GROUND REACTION FORCES ON STAIRS: EFFECTS OF STAIR INCLINATION AND AGE

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INTRODUCTION

Stair ascent and descent has become an alternative test procedure to level gait. As a baseline for a comparison with patient data, normative data of the vertical ground reaction force (GRF) measured on stairs are necessary, but are still rare. The goals of the study were to test whether selected parameters of the vertical GRF of stair ambulation of normal subjects differ with respect to (i) stair inclination and (ii) age of test subjects.

METHODS

Twenty healthy test subjects (between 27 and 83 years) were tested when walking on level ground, and during ascent and descent on stairs with 20° (flat), 31° (standard) and 41° steep inclinations; thus a total of 7 test conditions. Each test subject repeated all test conditions 10-12 times. Parameterization of two consecutive steps of the vertical GRF curves was performed with a computer routine adapted from Stüssi et al. (1980; Fig. 1). Absolute symmetry index (ASI) was computed after White et al. (1999). Statistical treatment included ANOVA and nonparametric tests.

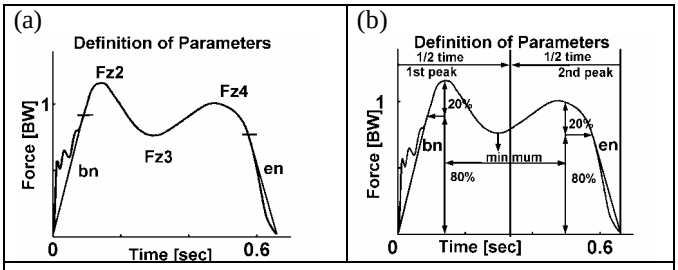

Fig. 1: (a) Definition and (b) detection of selected parameters of the vertical GRF curve measured during level walking.

RESULTS AND DISCUSSION

To (i): During all stair descent conditions the vertical GRF parameters Fz2, bn (left and right) increased compared to all stair ascent conditions (Table 1: (1)). During level gait the parameters Fz2, bn (left and right) were significantly smaller compared to all three stair descent conditions and compared to steep stair ascent (2). Time of foot contact (T, left and right) was significantly shorter in the following conditions: gait vs. steep up, all stair down vs. steep up, and standard down vs. flat up. As previously reported (Stacoff et al., 2002), ASI increased from level gait to stairs by a factor > 2. Significant ASI differences were found between gait vs. steep stair up (Fz3, Fz4, en), gait vs. all stair down (Fz2, bn,), and all stair up vs. steep stair down (Fz2, bn, T).

To (ii): In level gait and stair ascent, the young age group (33.7 ±8.0yrs, n=7) showed 14 significantly increased dynamic gait parameters (Fz3, Fz4, bn, en) compared to the old age group (76.5 ±4.2 yrs, n=8). The middle (n=5, 63.6 ±4.2yrs, n=5) and old age groups differed only in stair ascent with two parameters and in level gait the young group walked faster than the middle age group. No significance was found in the stair descent condition. Significant ASI differences with respect to age groups were only found in 5 comparisons (two young vs. old and three middle vs. old) over all test conditions and parameters.

SUMMARY

The results show that vertical GRF parameters alter systematically between level gait and stair descent as well as between stair ascent and descent. Age shows significant effects on various parameters between the young and the old age groups. Asymmetry increased significantly in several parameters from level gait to the steep stair and in few between the young and old as well the middle and old age groups.
In conclusion, when using normative data for comparison with patient data, the effects of (i) stair inclination and (ii) age have to be considered. Age reduces the dynamics of the vertical GRF. Inclination effects vertical loading (particularly on the steep stair down) and the asymmetry between left and right. The present normative data may be used as a baseline for comparison with patient data.

REFERNCES

Stacoff et al. *IV WCB, Calgary*, 2002, P162; Stüssi et al. *Biomed. Tech.*, 25: 222, 1980; White R. et al. *Clinical Biomechanics*, 14:185, 1999.

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		left Parameters						right					
Test		**T**	**Fz2**	**Fz3**	**Fz4**	**bn**	**en**	**T**	**Fz2**	**Fz3**	**Fz4**	**bn**	**en**
		[ms]	[BW]	[BW]	[BW]	[BW/s]	[BW/s]	[ms]	[BW]	[BW]	[BW]	[BW/s]	[BW/s]
Level Gait (2)		650.41 ± 46.19	1.19 ± 0.11	0.69 ± 0.08	1.17 ± 0.06	7.92 ± 1.51	-9.64 ± 1.39	652.35 ± 46.36	1.21 ± 0.12	0.68 ± 0.08	1.17 ± 0.08	7.90 ± 1.53	-9.78 ± 1.47
Stair up (1)	Flat	698.35 ± 70.55	1.12 ± 0.10	0.71 ± 0.09	1.13 ± 0.09	6.09 ± 1.24	-10.16 ± 0.97	700.99 ± 71.73	1.12 ± 0.10	0.69 ± 0.08	1.13 ± 0.08	6.11 ± 1.22	-9.82 ± 1.05
	Standard	692.13 ± 94.31	1.12 ± 0.10	0.70 ± 0.06	1.23 ± 0.10	5.79 ± 1.26	-11.12 ± 1.28	694.74 ± 93.39	1.12 ± 0.09	0.67 ± 0.04	1.22 ± 0.10	5.84 ± 1.01	-10.94 ± 1.45
	Steep (2)	739.06 ± 96.26	1.14 ± 0.09	0.69 ± 0.07	1.26 ± 0.15	5.34 ± 1.30	-11.44 ± 1.88	741.45 ± 100.85	1.10 ± 0.09	0.65 ± 0.06	1.22 ± 0.13	5.15 ± 1.06	-10.77 ± 1.70
Stair down (1)	Flat (2)	636.84 ± 62.0	1.49 ± 0.15	(--)	(--)	11.81 ± 2.53	(--)	640.41 ± 63.83	1.54 ± 0.16	(--)	(--)	12.16 ± 3.00	(--)
	Standard (2)	612.33 ± 97.57	1.56 ± 0.17	(--)	(--)	12.79 ± 2.69	(--)	618.80 ± 101.26	1.60 ± 0.17	(--)	(--)	12.70 ± 2.94	(--)
	Steep (2)	633.52 ± 92.9	1.57 ± 0.23	(--)	(--)	13.64 ± 4.01	(--)	644.43 ± 88.22	1.60 ± 0.21	(--)	(--)	13.66 ± 3.52	(--)