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Wpływ lecznictwa uzdrowiskowego na funkcję ręki u kobiet z reumatoidalnym zapaleniem stawów

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Ocena zmian przeciążeniowych kręgosłupa lędźwiowego pracowników o siedzącym charakterze pracy

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Wpływ odciążenia masy ciała poprzez system Parestand na kinematykę chodu – badanie pilotażowe

Influence of body weight support via Parestand system on gait kinematic — a pilot study

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Streszczenie
Wstęp. W wielu badaniach potwierdzono już skuteczność treningu na bieżni z odciążeniem masy ciała (ang. Body Weight Support Treadmill Training – BWSTT) u osób zdrowych i w różnych jednostkach chorobowych. W Polsce jest to nadal rzadko stosowana metoda. Do tej pory nie opublikowano jeszcze badania wpływu polskiego systemu odciążającego Parestand na wartości kinematyczne chodu.
Materiał i metody. Analizowano kinematykę prawego stawu biodrowego, kolanowego i stopy w płaszczyźnie strzałkowej u zdrowej kobiety, w trakcie chodu na bieżni bez odciążenia (0%) oraz z 25% i 50% BWS poprzez system odciążający Parestand z prędkością: 3, 4 i 5 km/h w fazie initial contact (IC), loading response (LR), terminal stance (TSt) i mid swing (MSw). Wartości kątowe zebrano za pomocą systemu Noraxon, a następnie poddano analizie statystycznej.
Wyniki. BWS poprzez Parestand 25% i 50% istotnie zmieniało kinematykę biodra przy każdej prędkości. Kinematyka kolana w znaczącym stopniu różniła się przy 25% BWS w IC oraz LR, a przy 50% BWS w IC, LR, TSt i MSw przy każdej prędkości. W zakresie stawu skokowego zmiany wartości kątowych nie różniły się znacznie przy 25% BWS przy żadnej z prędkości, a przy 50% BWS różniły się znacznie jedynie przy 3 km/h we wszystkich badanych fazach.
Wnioski. Zwiększanie BWS wpływa na zmiany kinematyki chodu. Już 25% odciążenie masy ciała poprzez Parestand może zmienić kinematykę biodra w trakcie chodu. 25% BWS poprzez Parestand może zmienić kinematykę kolana w początkowych fazach chodu, bez wpływu na kinematykę stopy. Należy przeprowadzić badanie na większej liczbie osób.

Słowa kluczowe:
chód, odciążenie masy ciała, kinematyka chodu, trening chodu na bieżni z odciążeniem masy ciała

Abstract
Background. Many studies have recently confirmed the effectiveness of the Body Weight Support (BWS) Treadmill Training in healthy subjects and various clinical conditions. It is rarely practised method in Poland. No study about influence of Polish Parestand system on kinematic parameters of gait have been reported to date.
Material and Methods. The kinematics of the right lower limb of a healthy woman was analysed, while walking on the treadmill without support (0%) and with 25% and 50% BWS via the body weight support system Parestand at velocity of 3; 4 and 5 km/h in the initial contact (IC), loading response (LR), terminal stance (TSt) and mid swing (MSw) phase. The joint angle parameters were collected using the Noraxon system and then subjected to statistical analysis.
Results. BWS via Parestand (25% and 50%) significantly changed hip kinematics at each velocity. Knee kinematics significantly differed at 25% BWS in IC and LR, and at 50% BWS in IC, LR, TSt and MSw at each velocity. Ankle angular values did not differ significantly at 25% BWS at any velocity, and at 50% BWS were significantly different only at 3 km/h in all tested phases.
Conclusions. Increasing of BWS changes gait kinematic in a bigger extent. Even a 25% of body weight support via Parestand could change hip kinematics during gait. 25% BWS via Parestand could change knee kinematic in the early gait phases without modifying the ankle kinematics. A study in this area should be carried out on a larger number of subjects.

Key words:
gait, body weight support, Gait Kinematic, Body Weight Supported Treadmill Training

Introduction

The Parestand system is a device thanks to which we obtain the body weight support (BWS). This device consists of a metal structure, on which the mobile trolley moves along with the harness carrying tape. The patient is fastened in a harness in order to obtain BWS and to prevent him from falling when walking velocity increases [1]. The unloading mechanism is a spring whose blockade ensures static work of the device during e.g. the patient's positioning [2], while unblocking allows application of dynamic body weight support during gait or balance exercises [3, 4]. Therefore, the Parestand system can be used in the Body Weight Support Treadmill Training (BWSTT) [5] – a high-intensity task-oriented training (whose high efficacy in stroke patients has been demonstrated in meta-analyzes [6, 7]. Until now, there were studies showing that Body Weight Support Treadmill Training could be successfully applied also in children with cerebral palsy [8], multiple sclerosis [9, 10], Parkinson's disease [11], incomplete spinal cord injury [12] muscular dystrophy [13], children with Down syndrome [14], or after hip arthroplasty [15].

Until now, a pilot study how BWSTT via Parestand influence on balance, endurance and walking speed in patients after stroke has been already conducted [2]. However, it hasn't been checked how BWS via Polish Parestand body weight support system influences on temporospatial and kinematic parameters during gait. Current research on the impact of BWS on these values was carried out using other foreign devices and systems [7]. There are doubts whether the body weight support causing changes in gait kinematic has a negative effect on the gait pattern [16, 17].

