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THE EFFECT OF BODY WEIGHT UNLOADING ON KINEMATIC GAIT PARAMETERS DURING TREADMILL WALKING

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Abstract: *Body weight unloading (BWU) has become a typical strategy of gait training for patients with neurological and musculoskeletal disorders. However, the unloading system has an impact on the gait parameters. The aim of this study was to investigate kinematic gait parameters of healthy person during treadmill walking by manipulating BWU and treadmill speed. The two type of unloading strategies has been studied - with stationary unloading system and with application of algorithm controlling a follow-up the movement of unloading system in horizontal axis.*

Keywords: Body weight unloading, Kinematic gait parameters, Rehabilitation, Treadmill walking.

1. Introduction

The use of mechatronic devices in gait rehabilitation field has increased substantially. In the recent years a gait rehabilitation with systems for body weight unloading (BWU) has become increasingly popular (Lee and Hidler, 2008; Patiño et al., 2007; Threlkeld et al., 2003). Because of the high reproducibility of exercises a body weight unloading (BWU) carried on treadmills is a high effective method of gait rehabilitation for patients with neurological and musculoskeletal disorders. The main premise behind this method is that the additional support of patients' body weight realized by a BWU system with suspension harness during treadmill walking will reduce the load applied on the lower joints. It is especially helpful when patients start walking and allowing them to generate the locomotor patterns (Fischer and Wolf, 2015; Sousa et al., 2009).

Gait rehabilitation with treadmills and supported by BWU system is usually recommended early after injury to induce sensory stimulation (Threlkeld et al., 2003) and improve locomotor ability (Dickstein, 2008; Lamontagne and Fung, 2004; Schmid et al., 2007; Sousa et al., 2009; Van Hedel et al., 2006).

The general assumptions of gait rehabilitation on treadmills was that treadmill and overground gait patterns were similar enough and gait corrections on treadmills could replace a conventional overground walking training. However, research comparing treadmill and overground gait showing that treadmill training introduces habits different from those assumed to be correct in walking (Fischer and Wolf, 2015).

Because of the many advantages (e.g. small area of training, reduction of hard physiotherapists work) the devices with BWU systems and treadmills should be improved continuously. Currently used devices of this type have a stationary unloading system, mounted in one position without any possibility of movement. This article presents an attempt to determine the effect of follow-up the movement of unloading system in horizontal axis (over the patient) on the kinematic gait parameters.

2. Methods

This studies was conducted with the device for the re-education of locomotion functions, which was developed in the Institute of Theoretical and Applied Mechanics of the Silesian University of

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Technology. The structure of the device is based on the structure of an overhead travelling crane. As a result of installing three drives, the movement of the sling of the person in rehabilitation is possible in all axes. In the experiment only the unloading system with rehabilitation harness and a drive winch relative to the girder were used as indicated in Fig. 1 (Duda et al., 2015). The treadmill was located directly under the BWU system and it worked independently.

