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Dynamic overloads during marching past gait

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The paper presents quantities which characterise overloads during marching past gait obtained from the time curves of the ground reaction forces. The following quantities were interpreted: time of single support, time of strike, extreme values of ground reaction force in the sagittal plane, build-up force indexes and velocity of marching past gait.

Key words: extreme forces, ground reaction forces, marching past gait, overloads

1. Introduction

Standard gait, being the natural form of man's locomotion, differs significantly from the military marching past gait. The main differences lie in the technique used to put the foot down in the support phase. In normal gait the foot is put down gently, the heel touches the ground and the entire sole then transfers the load to the foot's fore part [6]. In marching past gait, on the other hand, soldiers initiate the support phase by energetically hitting the entire sole against the ground. Consequently, when military shoes are hobnailed, soldiers can synchronise their marching gait by a strong acoustic effect produced by hitting the sole against the ground. Foot stamping against the ground is often the cause of pain, mainly located in foot joints, knee joint, soft tissues of shank, ischio-shin muscles and in the lumbar section of the spine. These observations gathered from conversations and lack of data on real forces acting during the marching past gait were the inspiration of the investigation.

This paper presents the levels of extreme forces and build-up force indexes that could cause the sensation of pain during marching past gait. Dynamic overloads occurring in marching past gait were compared with those in standard gait and referred to overloads occurring in motions other than gait [1]–[6].

2. Material and method

Twelve soldiers in active service, members of the honorary guard, aged 21.4 ± 0.5 years, weighting 83.2 ± 5.8 kg and 183.0 ± 3.3 cm tall were subjected to dynamometric examination of the ground reaction forces. The measurement setup consisted of the Kistler piezoelectric platform linked to an IBM PC computer and two photocells to determine average gait speed. Signals were sampled with the frequency of 1000 Hz. Each soldier went three times across the dynamometric platform, using a standard and a marching past gait. Ground reaction forces in the sagittal plane were recorded.

3. Results and discussion

One of the three time curves of the reaction forces for each of the gait types was used in calculation and analysis. The selection criterion was the greatest force R_{z1} in the standard gait and the greatest force R_{z0} in the marching past gait (figure 1). Using the time curves of the ground reaction forces $R_y(t)$ and $R_z(t)$ (figure 1), the following quantities were determined: T – time of single support phase in gait, T_u – time of strike in marching past gait R_{z0}, R_{z1}, R_{z2} – extreme ground reaction forces for the vertical component, expressed in units of body weight (BW). R_{z0} refers only to the strike

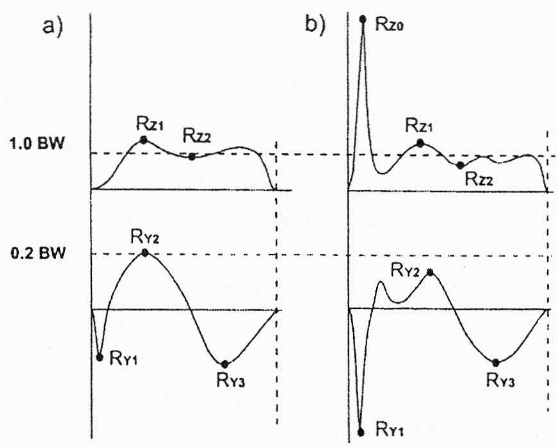

Fig. 1. Typical time curves of ground reaction forces:
a) standard gait, b) marching past gait

phase in marching past gait, R_{z1} (R_{z2}) is the global maximum (minimum), R_{y1}, R_{y2}, R_{y3} – extreme ground reaction forces for the horizontal component. R_{y1} refers to the strike phase, R_{y2} and R_{y3} are global extremes, I_{z0}, I_{y1} – build-up force indexes in strike phases, defined as quotients of extreme forces and times needed to reach them, v – average gait speed.

Table 1. Kinematic and dynamic quantities
(x and V – average values and their variability coefficients)

a) standard gait

No.	T [s]	R_{z1} [BW]	R_{z2} [BW]	R_{y1} [BW]	R_{y2} [BW]	R_{y3} [BW]	I_{y1} [BW/s]	V [m/s]
1	0.757	1.18	0.69	0.14	0.26	0.24	25	1.18
2	0.841	1.14	0.81	0.15	0.20	0.19	11	1.13
3	0.778	1.19	0.68	0.12	0.17	0.18	8	1.28
4	0.866	1.17	0.80	0.31	0.19	0.16	34	1.29
5	0.853	1.23	0.73	0.18	0.21	0.20	20	1.10
6	0.848	1.15	0.76	0.15	0.14	0.14	15	1.10
7	0.801	1.14	0.75	0.17	0.18	0.17	18	1.06
8	0.905	1.17	0.76	0.28	0.16	0.15	29	1.12
9	0.889	1.18	0.83	0.15	0.19	0.17	12	1.28
10	0.773	1.19	0.71	0.19	0.17	0.15	17	1.25
11	0.832	1.16	0.83	0.14	0.19	0.18	15	1.12
12	0.777	1.16	0.68	0.12	0.26	0.22	9	1.18
$\bar{x}$	0.827	1.17	0.75	0.18	0.19	0.18	17.8	1.17
V [%]	1.7	0.6	2.2	9.9	5.4	4.8	13.1	2.0