The aim of the study was to analyze the impact of body weight support via Parestand system during walking on a treadmill of different velocity on angular values in the hip, knee and ankle joint in the sagittal plane.

Materials and methods

Healthy 45-year-old woman, with the body weight of 50 kg and height of 152 cm participated in the study. The subject was placed in the harness of the Parestand body weight support system Inotec company (Figure 1). Subjet was walking on a BIODEX Gait Trainer 2 treadmill with different levels of body weight support, i.e. without support – 0%, with 25% and 50% BWS and at different speed, respectively: 3; 4 and 5 km/h. The Polish Parestand system, characterized by single-point suspension and dynamic body weight support. Kinematic data for angular changes in sagittal plane analysis was obtained with the 3D analysis Noraxon system and the MYOMOTION module MR3 3.6.8 of the Noraxon® company. The distribution of inertial sensors on the subject's body included the right lower limb: the hip joint (mid-thigh), knee (joint space) and ankle (lateral malleolus) and the belt with the inertial sensor in the waistline. Data obtained with the Noraxon system were exported to Microsoft Excel 2010. For the analysis, 5 randomly selected steps (gait cycles) of the right lower limb were used. In the analysis of gait kinematic variability, each cycle was divided into phases based on the inflection points of graphs from

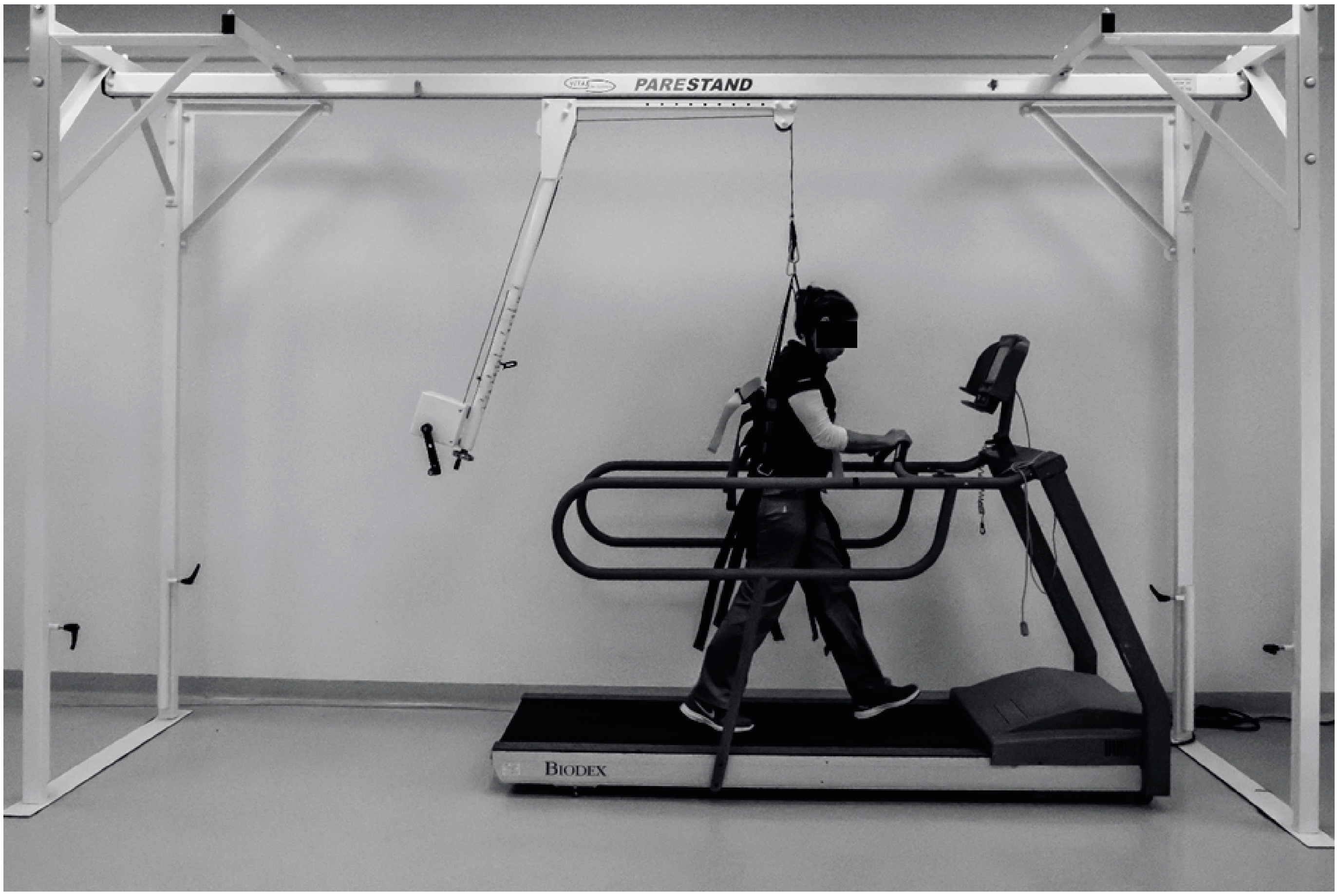

Fig. 1. PARESTAND system in combination with treadmill BIODEX

extension to flexion and vice versa (maximum extension, maximum flexion). 4 peak joint angles during following phases were charted (original English-language names were used) [18, 19]:

- initial contact (IC) – corresponds the moment the heel strikes the ground,
- loading response (LR) – eccentric knee flexion providing shock absorption,
- terminal stance (TSt) – when heel of the stance leg rises ,
- mid swing (MSw) – corresponds to proper, mid phase of swing [18, 20].