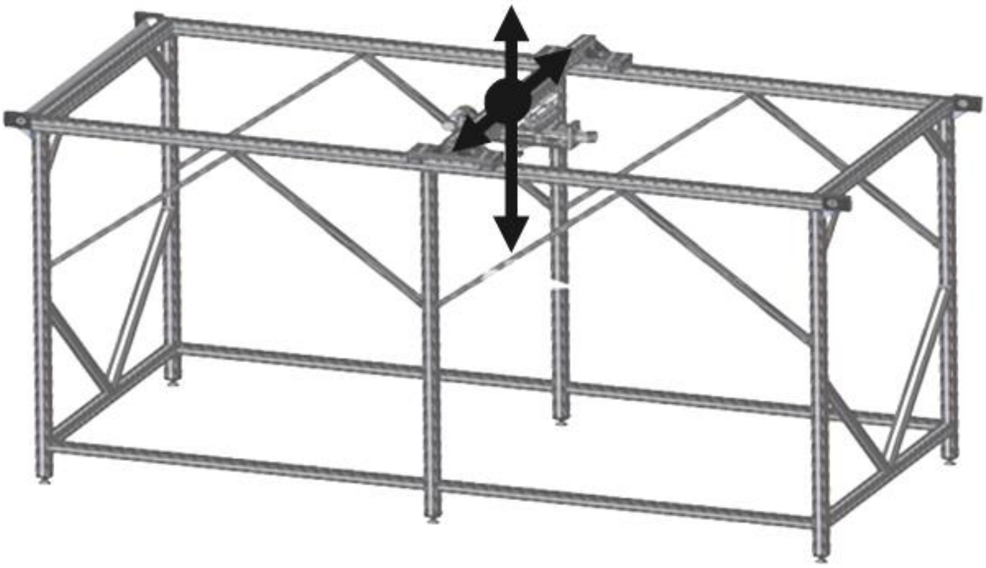

Fig. 1: Mechatronic device for locomotor training.

While testing with the TEMA motion analysis system, the movement of the point near to the centre of the subject mass (PM) has been established. The movement of the subject has been registered using two digital video cameras manufactured by Basler with a sampling frequency of 100 Hz. Reflective markers have been placed on anthropometric points on the body of the subject (Fig. 2), which allowed to estimate the trajectory of the movement of the centre of mass (Nordin and Frankel, 2001). Additionally, four reference points have been placed on fixed plane, parallel to the patients coronal plane.

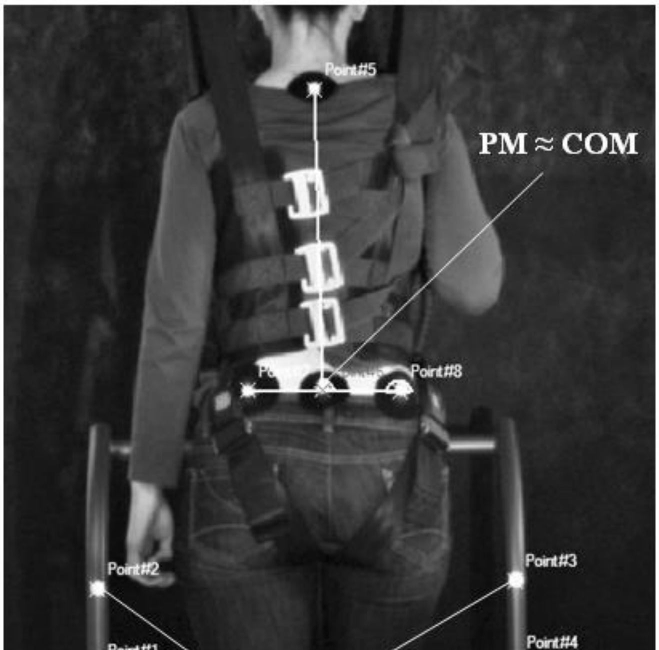

Fig. 2: Video camera image with measurement point marked.

3. Measurements and results

The tests have been conducted with the participation of a healthy person during treadmill walking with a different unloading conditions:

a) without unloading,

b) with unloading implemented by a stationary unloading system,

c) with unloading implemented by a unloading system with a movement follow-up in patients coronal plane.

In modes b and c, unloading at the levels of 100 N (20 % of subjects body weight), 150 N (26 % BW) and 200 N (35 % BW) has been applied. In each cases the treadmill speed equaled 1 km/h, 2 km/h and | 3 km/h. The treadmill speed was increased after at least 15 seconds. The value of unloading has been controlled by closed-loop control system with strain gauges force sensor and the maximum error between the reference and measured unloading force was smaller than 25 N, what is presenting in the figure below (Fig. 3).

