m/s were tolerated. '*Speed*' trials: Each subject had to

perform Nordic walking at 3 different speed levels: the individually chosen speed was defined as 'neutral' speed, 'slow' speed ('neutral' – 0.28 m/s) and 'fast' speed ('neutral' + 0.28 m/s). The pole length was set at 0.68 times body height. '*Pole length trials*': All trials with different pole length were performed at the 'neutral' (individual) speed (assessed at the 'speed' trials). The 'neutral' pole length was set at 0.68 times body height, which represents a value in the middle of the different pole length recommendations. The other pole length conditions were chosen to be at -5 cm, -2.5 cm, +2.5 cm and +5 cm of the neutral pole length. Trials with incorrect speed or changes in moving patterns for hitting the force platform were not considered for further evaluation. Three valid trials for each condition were recorded. The technically best out of these was selected for further analysis.

Data Analysis: Three-dimensional coordinates of the markers were obtained (Vicon Peak, Oxford, UK) for the quantification of the gait parameters step length, step frequency and ground contact time. Additionally, the angles of the shoulder, elbow, hip, knee and ankle in the sagittal and in the frontal plane during one gait cycle were assessed. The sagittal plane projection angle between the pole and the horizontal during the stance phase and the distance between pole plant and heel were examined for the 'pole length' trials. Kinematic data was time normalized and peak and range variables were calculated. Vertical ground reaction force of the stance phase of the right foot was analysed for all trials. In addition to time normalization the dynamic data was normalized to body weight. The peak values at F_z1 (initial stance) and F_z3 (push-off) and the minimum value at F_z2 (mid stance) were chosen for further analysis. Statistics were calculated by using a one-factorial ANOVA with repeated measures. The level of significance was set at $p \leq 0.05$.

RESULTS & DISCUSSION:

'Speed' trials: On average the participants chose an individual speed of 1.90 ± 0.14 m/s. The increase in speed led to an expected significant increase of stride length and stride frequency, while the ground contact time decreased (Table.1). The kinematic analysis revealed no significant changes in the angles of the above named joints, with the exceptions from higher maximum abduction angles of the hip and a wider range of motion in the sagittal plane of the shoulder angle due to faster walking pace (Table 1). The influence of walking speed on the vertical ground reaction force is shown in Figure 1. An increase in speed by 0.28 m/s led to 8 % (slow–neutral) and 9 % (neutral-fast) significant higher values in F_z1 while the values in F_z2 decreased significantly by 23 % (slow-neutral) and by 26 % (neutral-fast). No relevant changes could be detected in the ground reaction forces during the push-off phase (F_z3).

Table 1: Kinetic and dynamic data of Nordic walking at three different speed levels.

Parameter	[]	NW slow		NW neutral		NW fast	
		mean	±SD	mean	±SD	mean	±SD
step length	m	1.83	0.132	1.92	0.160	2.03	0.129
step frequency	steps/min	111	7	123	8	133	10
ground contact time	sec	0.645	0.051	0.576	0.045	0.526	0.048
shoulder retroversion	° (max)	-27.2	9	-30.3	12	-32.3	11
shoulder ROM	°	46.7	20.1	53.7	25.7	62.7	21.1
hip abduction	° (max)	-10.4	4.5	-11.1	4.8	-13.2	3.9
F _z 1	N/BW	1.45	0.22	1.56	0.23	1.70	0.22
F _z 2	N/BW	0.54	0.11	0.42	0.09	0.31	0.10
F _z 3	N/BW	1.09	0.08	1.13	0.08	1.09	0.10