Statistical analysis

Statistical analysis was performed with STATYSTICA 13.1. To check if distribution is normal Shapiro-Wilk test was used. For comparison of dependent variables (angular values) with a normal distribution, a one-way analysis of variance (ANOVA) was used. Mann–Whitney U test was performed for comparison of dependent variables diverged from normal distribution. All calculations used standard statistical significance ($p < 0.05$). The angular values of respective joints were compared in the absence of support (0%) and with 25% and 50% body weight support for each of the velocity separately. In assessing the significance of the difference in respective joint angle values, the intrarater-intersession

Minimal Detectable Change (MDC) developed by Wilken et al. for healthy people walking was used. MDC is the amount of change which is sufficiently greater than measurement error for the variable of interest [19]. Significant differences were considered as both statistically significant and exceeding the MDC.

Results

The figures shows the average angular values collected from the entire 5 minute walk on the treadmill.

The figures show changes in angular values in the hip joint without BWS (0%), with 25% and 50% body weight support during gait velocity of 3 km/h (Fig. 2.), 4 km/h (Fig.3) and 5 km/h (Fig. 4.).

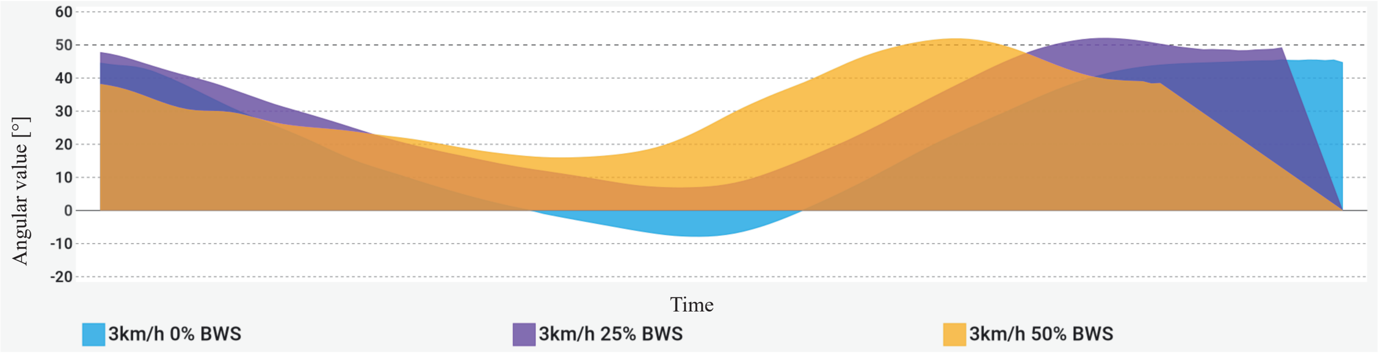

Fig. 2. Comparison of changes in hip joint angles during gait at 3 km/h at different levels of body weight support with the Parestand system

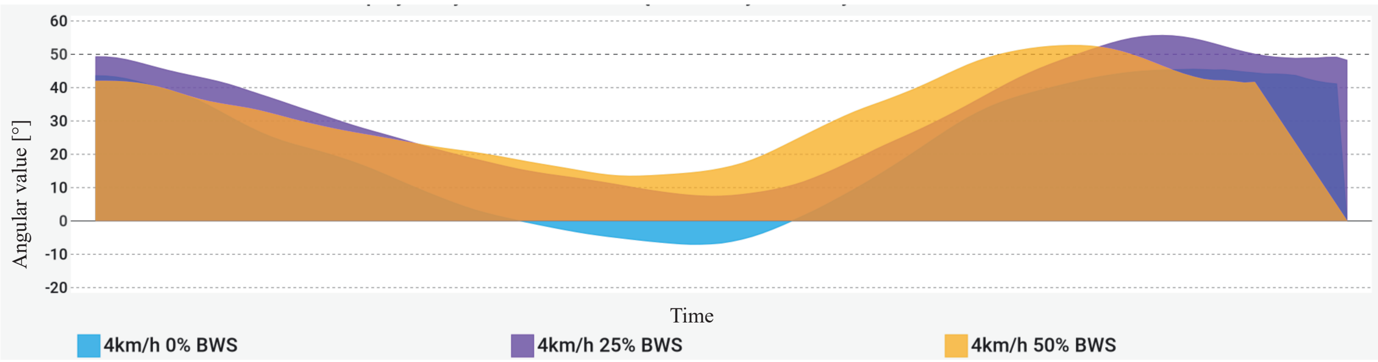

Fig. 3. Comparison of changes in hip joint angles during gait at 4 km/h at different levels of body weight support with the Parestand system

