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EFFECTS OF BODY WEIGHT UNLOADING ON BIOMECHANICAL GAIT PARAMETERS DURING OVERGROUND WALKING AT A CONSTANT SPEED

[1,2] Arielle G Fischer, [1]Eytan M Debbi and [1]Alon Wolf
[1] Faculty of Mechanical Engineering, Technion I.I.T., Haifa, Israel
[2] Corresponding Author; email: ariellef@technion.ac.il, web: brml.technion.ac.il

INTRODUCTION

Rehabilitation of gait deficits with a Body Weight Unloading (BWU) system is a common therapeutic intervention. Manipulation of the levels of BWU allows to decrease the biomechanical gait restrictions, to ease the pain that limits range of motion of the lower extremities and thus enable clinical patients to produce the force required for forward propulsion during daily walking [3,6]. Studies on the effects of BWU on gait kinetics, kinematics and muscle activation patterns have been confounded by the walking modalities (treadmill vs. overground) and lack of constant walking speed. Significant differences between treadmill vs. overground walking under various levels of BWU were indicated in the sagittal plane motion of the ankle, hip, knee, and pelvis leading to the conclusion that treadmills do not replicate daily walking[4].

Variability in walking speed also confounded the unique effects of BWU during overground walking. Walking at a speed lower than 2.5km/h was found to distort knee and ankle joint trajectories, while increased speeds impaired subjects' ability to produce adequate plantar-flexor propulsive force [1,2,5]. So far, however difficulties in designing a proper device capable of maintaining a constant speed when using the BWU system without a treadmill prevented the examination of the unique effects of BWU.

Once the proper apparatus was designed this study allowed for the examination of the unique effects of BWU during overground walking at a constant speed. By broadening our understanding of the effects of BWU on gait biomechanics under conditions that approximate daily walking, this research is expected to have implications for gait deficit retraining in clinical populations.

Subjects: Eight healthy male subjects (age 24.1 years, BMI 22.8 kg/m^2) were recruited to the study. After approval of the IRB, the purpose of the study was explained to all subjects and informed consent was obtained.

Apparatus: The Biodex BWU system used consists of an overhead harness vertically supporting the subject with a pelvic belt around the hips and a groin piece. This system provides a dynamic suspension during gait, and can be set at different levels of BWU. An electric winch apparatus was designed and added to pull the system and maintain gait at the constant speed of 4km/h.(Fig1)

Biomechanical measurements: An eight-camera infrared Vicon motion tracking system (Oxford Metrics Ltd.,) recorded at 100 Hz the position of 16 reflective markers placed on anatomical landmarks. A knee alignment device calibrated the knee axis during a static trial. The Plug-In-Gait Model was used to calculate the sagittal plane motion for the ankle and hip joints. Kinetic and impulse parameters were calculated using inverse dynamics. Data were recorded using the Vicon Nexus software and exported to MATLAB™ software for analysis. Results were normalized to 100% of gait cycle.

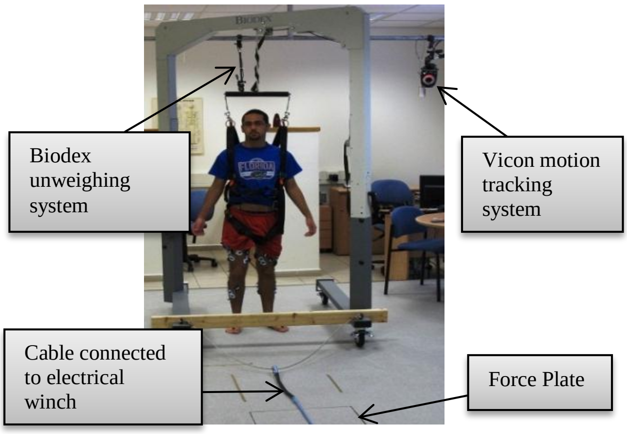


Figure 1: The BWU Biodex system

Procedure: The subjects were asked to walk on the ground along a 10 m walkway with two AMTI OR6-7-1000 force plates placed in a tandem at the center of the walkway. The winch was activated when the subject began moving. Each experimental condition 0%, 15% and 30% BWU included six trials, subsequently averaged for each condition.

Statistical analysis: Correlation coefficients (r) and root mean square errors (RMSE) were used for pairwise comparisons of kinematic trajectories of each joint under 0 to 30% BWU. ANOVA and t-tests were used to compare the peak kinetic and impulse values of the various BWU.

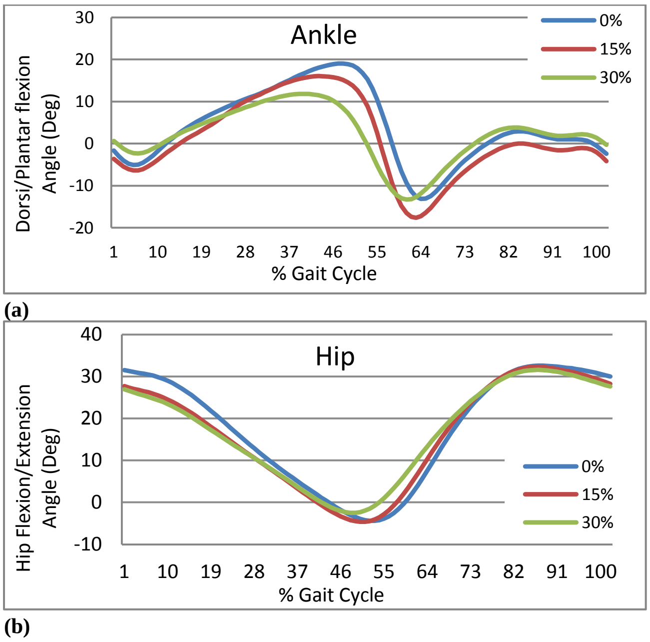
RESULTS AND DISCUSSION

Kinematics: Table 1 shows the Mean (± SD) for peak extension, flexion and range of motion of the ankle and hip in the sagittal plane during a gait cycle, under 0%, 15% and 30% BWU.

