BIOMECHANICAL LOADING OF THE LOWER EXTREMITIES DURING NORDIC WALKING – A FIELD STUDY

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The purpose of this study was to analyse under field conditions the loading of the lower extremities during nordic walking compared to walking. For that purpose 14 experienced, middle aged nordic walkers and 6 nordic walking instructors have been asked to walk a 1575m field track in randomised sequence, once with and once without poles. The mean vertical ground reaction forces are not different between nordic walking and walking. The present results are showing that the common opinion of a load reduction of the lower extremities by 30-50 % during Nordic Walking has to be rejected.

KEY WORDS: pole walking, nordic walking, vertical forces, biomechanical loading, field study

INTRODUCTION: Nowadays, according to the German nordic walking association, 2 million people are doing nordic walking in Germany. The benefits - like higher oxygen consumption, heart rate and caloric expenditure on the cardiovascular and cardiopulmonary systems have been reported amongst others by Porcari et al. (1997) and Church et al. (2002). However, recent studies have shown that the physiological effects seem to be overestimated (Schiebl et al., 2003; Höltke et al., 2005). The same situation might refer to the biomechanical loading of the lower extremities during nordic walking compared to walking. Several sports associations or journals of physical exercise still state that walking with nordic walking poles provide 30-50% load reduction to the lower extremities (e.g. Geyer 2005). In contrast to these statements, several studies already focused on biomechanical loading in experimental set-ups and found only little evidence of load reduction (Willson et al., 1999). Therefore, the aim of this study was to analyse the loading of the lower extremities during Nordic Walking compared to walking in real field circumstances with different walking tracks.

METHOD: For that purpose 14 experienced, middle aged nordic walkers and 6 nordic walking instruc-tors (mean±SD: age 51±9; length 1.71±8; weight 72±14; 12 month experiences on average, at least one time a week nordic walking exercises) have been asked to walk a 1575m track. The track consisted of four different walking tracks: 1) two asphalt tracks (both 199,42m) little inclination of 1.05% and little declination of 1.05%, 2) two cast tracks (both 155,42m), inclination and declination of 0.36% 3) moderate downhill track (104,98m) with a declination of 4.37% and 4) a moderate uphill track (55,33m) with an inclination of 5.8%. Subjects were asked to walk the whole track two times. One time with and one time without walking poles. The only instruction was given to practice their own technique and try to keep the same walking velocity for both conditions. The sequence of conditions was randomised. All subjects wore a little backpack (2.5 kg) with mobile data acquisition equipment (Novel, Biovision). Biomechanical variables like the vertical ground reaction force (measured by insoles, carefully calibrated each sequence by Kistler force plates), vertical forces and positions (by force transducers and inclinometers, embedded in the walking poles), range of motion of the knee joint (by goniometers) and position and acceleration of the thigh (by inclinometers and dual axis accelerometers) have been recorded. All walking tracks were measured in detail by an institute of surveying and mapping affaires. The time for the different tracks was recorded by a stopwatch. The biomechanical data of approximately 20.000 of as a whole 70.000 steps were recorded, triggered and sampled by a frequency of 100Hz (insoles) and for the other biomechanical parameters by 500Hz, and analysed. The primary statistical analysis concerned matched paired t-test after checking with the Kolmogornov-Smirnov test that the data were normally distributed. The statistical analysis was done by SPSS 12.0.

RESULTS: The averaged vertical reaction forces and the vertical pole forces of all subjects (for the nordic walking condition) of all walking trails are shown in figure 1.