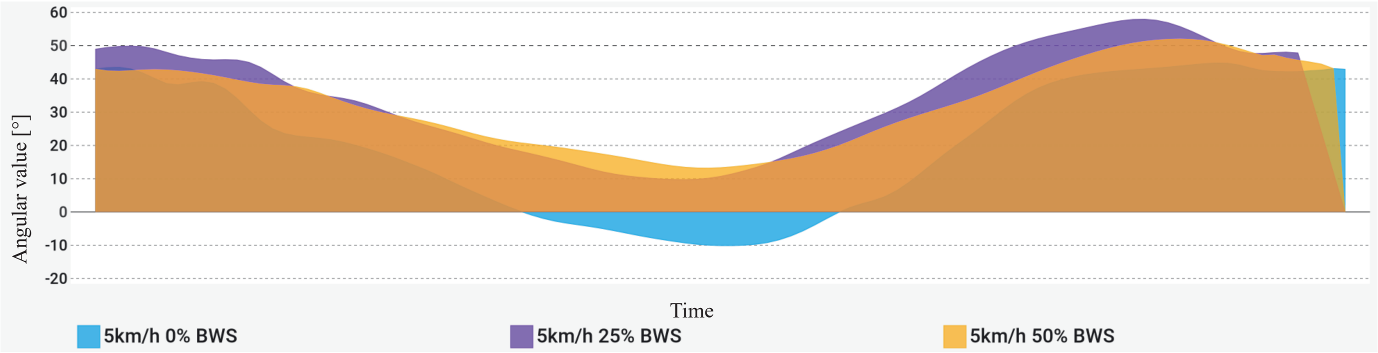

Fig. 4. Comparison of changes in hip joint angles during gait at 5 km/h at different levels of body weight support with the Parestand system

Figures 5, 6 and 7 compare the various body weight support conditions for knee joint kinematic at gait velocity of 3 km/h (Fig. 5.), 4 km/h (Fig. 6.) and 5 km/h (Fig. 7.).

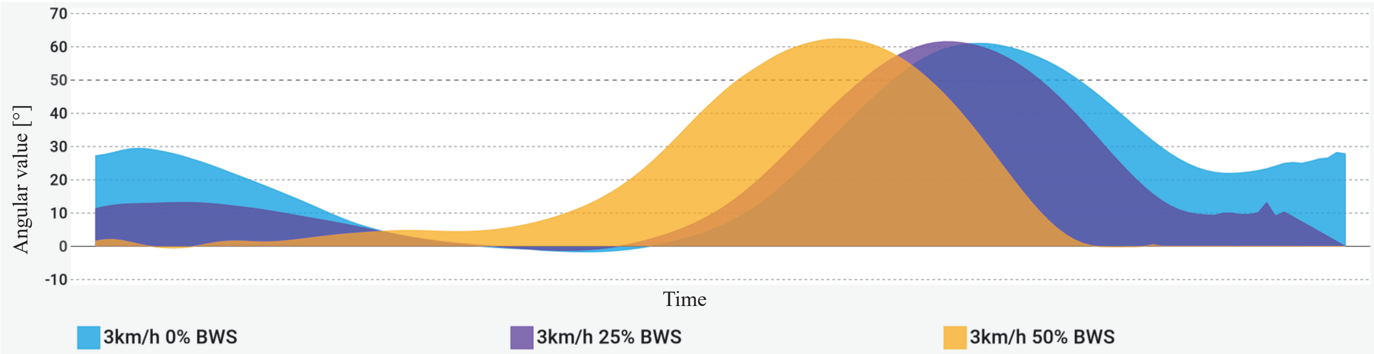

Fig. 5. Comparison of changes in knee joint angles during gait at 3 km/h at different levels of body weight support with the Parestand system

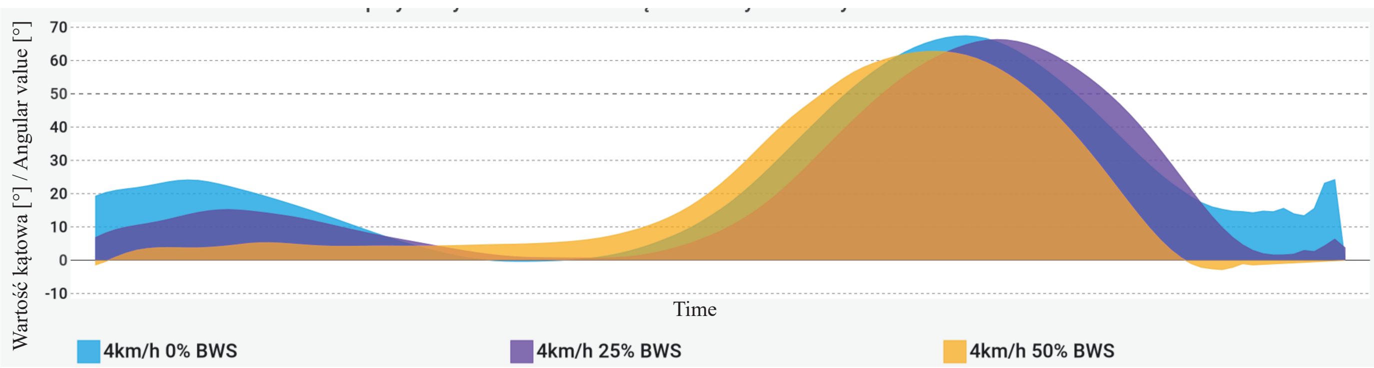

Fig. 6. Comparison of changes in knee joint angles during gait at 4 km/h at different levels of body weight support with the Parestand system