Table 1: Mean values for the peak extension and flexion of ankle and hip kinematic parameters under three BWU conditions **N=8**

	Measures (º)	**BWU Conditions**		
		0%	**15%**	**30%**
Ankle	Max dorsi flexion	19.48 ± 1.35	17.06 ± 1.52	12.63 ±1.7
	Max plantar flexion	-13.7 ± 2.03	-18.12 ± 2.71	-7.92 ± 3.73
	Range of motion	33.19 ± 1.05	36.42 ± 2.56	27.21 ± 2.95
Hip	Peak Extension	-4.57 ± 1.05	-4.79 ± 0.93	-3.02 ± 1.17
	Peak Flexion	31.68 ± 0.91	27.77 ± 1.8	27.56 ± 1.72
	Range of motion	36.25 ± 1.39	33.15 ± 1.8	29.69 ± 1.59

Figure 2: Sagittal plane kinematics trajectories for (a) ankle and (b) hip during a gate cycle under 0%, 15%, 30% BWU.



Each curve is an average of all subjects' angular trajectories for the ankle and hip during a gait cycle under under 0%, 15%, 30% BWU conditions

Table 2: Linear pairwise comparisons for hip and ankle kinematics at 0% and 15%, 0% and 30%, and 15% and 30% of BWU.

Sagittal trajectory	**Measure**	**0%-15%**	**0%-30%**	**15%-30%**
Ankle	r	0.96*	0.84*	0.89*
	RMSE(º)	2.38	4.58	2.98
Hip	r	0.98*	0.97*	0.99*
	RMSE (º)	2.84	4.09	2.52

r - correlation coefficient; RMSE- root mean square error; *p<.001

Table 2 shows highly significant correlations of all pairwise comparisons of 0% to 30% BWU for the ankle (r>84; p<.001) and the hip (r>98; p<.001) kinematics and low root mean square errors (RMSE) (2.38<RMSE<4.58). These findings suggest that 0 to 30% BWU may safely be used to decrease joint loading without significantly distorting ankle and hip motion trajectories during overground walking**.**

Kinetics analysis

ANOVA conducted on peak kinetic parameters under 0%, 15%, and 30% BWU shows significant (p<.001) differences in sagittal plane kinetics and impulses of the ankle and hip at terminal stance phase of gait, and no significant (p>.05) differences at the loading response phase of ankle peak plantarflexion and hip peak flexion moments (Table 3, Fig.3). These findings suggest that BWU is an efficient method of reducing loads on the lower joints without affecting joint function in gait.

Table 3: Mean (SD) and ANOVA for sagittal plane and impulses of the ankle and hip over a gait cycle, under 0%, 15% and 30% BWU

	Measures	**BWU Conditions**			
		0%	15%	30%	F(8,2)
Ankle	Peak Plantarflexion Moment $(\%BW \cdot Ht)$	-1.27 ± 0.34	-1.28 ± 0.22	-1.17 ± 0.28	1.75
	Peak Dorsiflexion Moment $(\%BW \cdot Ht)$	7.11 ± 0.57	5.57 ± 0.51	4.46 ± 0.41	191.5*
	Moment Dorsiflexion Impulse $(\%BW \cdot Ht \cdot \%GC)$	191.53 ± 36.11	141.21 ± 21.1	121.37 ± 21.33	42.67*
Hip	Peak Flexion Moment $(\%BW \cdot Ht)$	5.01± 1.05	4.58 ± 1.04	4.87 ± 1.55	0.69
	Peak Extension Moment $(\%BW \cdot Ht)$	-5.33 ± 0.71	-4.32 ± 0.46	-3.09 ± 0.54	51.43*
	Moment Extension Impulse $(\%BW \cdot Ht \cdot \%GC)$	-139.09 ± 19.65	-125.16 ± 22.75	-90.77 ± 15.06	42.42*

* p<.001

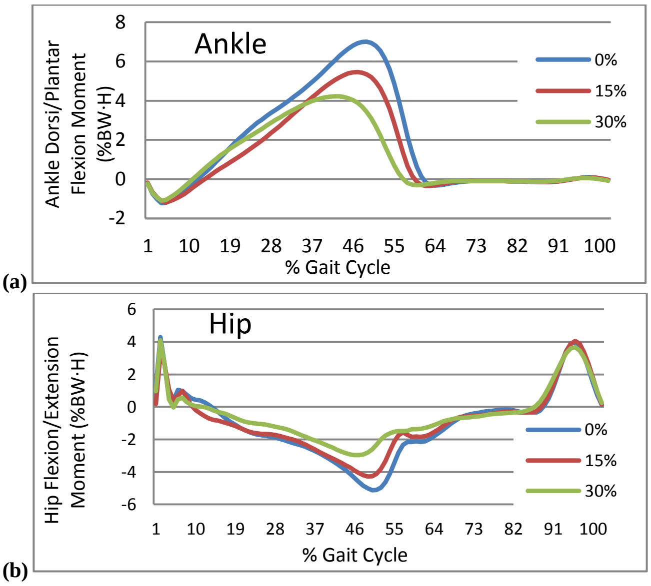


Figure 3: Sagittal plane kinetics of (a) the ankle and (b) hip under three (0%, 15% and 30%) BWU conditions.

CONCLUSIONS

This research has broad implications in the rehabilitation of gait deficits. Once a constant comfortable walking speed is maintained, BWU may safely be used to decrease the loading and the pain on lower joints without the risk of impairing the propulsive force essential for daily walking.

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