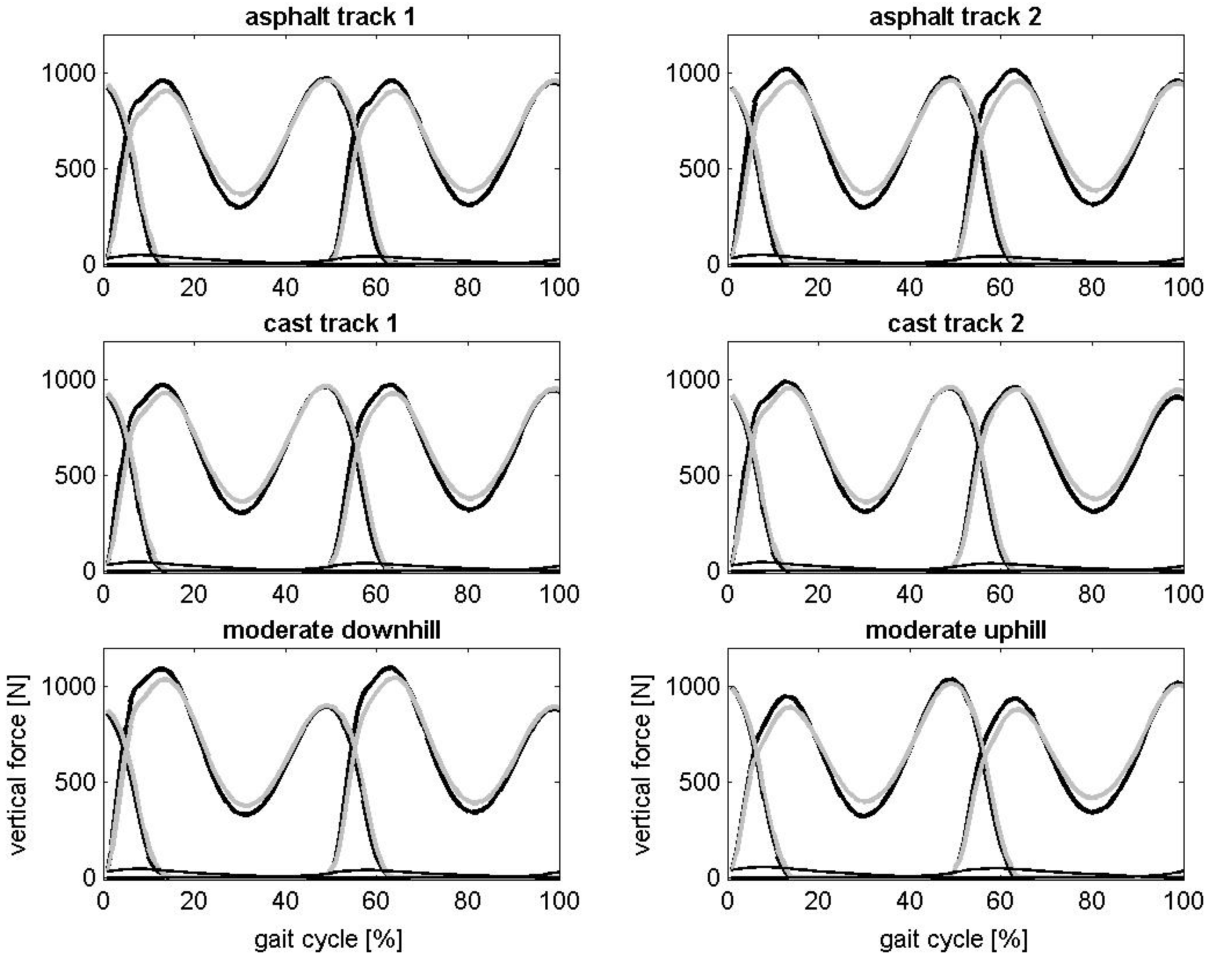

Figure 1: Mean vertical reaction forces of the left and the right foot and the vertical reaction force of the walking poles of all subjects. The beginning of the gait cycle was set at the heel contact phase of the left foot. The black solid line represents the nordic walking condition, the grey solid line the walking condition. The other two black lines show the vertical forces of the right pole (maximum at 10% gait cycle) and the left pole (maximum at 60% gait cycle).

Due to dynamic forces, peak loads of approximately 140-170% of the body weight have been measured. First of all, no lower vertical reaction forces during nordic walking compared to walking have been found. Neither a reduction of the loading response at heel contact and push off, nor due to one of the different walking tracks, have shown less vertical reaction forces. In contrast, in most of the sequences higher vertical reaction forces during heel contact were recorded for the nordic walking condition (see figure 1). Though, these differences were not significant (except for the asphalt track 2 ($p<0.05$), see table 1). In addition, the same trend is confirmed by no significant differences of the impulse (table 1). Only the minimum of force in the mid stance phase is significantly lower in nordic walking condition. Secondly, the vertical reaction forces measured in the walking poles are very marginal (46N on average for all walking tracks, see table 1). The peak of the highest forces does not overlap with the time to peak of the maximum vertical reaction forces of the foot (figure 1). The ground contact of the poles has been measured in an angle of 30-50°, so that an effective release through the poles becomes less in vertical direction (data not presented).