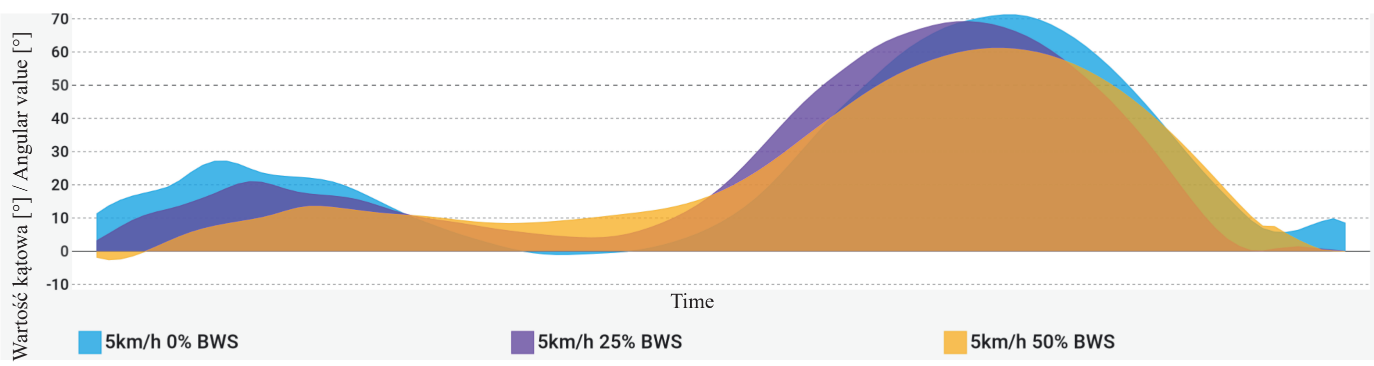

Fig. 7. Comparison of changes in knee joint angles during gait at 5 km/h at different levels of body weight support with the Parestand system

Comparison of the joint angles variability with different BWS for the ankle was placed for the gait velocity of 3 km/h (Fig. 8), 4 km/h (Fig. 9) and 5 km/h (Fig. 10).

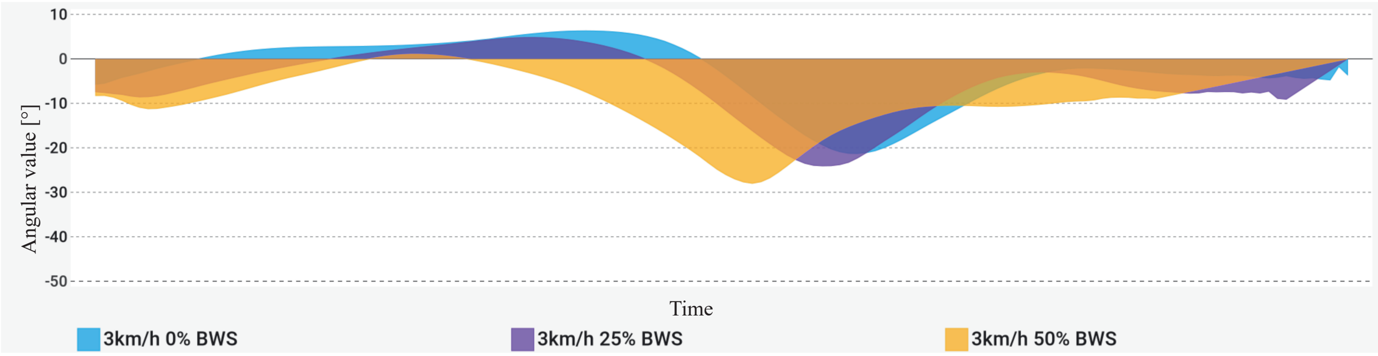

Fig. 8. Comparison of changes in ankle joint angles during gait at 3 km/h at different levels of body weight support with the Parestand system

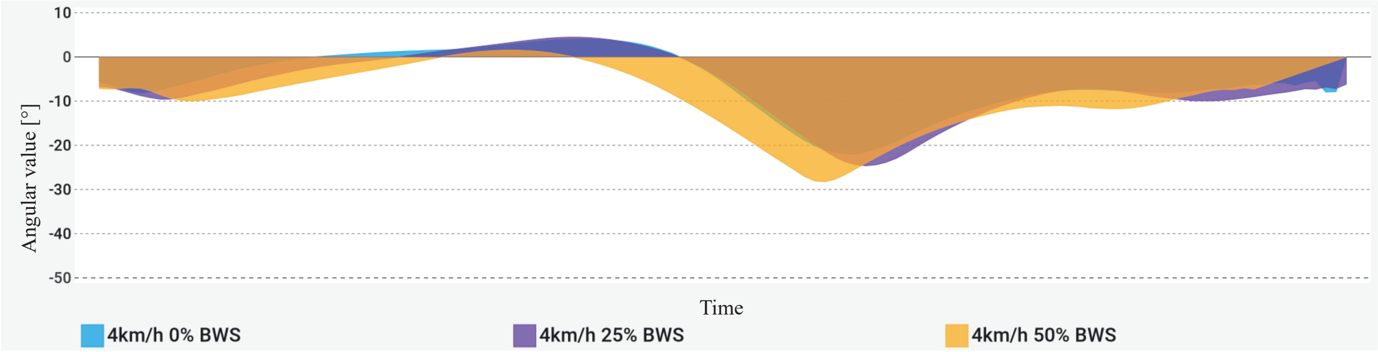

Fig. 9. Comparison of changes in ankle joint angles during gait at 4 km/h at different levels of body weight support with the Parestand system

