GROUND REACTION FORCES, REARFOOT MOTION AND WRIST ACCELERATION IN NORDIC WALKING

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The aim of this study was to analyze loading parameters in nordic walking (NW) compared to ordinary walking (W) with respect to upper and lower limb injury risks. 24 licensed NW-instructors, 12 male and 12 female (38±13 years, 175±9 cm, 78±14 kg, BMI 25±3 kg/m2), performed W and NW trials on a runway covered with artificial turf. Walking speed was controlled by two photo cells. By using an electrogoniometer and a Kistler platform, pronation and ground reaction forces were measured. Wrist acceleration was quantified by an uniaxial accelerometer attached to processus styloideus radii of the right forearm. Statistical evaluation was done by ANOVA and post hoc t-tests ($p<0.05$). Similar results were found for all three walking velocities chosen (5 km/h, 7km/h, 8 km/h). Except for the 2nd peak of the vertical ground reaction force, nordic walking results in higher loading rates and horizontal forces as well as higher pronation and pronation velocity values compared to ordinary walking. Wrist accelerations values up to 7 times gravitational acceleration were recorded in NW.
The data clearly indicate that nordic walking can be recommended as low impact sport with relatively small loads to the lower extremities. However, the high wrist accelerations reveal that the upper extremities are exposed to considerable repetitive shocks, which may cause overuse injuries of wrist-, elbow, and shoulder joints. Thus, additional preventive exercises for the upper limb muscles are recommended as well as using shock absorbing walking poles.

KEY WORDS: nordic walking, walking, pronation, ground reaction forces, wrist acceleration", injury risk.

INTRODUCTION: In the last few years nordic walking has rapidly increased in popularity in the field of fitness sports in Europe and is recommended as an alternative training method for running. Well skilled Nordic Walkers are able to generate velocities up to 10 km/h. Compared with ordinary walking there is on the one hand evidence of the higher energy consumption due to the increased use of the upper extremities and the additional weight of the walking poles. The results of Porcari et al. (1997) and Church et al. (2002) indicate higher energy rates of 20 to 25 per cent. But recent studies show remarkably lower effects of only 9.5 % and 4.3 %, respectively (Schiebel et al., 2003; Höltke et al, 2005). On the other hand the most popular nordic fitness magazines suppose that – compared with walking - nordic walking results in lower impacts on the lower extremities because of joint unloading effects when using the poles during stance phase. But biomechanical studies show contradictive results (Brunelle & Miller, 1997; Rist et al., 2004; Streich et al., 2005). Therefore the aim of this study was to explore the injury risks of lower and upper extremities when using walking poles.

METHOD:
Data Collection: 24 licensed nordic walking-instructors (12male; 12 female; 38±13 years, 175±9 cm, 78±14 kg, BMI 25±3 kg/m2) took part in this study. Wearing their own shoes the test persons performed walking (W) and nordic walking (NW) trials with their own walking poles over two adjoining Kistler force platforms (120cm x 40 cm). As recommended by the nordic walking associations the subjects chose a pole length of 66-67% of body height. The walking path was covered with artificial turf. In randomized order the subjects performed five repetitive walking trials at each of the three speeds 5, 7, and 8 km/h. Walking speed was controlled by two photo cells at equal distance in front of and behind the platform location. All trials within a range of 3 % of the target speed were accepted. In the NW test conditions the touchdown area of the walking poles was located outside of the force plate so that only vertical and anterior-posterior GRF data of the feet were registered. By attaching an

electrogoniometer to the right heel counter, pronation and pronation velocity of the right foot were measured during stance phase. A good prediction of shock waves travelling through the body can be achieved from maximum vertical force rates (Hennig et al., 1993). Shock wave transmission through upper extremities was measured by using an uniaxial accelerometer (ENTRAN EGAX 25) that was glued to the right wrist and fixed with an elastic strap. The accelerometer was attached to the skin on the medial side of the right processus styloideus radii and quantified wrist acceleration.

Data Analysis: For each subject the measurement parameters of the five repetitive trials were averaged before further statistical treatment. A repeated measures ANOVA with post hoc t-tests ($p<0.05$) was applied to analyze mean values.