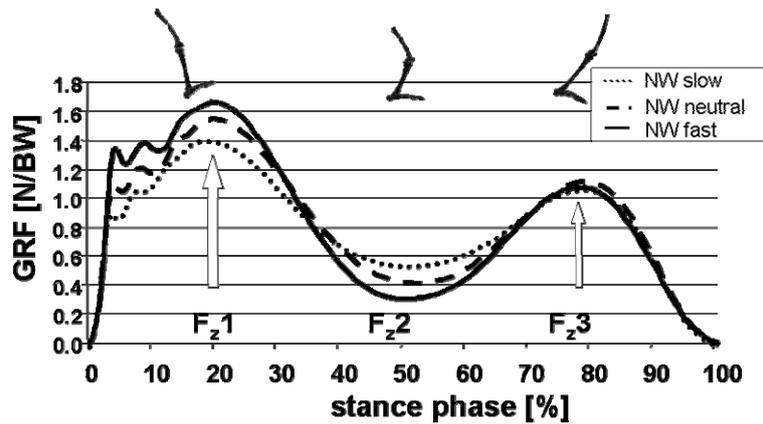


Figure 1: Vertical ground reaction forces of Nordic walking at three different speed levels

'Pole length' trials: It is expected, that different pole lengths lead to a changed kinematic pattern in the Nordic walking technique. However, the analysis of the shoulder, elbow, hip and knee angle over a gait cycle did not show altered kinematics due to different pole lengths. Sabo (2005) reported that poles that are too long led to a lateral movement of the hand. The subjects in this study did not change their kinematic pattern but the pole length influenced the sagittal projection angle of the pole plant. The shorter the pole length, the steeper the subjects planted the pole (Figure 2). Similarly, the subjects varied the pole plant with respect to the anterior heel. By using longer poles the distance increased, while with shorter poles the distance was decreased with a variation of 28 to 34cm (Figure 3). A recommendation for the optimal (magnitude of angle between pole and horizontal) in order to enable an effective Nordic walking technique cannot be given by this study. The comparison of the dynamic data revealed no significant effect on the ground reaction forces over the stance phase as a result of using different pole lengths (Figure 4).

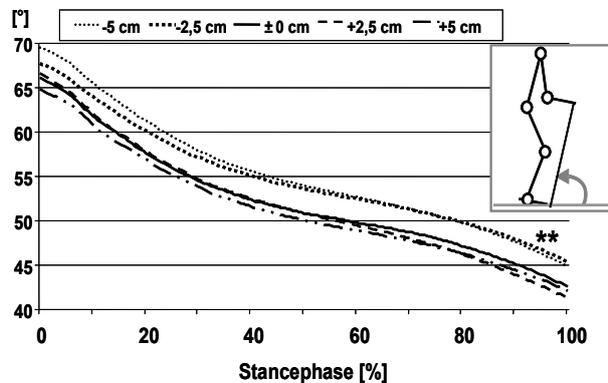


Figure 2: Angle between pole and ground in sagittal plane at five different pole lengths

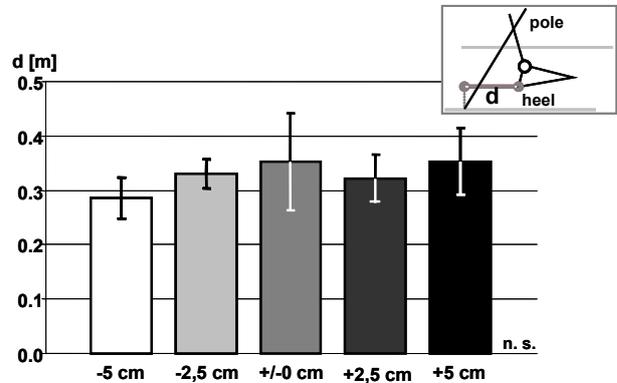


Figure 3: Distance set in point of the pole and anterior heel at five different pole lengths.

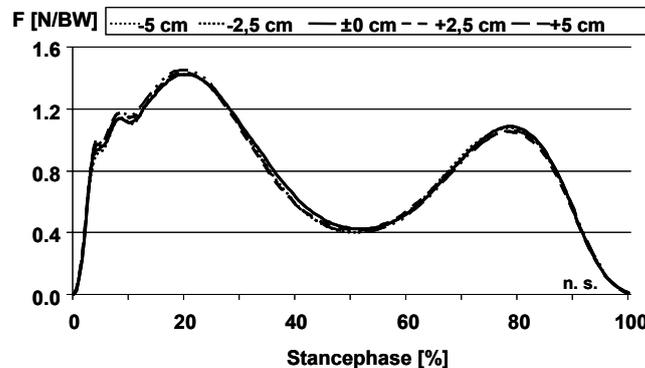


Figure 4: Vertical ground reaction forces during the stance phase with 5 different pole lengths.