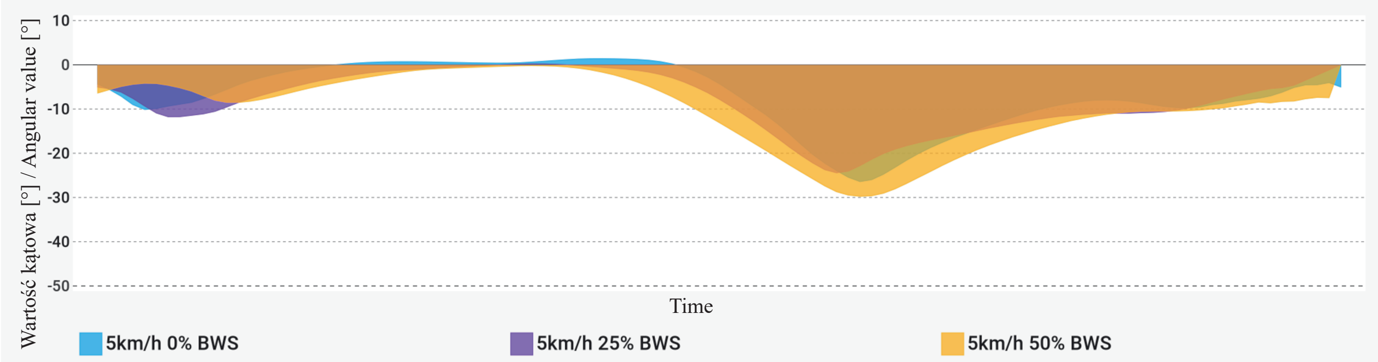

Fig. 10. Comparison of changes in ankle joint angles during gait at 5 km/h at different levels of body weight support with the Parestand system

Table 1. shows the peak angular values in the hip, knee and ankle joint in the 4 tested gait phases, depending on body weight support and gait velocity with reference to MDC.

Table 1 Peak angular values in the hip, knee and ankle joint in 4 gait phases, depending on body weight support and gait velocity

		0% BWS Mean ± SD (º)	25% BWS Mean ± SD (º)	Difference (º)	50% BWS Mean ± SD (º)	Difference from 0% BWS (º)	MDC (º)
Biodro – zgięcie / Hip – flexion							
3 km/h	IC	44.2 ± 1.4	51.3 ± 1.7	**7.1*** **	51.8 ± 0.5	**7.6*** **	4.80
	TSt	-8.4 ± 0.4	7.7 ± 0.4	**16.1*** **	16.3 ± 0.8	**24.7*** **	5.16
4 km/h	IC	45.1 ± 1.2	54.9 ± 0.9	**9.7*** **	51.8 ± 0.7	**6.7*** **	4.80
	TSt	-9.7 ± 0.4	6.5 ± 0.5	**16.1*** **	13.6 ± 0.7	**23.3*** **	5.16
5 km/h	IC	44.7 ± 1.7	57.7 ± 0.9	**12.9*** **	52.8 ± 0.6	**8*** **	4.80
	TSt	-9.7 ± 1.2	9.2 ± 0.5	**18.9* **	13.7 ± 0.5	**23.1* **	5.16
Kolano – zgięcie / Knee – flexion							
3 km/h	IC	19.2 ± 2.9	2.7 ± 2.5	**-16.5*** **	-1.1 ± 0.8	**-20.3*** **	4.12
	LR	28.2 ± 2.4	11.8 ± 2.6	**-16.4*** **	3.1 ± 0.8	**-25.1*** **	4.83
	TSt	-0.6 ± 0.5	-0.2 ± 0.3	0.4	0.2 ± 0.6	0.8	5.28
	MSw	61.4 ± 1.1	64 ± 0.7	2.6**	62.4 ± 1.1	1	7.33
4 km/h	IC	9.3 ± 2.8	-0.3 ± 0.4	**-9.6* **	-3.4 ± 1.1	**-12.7*** **	4.12
	LR	23.6 ± 2.8	16.5 ± 1.2	**-7.1*** **	5.6 ± 1.6	**-18*** **	4.83
	TSt	-1 ± 0.4	0 ± 0	1**	4.5 ± 1.5	**5.5*** **	5.28
	MSw	68.1 ± 0.2	65.1 ± 0.9	-3**	60.5 ± 0.4	**-7.6** **	7.33
5 km/h	IC	4.8 ± 0.6	-1.3 ± 0.4	**-6.1* **	-1.4 ± 1.5	**-6.2*** **	4.12
	LR	26.2 ± 0.6	18.8 ± 0.8	**-7.4*** **	13.8 ± 0.3	**-12.4* **	4.83
	TSt	-0.7 ± 0.3	2.9 ± 0.9	3.6*	9.9 ± 1.3	**10.6** **	5.28
	MSw	69.8 ± 0.8	67.5 ± 0.5	-2.3***	61.4 ± 0.4	**-8.4*** **	7.33
Staw skokowy – zgięcie grzbietowe / Ankle – dorsiflexion							
3 km/h	IC	-1.0 ± 0.2	-1.6 ± 0.4	-0.6*	-7.3 ± 1.2	**-6.4*** **	3.66
	LR	-6.4 ± 1	-10.3 ± 1.7	**-3.8** **	-12 ± 0.5	**-5.5*** **	3.66
	TSt	6.1 ± 0.6	5.2 ± 0.3	-0.8**	1.4 ± 0.2	**-4.7*** **	3.66
	MSw	-24.2 ± 1	-27.2 ± 0.5	-2.9***	-29.9 ± 1	**-5.7*** **	3.66
4 km/h	IC	-6.9 ± 0.5	-7.3 ± 0.4	-0.4	-5.9 ± 1.6	1	3.66
	LR	-9.5 ± 1.3	-11.3 ± 0.6	-1.8*	-10.4 ± 1.2	-0.9	3.66
	TSt	4.1 ± 0.4	4.4 ± 0.1	0.3	1.4 ± 0.6	-2.7***	3.66
	MSw	-25.3 ± 0.7	-26.8 ± 0.6	-1.6**	-27.9 ± 0.6	-2.6***	3.66
5 km/h	IC	-8.2 ± 1.2	-5 ± 0.9	3.2**	-3.9 ± 1.7	**4.3** **	3.66
	LR	-10.8 ± 0.4	-12.4 ± 0.9	-1.6**	-8.4 ± 1	2.3**	3.66
	TSt	1 ± 0.5	0.3 ± 0.3	-0.7*	0.6 ± 0.5	-0.4	3.66
	MSw	-28.2 ± 0.9	-25.5 ± 0.5	2.8***	-30.7 ± 0.8	-2.4**	3.66