Figure 1: Accelerometer at right wrist

Figure 2: Goniometer at right heel

RESULTS: The following two figures and table 1 present the results. The force and wrist acceleration values were calculated as multiples of body weight (bw) and gravitational acceleration (g), respectively. Pronation represents the range of motion of achilles tendon angle (in degrees) from supination at heel strike to maximum pronation during mid-stance. Maximum pronation velocity was calculated as degrees/s. Significant differences between W and NW are marked by * ($p<0.05$) and ** ($p<0.01$).

Table 1: Mean values of maximum vertical force rate, pronation, maximum pronation velocity and maximum wrist acceleration in W and NW at 5, 7 and 8 km/h.

Velocity	Movement	Maximum vertical force rate (bw/s)	Pronation (°)	Maximum pronation velocity (°/s)	Maximum wrist acceleration (g)
5 km/h	NW	22,0 **	11,3 *	149	3,4
	W	18,7	10,4	142	
7 km/h	NW	39,2 *	11,4 **	194 *	5,3
	W	37,2	9,6	168	
8 km/h	NW	50,8	10,8 **	186 **	7,1
	W	49,7	9,3	164	

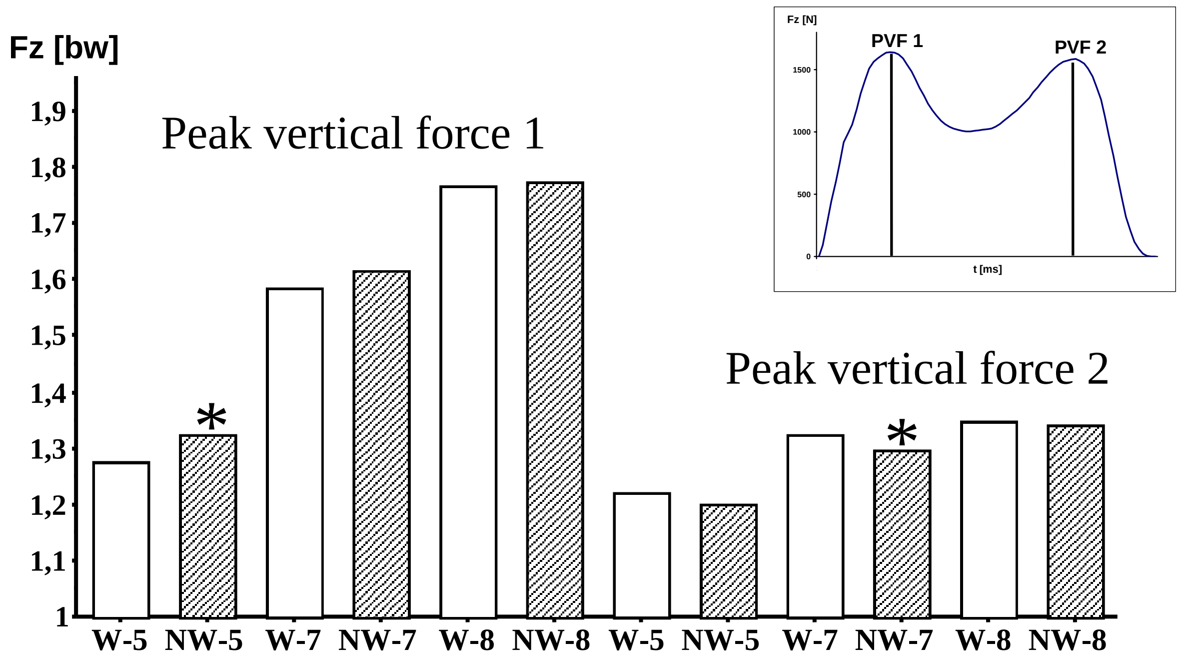

Figure 3: 1st and 2nd Peak vertival force (PVF1 and PVF2) of vertical GRF-curves during Walking (W) and Nordic Walking (NW) at velocities of 5, 7 and 8 km/h.