b) marching past gait

No.	T [s]	T_U [s]	R_{z0} [BW]	R_{z1} [BW]	R_{z2} [BW]	I_{z0} [BW]	R_{y1} [BW]	R_{y2} [BW]	R_{y3} [BW]	I [BW/s]	v [m/s]
1	0.824	0.022	5.28	1.19	0.73	880	1.97	0.16	0.27	219	1.02
2	0.853	0.027	3.34	1.17	0.69	278	1.68	0.12	0.31	140	1.00
3	1.005	0.023	2.38	1.14	0.77	199	1.17	0.15	0.16	97	0.97
4	0.883	0.022	3.42	1.15	0.72	244	1.48	0.13	0.17	114	1.15
5	1.014	0.020	4.27	1.10	0.68	936	2.34	0.14	0.21	260	1.16
6	0.807	0.018	7.42	1.21	0.69	928	2.53	0.15	0.35	362	0.97
7	0.877	0.021	7.49	1.22	0.67	935	2.25	0.15	0.38	321	1.01
8	0.980	0.019	6.31	1.16	0.70	578	2.41	0.11	0.23	301	1.19
9	0.892	0.024	9.83	1.20	0.68	969	2.69	0.14	0.39	308	1.06
10	0.938	0.020	5.62	1.19	0.71	643	2.05	0.14	0.28	216	1.13
11	0.921	0.019	6.09	1.18	0.73	764	1.82	0.12	0.18	243	1.10
12	0.983	0.025	3.66	1.16	0.67	390	1.68	0.18	0.25	162	1.11
$\bar{x}$	0.915	0.022	5.42	1.17	0.70	645	2.00	0.14	0.26	228	1.07
V [%]	2.2	3.6	11.5	0.8	1.2	13.4	6.6	3.9	8.7	10.9	2.1

Results of the calculations for the standard gait are presented in table 1a, whereas those for the marching past gait in table 1b. As the average speeds of standard gait and marching past gait are similar (1.17 and 1.07 m/s), it is justified to compare the quantities characteristic of both gait types. The discussion of kinematic and dynamic quantities pertains to average values. The time of single support phase in marching past gait (0.915 s) is longer than in standard gait (0.827 s); this is partly connected with slightly lower speed of the marching past gait. The time of the strike phase in marching past gait (22 ms) is comparable with, e.g., hand or leg strikes in shotokan karate (19–26 ms) [3] and with the time of reaching maximum reaction force in, e.g., triple jump and races by the heel technique [1], [6].

Extreme ground reaction forces were adopted as the global indices defining overloads in bones. Greater reaction forces in lower extremity joints, e.g. greater stresses in long bones, correspond to greater overloads. The values of extreme forces R_{z1} and R_{z2} in both gait types are not much differentiated (1.17 and 1.17, 0.75 and 0.70 BW) and are identical to Winter's data [6], unlike R_{y2} and R_{y3} (0.19 and 0.14, 0.18 and 0.26 BW). Very great forces R_{z0} and R_{y1} in the strike phase of support in marching past gait are a very interesting result of the investigation. The values of vertical extreme forces R_{z0} change from 2.38 to 9.83 BW, which is typical of percussive forces. Horizontal extreme forces R_{y1} of marching past gait are about 11 times greater than in standard gait (0.18 and 2.00 BW); they are comparable with vertical forces developed in very fast gait and slow run [5, 6].

Such high levels of forces R_{z0} and R_{y1} explain the causes of pain sensation in soldiers during marching past gait, particularly considering the cyclic character of motion leading to changes due to overloads. Extreme forces in strike phases of the marching past gait occur after a few milliseconds; this is the reason of very large values of the indexes of build-up forces I_{z0} and I_{y1}. In the case of marching past gait index I_{y1} is several times greater than in standard gait (228 and 18 BW/s). Force R_{z0} in marching past gait (5.42 BW) is comparable with the strike force of foot mae-geri (4.27 BW, force building – 390 BW/s) [3], with the ground reaction forces developed in the hurdle race (2.55–7.30 BW) [4] and with forces in some jumping exercises of light athletics jumpers [1]. However, quantity R_{z0} is slightly smaller than the ground reaction forces generated during landing in back standing somersault (7.18–15.52 BW, force build-up 209–728 BW/s) [2]. It is also smaller than forces generated in foot yoko-geri strikes (8.92 BW, build-up 852 BW/s) or maweshi-geri strikes (7.31 BW, build-up – 1070 BW/s) in karate [3]. It is also smaller than maximum values of take-off forces in triple jump and high jump (8–13 BW) [1].

4. Conclusions

Very large forces occurring in the strike phases of the marching past gait, comparable with the forces generated in the motorial structures of professionally trained sportsmen (jumpers, runners, gymnasts, karate fighters) [1]–[5], trigger a pain mechanism, which is a symptom of overloads in the tissue structures of soldiers. It seems necessary to look for other ways of obtaining the acoustic effect in marching past gait by redesigning the shoes. Selection of soldiers subjected to such considerable overloads and proper prevention are also necessary.

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