BWS – Body Weight Support;
SD — standard deviation;
Bold – statistical significant difference and bigger than MDC;
MDC — Minimal Detectable Change;
*- $p<0,05$; **- $p<0,01$; ***-$p< 0,001$;
IC – initial contact;
LR – loading response;
TSt- terminal stance;
MSw- mid swing

Influence of body weight support

Hip

1. In the IC, the highest values of hip flexion were achieved at 25% BWS.
2. In TSt, as the BWS increased, the extension went into a flexion.

Knee

1. In the initial contact - the greater BWS, the flexion of the knee more went into extension.
2. In the loading response - the greater BWS, the knee flexion decreased.
3. In the terminal stance - with an increasing BWS, the knee from the extension went into flexion.
4. In mid swing, the knee flexion decreased with greater BWS.

Ankle

1. In the IC, the foot dorsilflexion increased at 25% BWS, and decreased at 50% BWS.
2. In the lR, the increase of the dorsiflexion with the increase BWS.
3. In the TSt, with the increase of BWS - the plantar flexion decreased.
4. In the MSw the dorsiflexion increased with increasing BWS.

Influence of gait velocit

Hip

1. In the IC at 25% BWS, the increase in velocity caused an increase in hip flexion of 3° for each speed.
2. In the TSt with increasing velocity and no support - the extension increased.
3. No general velocity effect was observed under any BWS condition.

Knee

1.W IC im większa prędkość, tym mniejsze zgięcie.
2. W LR im większa prędkość tym większe zgięcie.
3. W TSt wzrost prędkości nie ma wpływu na wyprost.
4. W MSw im większa prędkość, tym większe zgięcie.

Ankle

1. In the IC and LR, the increase in velocity at 0% BWS and 25% BWS results in an increase in the foot dorsiflexion, and at 50% BWS the dorsiflexion decreased.
2. In the TSt, the plantarflexion decreased with increased velocity and BWS.
3. In the MSw, the higher velocity, the greater the dorsiflexion.

Discussion

This is the first published study of gait kinematic with body weight support via Parestand system. Considering both statistical significance and MDC, the following interpretation could be made. The body weight support via Parestand (both 25% and 50%) significantly changed hip joint kinematic during gait on the treadmill at each tested velocities 3; 4 and 5 km/h) for both IC and TSt, compared to the lack of BWS (0%). At 25% and 50% BWS, the extension did not occur at all, which could have caused by the harness. Knee joint kinematics were significantly different at 25% BWS in IC and LR, and at 50% BWS in all examined phases (IC, LR, TSt, MSw) compared to

0% BWS. As BWS increased in the LR, knee amortization decreased- flexion decreased, contrary to TSt, where the extension went in to flexion. The angular values of the ankle didn't differ significantly at 25% of BWS in any of tested phases compared to no BWS. In turn, at 50% BWS, ankle kinematics was significantly different at 3 km/h in all tested phases.