CONCLUSION:

To accomplish higher Nordic walking speed a more dynamic walking pattern is needed. It is shown by this study that apart from an increase in temporospatial parameters of the gait, an increase in speed leads to an increase in F_z . Similar effects were reported by Winter (1991) for level walking. Therefore it is recommended that, especially if Nordic walking is performed in rehabilitation programs, an emphasis should be placed on the walking speed. This appears to be a better means to control loading on the lower extremities than (changing from walking to Nordic walking).

The results regarding the different pole length showed only a slight and insignificant change in the analysed kinematic and dynamic parameters. The subjects did not react with a change in Nordic walking technique with respect to the different pole lengths. It seems that the commercial available pole lengths are sufficient and more subdivided lengths are not of need. For cross country Nordic walkers, it might be difficult to determine the optimal Nordic walking pole length since the walking ground cannot be assumed to be totally even. Natural unevenness requires permanent adaptation of the Nordic walker to the different ground conditions. It can be concluded that the pole length should be chosen individually with respect to effectiveness and comfort.

REFERENCES:

- Church, T.S., Earnest, C.P., Morss, G.M. (2002). Field testing of physiological responses associated with Nordic walking. In: *Research Quarterly for Exercise and Sport*. 73, 4, 296-300.
- Jöllenbeck, T., Leyser, D., Classen, C., Mull, M., Grüneberg, C. (2006). Biomechanical loading of the lower extremities during Nordic Walking – A field study. In: Schwameder, H., Strutzenberger, G., Fastenbauer, V., Lindinger, S., Müller, E. *XXIV International Symposium on Biomechanics in Sports*. July 14-18, 2006. Proceedings. Volume 2. 624-627. Salzburg
- Kleindienst, F.I., Stief, F., Wedel, F., Campe, S., Krabber, B. (2006). Joint loading of lower extremities during Nordic walking compared to walking based on kinetic and kinematic data. In: Schwameder, H., Strutzenberger, G., Fastenbauer, V., Lindinger, S., Müller, E. *XXIV International Symposium on Biomechanics in Sports*. July 14-18, 2006. Proceedings. Volume 2. 629-632
- Porcari J.P., Hendrickson, T.L., Walter, P.R., Terry, L., Walkso, G. (1997). The Physiological Response to Walking with and without Power Poles on treadmill exercise. In: *Research Quarterly for Exercise and Sports*. 68, 2, 161-166.
- Rodgers, C.D., Vanheest, J., Schachter, C.L. (1995). Energy expenditure during submaximal walking with exerstriders. In: *Medicine and Science in Sports & Exercise*. 27, 4, 607-611
- Sabo, A. (2005). Wechselwirkung zwischen Stocklänge und Nordic Walking Technik. In: Gollner, E., Marx, S. 3. Internationaler Nordic-Walking Kongress. Nordic Walking – Eine Innovation mit Nachhaltigkeit. Abstract Book. 32-39. Bad Tatzmannsdorf.
- Schwameder, H., Roithner, R., Müller, E., Niessen, W., Raschner, C. (1999). Knee joint forces during downhill Walking with hiking poles. In: *Journal of Sports Science*. 17, 969-978.
- Schwameder, H. & Ring-Dimitriou, S. (2005). Fakten und Legenden. Nordic Walking auf dem Prüfstand. Eine Untersuchung zu Energiebilanz und Gelenkbelastung. In: *Nordic Sports*. 4, 28-31.
- Strunz, U. (2004). Nordic fitness. München: Wilhelm Heyne Verlag
- Vicon Motion Systems. User Manual. Preparation_v1_2. 28-33
- Voloshin, A. (2000). The influence of walking speed on dynamic loading on the human musculoskeletal system. In: *Medicine and Science in Sport and Exercise*. 32, 1156-1159
- Winter, D.A., (1991). The biomechanics and motor control of human gait: normal, elderly and pathological (2nd ed). Waterloo: University of Waterloo Press