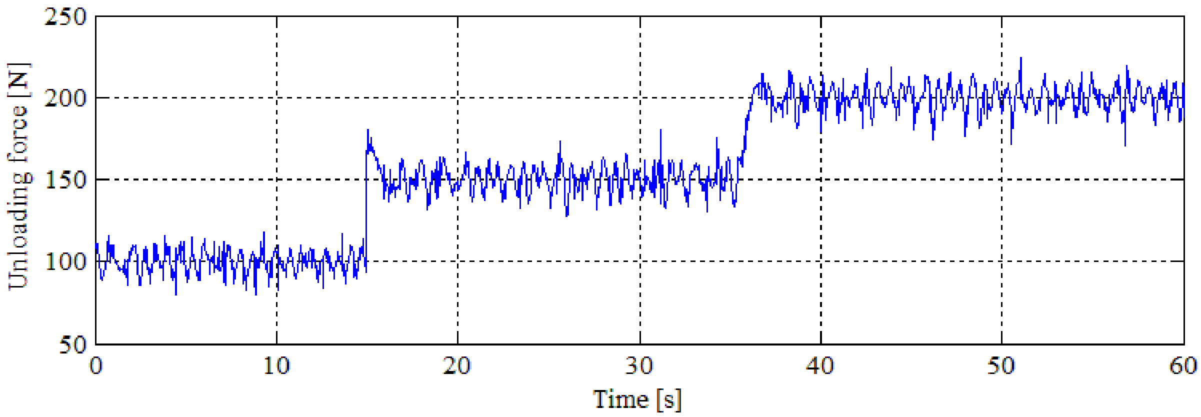

Fig. 3: The value of unloading force as a function of time.

The displacements of the centres of subjects mass established in the tests in each of the modes were used to determine the average displacement ranges in relation to the frontal and longitudinal axes of the subjects.

Tab. 1 presents the mean values of the range of displacement of the centre of the subject's mass in the normal treadmill walking and with three experimental BWU conditions. The BWU was realized by stationary winch. Tab. 2 contains the same values but obtained for devices with a follow-up movement of the winch in the horizontal axis, parallel to subjects frontal axis. The follow-up movement has been realized with PID controller in feedback with rope inclination angle (Mężyk et al., 2016).

As we can see, for a slow speed and low value of unloading force, kinematic gait parameters were comparable with a case without unloading. Increasing levels of BWU resulted in a significant increase in displacement of the centre of the subject's mass. The application of follow-up movement system in unloading winch allowed to decrease the excessive displacements in relation to the horizontal axis and to improve the range of movement in relation to the vertical axis.

Tab. 1: The range of displacement of the centre of the subject's mass- mean values.

	Unloading force [N]				**Unloading force [N]**			
	0	**100**	**150**	**200**	**0**	**100**	**150**	**200**
	Range of displacement in horizontal axis [mm]				**Range of displacement in vertical axis [mm]**			
Vt = 1 [km/h]	63.88	63.49	67.99	87.47	8.70	4.18	5.31	4.64
Vt = 2 [km/h]	48.14	49.47	64.87	71.12	14.13	13.13	18.16	16.32
Vt = 3 [km/h]	32.02	56.64	62.15	63.78	25.38	28.97	31.87	32.48

Tab. 2: Ranges of displacement of the centre of the subject's mass with - mean values (test with follow-up movement in frontal axle).

	Unloading force [N]				**Unloading force [N]**			
	0	**100**	**150**	**200**	**0**	**100**	**150**	**200**
	Range of displacement in horizontal axis [mm]				**Range of displacement in vertical axis [mm]**			
Vt=1 [km/h]	63.88	63.65	54.21	61.54	8.70	4.54	5.18	5.39
Vt=2 [km/h]	48.14	47.78	58.88	62.99	14.13	18.49	18.71	15.35
Vt=3 [km/h]	32.02	50.38	53.56	56.06	25.38	25.62	29.86	31.45

4. Conclusions

The article presents the results of empirical research on kinematic gait parameters while walking on a treadmill with different cases of body weight unloading. During the experiment a typical and new strategy of unloading, with follow-up movement of unloading system in patients coronal plane, has been tested.

The use of high value of BWU resulted in significant changes on kinematic gait parameters in relation to the normal treadmill walking. The application of follow-up movement allowed to decrease the excessive ranges of displacement of the centre of the subject's mass. This confirms the efficiency of the applied unloading strategy, ensuring a greater reflection of the correct walk.

During the study also other parameters like the angle of rope inclination have been registered but a range of displacement has been considered the most representative.

The main limitation of the measurements was the participation of a healthy person since the effectiveness of the proposed unloading strategy should be verified with the participation of people with the gait disabilities.

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