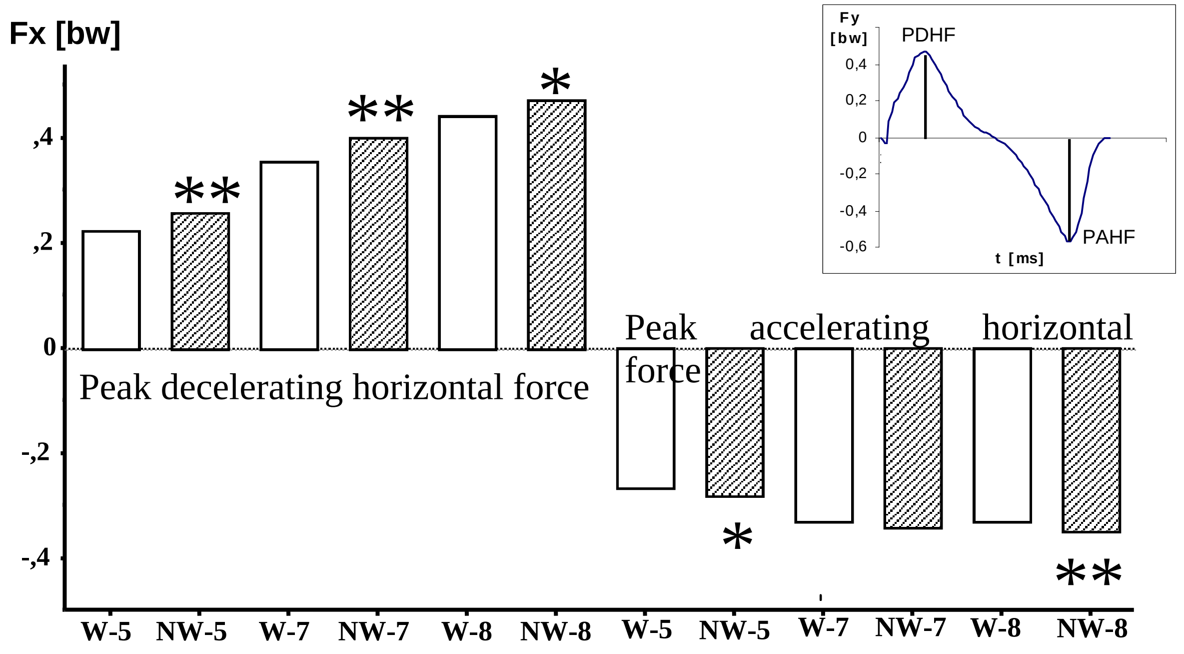

Figure 4: Peak decelerating and accelerating horizontal forces (PDHF, PAHF) in anterior-posterior direction during walking (W) and nordic walking (NW) at velocities of 5, 7 and 8 km/h

DISCUSSION: Except for the 2nd peak of vertical force, nordic walking results in higher loading rates and horizontal forces, as well as higher pronation and pronation velocity values compared to ordinary walking. The specific movement recommendations for the nordic walking technique are probably the reason for higher mechanical strain on the human locomotor system. The recommended accentuated foot dorsiflexion at heel touchdown with larger step lengths cause higher braking forces that lead to increased pronation and pronation velocity values as compared to normal walking. Additionally, the stronger dorsiflexion of the foot results in a higher effective mass at touchdown. Thus, the findings reveal higher mechanical loading in NW during initial contact. In this study an additional comparison of lower extremity loading between NW and slow running at the same speed was performed (Hagen et al., 2006).

In contrast to W and NW slow running results in 30% higher vertical forces and 50 % higher loading rates. Although rearfoot motion in NW is significantly higher ($p<0.01$ at 8.0 km/h and $p<0.05$ at 8.5 km/h) than in slow running, lower limb injury risks do not seem to increase because pronation velocities are remarkably lower by a factor of 2.4 to 2.7. The significantly higher vertical forces and pronation velocities ($p<0.01$) reveal that slow running causes noticeably higher mechanical stress for the lower extremities than both kinds of walking.

CONCLUSION: Considering these results, nordic walking can be recommended as a low impact sport with regard to the lower extremities. But the repetitive high wrist shocks of up to 7 times gravitational acceleration show that the upper extremities may be exposed to a considerable injury risk that should not be neglected. First prospective evaluations from 122 nordic walkers (Knoblauch & Krettek, 2006) revealed that the most injuries are located at the wrist, elbow, shoulder and neck. Therefore additional preventive exercises for the upper limb muscles are recommended as well as using shock absorbing walking poles. A future study will investigate shock transmission to the wrist in different pole length conditions.

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