There was no effect of velocity on the hip kinematics, which was repeated under every BWS conditions. However, at 25% and 50% BWS, the extension did not occur at all. It could be caused by the harness. Analysing knee joint kinematic values, it was found that the increase in velocity causes the most visible growth in knee flexing in the LR phase, but also in the mid swing phase. Analysing the ankle, the study showed that along with the increase in velocity, the values of dorsiflexion increased, and plantar flexion decreased.

Considering that it was a pilot study with one person, no binding conclusions can be drawn regarding the influence of BWS on the gait kinematic based solely on the above results. Therefore, the broader context of the literature is given below.

Threlkeld et al. [22] compared the gait of 17 healthy people walking at 4.5 km/h with various body weight support conditions: i.e. with a minimum of 10, 30, 50 and 70% BWS. It was shown that only at higher (50 and 70%) body weight support the temporospatial and kinematic values were significantly different with those at 10% BWS. In turn, no differences were observed between the minimum and 10% BWS. In the study of Hedel et al. [16], 20 young people were walking at different velocities (0,5 - 5 km/h) and various BWS (0%, 25%, 50% and 75%). This time, joint trajectories of the knee and the foot changed significantly exclusively at 75% BWS. However, the 50% and 75% BWS reduced the hip extension in the terminal stance phase. In our study, the reduction of hip joint during terminal stance has just took place at 25% BWS. Hedel et al. also noted that the walking velocity much more affects the cadence and length of the step than BWS, which only affected exclusively at 75% [16]. Threlkeld et al. [22] and Hedel et al. [16] did not, however, refer to the impact of the harness on kinematic values, which in our study seems to be a key problem. In the next study, Kuno et al. [23] referred to the influence of BWS on kinematic and temporospatial parameters of walking as well as muscular activity. 16 healthy men were examined during BWSTT (0, 15, 30 and 45% BWS and velocity of 4,17 km/h). The values of joint angles did not significantly differ with increasing BWS, except for the reduction of the hip extension, which also took place in our study. Kyvelidou, et al. [24] examined body weight support in healthy 10 young and 10 older women. In their work increased levels of BWS increased hip, knee and ankle joint kinematic variability during gait (greater irregularity). As a possible reason, the authors reported disturbances of muscle activity and coordination by BWS. What could be confirmed by the observation of the subjects Kuno et al., [23] whose vertical reaction forces and peaks of muscle activity during stance phase decreased along with the increase of BWS. In turn, in the study of Finch et al. BWS did not generate pathological gait. After examining 7 healthy males, the authors suggested that BWS may even support temporary and kinematic gait patterns as well as muscle activity [25]. It has also been shown that the gait parameters are influenced by the method of body weight support. In the study of Franz et al., 6 healthy adults underwent 20% passive (static) BWS, which resulted in 5° reduced sagittal plane hip joint range of motion and increased ankle platarflexion in TSt as compared to dynamic body weight support or unsupported walking [26]. The Parestand system also used dynamic BWS, which was achieved by activating the spring. Analyzing the gait determinants during normal walking the center of gravity moves 3-5 cm in the vertical axis [21]. The dynamic body weight support system allows the center of gravity to move in the vertical axis during walking, thanks to which walking is approximate to natural [3, 4, 21]. Therefore, dynamic BWS could be using in gait reeducation and learning of position changes [2]. A very interesting study was conducted by Aaslund and Moe-Nilssen [3], about the influence of three factors on gait quality separately: the way of BWS, walking on a treadmill and the carrying of a harness. Examining 28 healthy people, it was shown that the use of the treadmill resulted in cadence increased, more forwards trunk tilts ,increasing vertical acceleration and anteroposterior acceleration became more variable. Body weight support restricted trunk acceleration in all directions, especially with static BWS. In turn, wearing a harness resulted in more restricted vertical acceleration. In our work it was noticed that even in the absence of support (0% BWS), the angular values in the hip joint deviated from the norm, which could have been due to the harness set on the hips.

It should also be noted that the influence of BWS on gait parameters depends on the health/ illness of the examined person. In some cases could have positive impact, in others negative. Burgess et al. [27] examined 11 people without neurological disorders and 12 after stroke. In healthy persons, gait velocity and step length decreased with increasing BWS. In turn, in stroke patients at 10% BWS, the own walking speed increased on average by 13%, and the average step length by 11%. Instead, the age may not differentiate the tendencies of influence. For example, in the Thomas et al. [28] study, it was observed that BWS allowed healthy both older and younger women to achieve higher speed - longer step and higher frequency at the same energy cost.

The limitation of this work was the short time of borrowing the Noraxon measuring equipment, which affected the possibility of testing only one person. Which, in turn, does not allow to draw any binding conclusions and decreases the reliability of statistical analysis.

In summary, fast walking (approximated to normal) with body weight support devices and treadmill turns out to be the most effective in improving gait [29]. However, the increase of BWS could have an influence on gait kinematic.

Conclusion

Even a 25% body weight support via Parestand and the treadmill may change hip kinematics during walking. At 25% BWS via Parestand system and the treadmill kinematics of the knee could be modified in the initial gait phases, but such support did not affect the foot kinematics. Increasing BWS affects the greater changes in walking kinematics. The observed problem is important. However, in order to reliably assess the impact of the Parestand body weight support system, the study with more subjects should be carried out.

Thanks
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