Table 1: Mean of the first maximum (F1), minimum (F2), second maximum (F3), impulse, vertical reaction force and impulse of the poles, gait cycle (GC) and gait velocity across all subjects and walking tracks. The data highlighted with bold letters indicate significant differences between Nordic Walking (NW) and Walking (W) ($p<0.05$)

		asphalt track 1		**asphalt track 2**		**cast track 1**		**cast track 2**		**moderate downhill**		**moderate uphill**	
foot forces		**left**	**right**	**left**	**right**	**left**	**right**	**left**	**right**	**Left**	**right**	**left**	**Right**
F1-NW	mean	1010	1012	**1047**	1061	1017	1013	1018	1016	**1111**	1124	**1059**	1044
[N]	± SD	184	178	200	48	195	193	194	192	232	261	229	217
F1-W	mean	984	985	**995**	1011	994	993	995	998	**1050**	1068	**1019**	1014
[N]	± SD	170	157	168	41	179	176	177	181	194	210	206	194
F2-NW	mean	**291**	**304**	**290**	**303**	**297**	**312**	**304**	**297**	**319**	**329**	**316**	**333**
[N]	± SD	132	144	124	138	122	125	131	149	152	149	140	146
F2-W	mean	**358**	**374**	**361**	**377**	**356**	**372**	**343**	**361**	**360**	**376**	**383**	**404**
[N]	± SD	114	113	110	111	109	110	108	114	106	111	99	111
F3-NW	mean	971	955	977	96	965	949	957	904	891	879	1036	1018
[N]	± SD	185	177	185	183	195	188	194	277	180	168	221	214
F3-NW	mean	965	961	961	948	967	954	954	943	885	881	1008	1001
[N]	± SD	168	164	167	167	178	175	182	178	149	149	205	194
imp.-NW	mean	392	399	395	405	407	416	422	427	412	423	415	429
[N·s]	± SD	100	104	104	112	104	111	108	117	118	122	118	122
imp.-W	mean	391	400	398	414	401	414	407	417	404	419	410	431
[N·s]	± SD	82	82	84	87	88	88	83	88	92	93	89	93

		asphalt track 1		**asphalt track 2**		**cast track 1**		**cast track 2**		**moderate downhill**		**moderate uphill**	
pole forces		**left**	**right**	**left**	**right**	**left**	**right**	**left**	**right**	**Left**	**right**	**left**	**right**
Fmax-NW	Mean	43	49	43	49	42	48	40	46	41	47	51	57
[N]	± SD	16	15	18	17	19	17	17	16	16	16	21	20
Imp.-NW	Mean	12	13	11	12	11	12	11	12	11	12	14	16
[N·s]	± SD	4	4	4	4	4	4	4	4	4	4	7	6

gait parameter		**asphalt track 1**	**asphalt track 2**	**cast track 1**	**cast track 2**	**moderate downhill**	**moderate uphill**
cycle-NW	Mean	1.000	0.994	**1.053**	**1.068**	1.017	1.040
[s]	± SD	0.091	0.098	0.092	0.107	0.104	0.103
cycle-W	Mean	0.989	0.996	**1.025**	**1.036**	1.003	1.033
[s]	± SD	0.073	0.082	0.081	0.083	0.082	0.079
v-NW	Mean	**1.859**	**1.919**	**1.812**	**1.775**	**1.869**	**1.946**
[m/s]	± SD	0.144	0.245	0.138	0.138	0.169	0.218
v-W	Mean	**1.740**	**1.789**	**1.730**	**1.725**	**1.783**	**1.839**
[m/s]	± SD	0.170	0.249	0.149	0.147	0.135	0.153

Derived from the results of this study presented in table 1, the walking velocity during nordic walking was for all walking tracks significantly higher compared with the walking condition. However, the differences are rather marginal.
Similar results were found comparing the nordic walking practitioners with the instructors.

DISCUSSION: The present study analysed for the first time the loading of the lower extremities during nordic walking compared to walking in real field circumstances with different walking tracks. The results show that the common opinion of a load reduction of the lower extremities by 30-50 % during nordic walking has to be rejected. The lower forces during the very low loaded mid stance phases in nordic walking are not relevant in this context.
All data has shown that there is no reduction of the vertical reaction force due to nordic walking. In contrast, in almost all walking tracks, the forces at heel contact are higher during the nordic walking condition compared to the walking condition. At the present study, subjects were introduced to practice both conditions with the same walking velocity. The results have shown that the subjects during the nordic walking conditions were significantly faster than during the walking conditions. This might be an explanation why during heel contact the vertical reaction forces are higher for nordic walking. On the other hand, the differences between these conditions are marginal. All in all, there were no indications of a load reduction at all.
At this point, nordic walking as a sport to reduce joint loading of the lower extremities should not longer be recommended.

CONCLUSION: In future, research should focus on clinical examples of patients with anterior knee pain who indicate less pain after nordic walking. Results of this study concerning the range of motion of the knee joint even as the position and acceleration of the thigh finished before long may provide some helpful indications. One additional factor of pain relief might be in these cases a different neuromuscular control mechanism compared to walking.

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