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The Relationship between Antigravity Treadmill Therapy Settings and Gait Cycle Parameters

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Abstract

Background: The effective gait restoration due to antigravity treadmill exercise has been demonstrated in patients with locomotor or nervous system disorders. The element of unweighting, its effect on the parameters of the gait cycle and possible deviation from overground walking, despite all the clinical evidence, remains questionable.

Methods: A retrospective analysis of 405 therapy records of patients recovering after lower limb surgery focused on the dependence between body-weight supported treadmill settings (speed, unweighting) and gait cycle parameters (cadence, stance time, step time, swing time, step length and stride length) together with their symmetry indexes. The relationship between therapy settings and respective gait parameters and their symmetry indexes has been evaluated by Pearson correlation coefficient.

Results: While a significant relationship between speed and all analyzed gait parameters, except of swing time of unaffected limb, has been found, no significant impact of unweighting has been proven on any of the gait parameters. The symmetry index turned out to be a suitable tool for monitoring the state of recovery, as no dependence on speed or unweighting settings was proven.

Conclusion: The results of this study show that walking on an antigravity treadmill, similarly to overground walking, has no negative effect on walking parameters. In addition, the unweighting element enables performing the same movement with a lower load on the lower extremities and thus might be more suitable for gait recovery after surgery or injury of the locomotor system.

Keywords: Antigravity treadmill; Symmetry index; Body-weight unloading; Overground gait; Post-surgery recovery

Introduction

Gait retraining is an integral part of the rehabilitation program of patients with musculoskeletal or neurological impairment. In addition to conventional and overground walking rehabilitation, Body-Weight Supported Treadmill Therapy (BWSTT) is gaining more and more popularity [1]. Walking with partially unloaded body-weight has proven to be a suitable therapy for post-stroke survivors [2-6], patients suffering from Parkinson's disease [7,8], spinal cord injury [9,10] or children with cerebral palsy [11,12] as well as conditions post musculoskeletal injury or surgery [13-16]. Despite the fact that the benefits of this modern approach have been proven across various indications, there is an on-going discussion regarding the influence of weight support on the gait alteration during walking.

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Multiple experiments were conducted on health participants in order to evaluate this influence and modify the gait retraining protocol for patients with impairment [17]. Fischer and Wolf [1] conducted a study on ten healthy subjects. They monitored the effect of a suspension vest allowing weight support on multiple spatiotemporal kinematic and kinetic measures. While a positive effect on the reduction of joint loads was discovered, no effect on gait curvature patterns was demonstrated [1]. A similar suspension system was the subject of research by Barela et al. [17] Unlike its predecessor, however, she demonstrated a significant impact of body-weight support (BWS) on spatiotemporal gait parameters. Van Hedel et al. [18] and Threlkeld et al. [19] also partly agree with this conclusion. They confirmed the influence of the suspension vest on the gait cycle parameters, but only for certain settings - for speeds less than 2.5 km/h and weight unloading greater than 50%. Błaszczyk et al. [20] did not monitor the effect of weight unloading, but monitored the effect of excessive loading on spatiotemporal gait measures. By comparing the measurements of obese and lean subjects, it was shown that some walking parameters are indeed influenced by one's own weight. The subject of Lee and Hidler's [21] research was not the effect of the load, but the effect of the walking surface. They concluded that there are differences between overground and treadmill walking, but the overall patterns are preserved.

The relationship between BWSTT settings and gait parameters, or their symmetry indexes, is important to know not only for comparison with overground walking, but also from the point of view of suitability for recovery evaluation. If gait parameters or their symmetry indices are recorded during the BWSTT, it is desirable to know if these are suitable for monitoring the gait restoration process or if they are influenced by the therapy settings and thus should not be related to the recovery process. Hassid et al. [22] have observed improved symmetry of single limb stance time during BWSTT in otherwise asymmetrically stepping hemiparetic patients induced by appropriate setting of speed and BWS level. Unfortunately, this is the only research on the effect of BWSTT setting on gait symmetry.

The reason for conducting this research is the absence of evidence tracking the effect of body-weight supported treadmills on the principle of lower-body positive pressure. Weight unloading works without the need for a suspension vest, but with the help of an air-tight chamber surrounding the lower half of the body. The higher the pressure is created in the chamber, the more the weight load is reduced. It is assumed that the difference in the principle of operation is so significant that it is not possible to anticipate the same conclusions and thus deserves separate research. The primary aim of this study is to statistically evaluate and compare the effect of BWS with the effect of speed on basic spatiotemporal gait parameters (cadence, stance time, step length, step time, stride length, swing time) in patients recovering after lower-limb surgery. As a secondary outcome measure, relationship between BWSTT settings and symmetry indexes of respective gait parameters was determined and differences in respective gait parameters between affected and unaffected limb were compared.

Materials and Methods

The Body-Weight Supported Treadmill Therapy (BWSTT) was provided to patients recovering from lower limb surgery as part of a routine rehabilitation protocol between January and June 2023 at multiple rehabilitation centers. Patients were fully informed about the course of treatment and agreed with the participation. Pregnant and those suffering from severe cardiovascular diseases, epilepsy, bronchial asthma or angina pectoris, severe disc herniation, acute, unstable fractures or conditions where increased abdominal pressure is contraindicated were excluded. Therapy records, automatically stored in the devices, were retrospectively exported and analyzed. As part of the study, no personal or other patient data were processed.

The study data was collected and processed in accordance with the 1975 Declaration of Helsinki ethical guidelines adopted by the General Assembly of the World Medical Association (1997-2000) and by the Convention on Human Rights and Biomedicine of the Council of Europe (1997) [23].

Body-weight supported treadmill (BTL Industries, Ltd.) with embedded load cell (H8C) measuring and storing the gait parameters recorded throughout each session was used. The device works on the principle of lower-body positive pressure, which means that the patient performs exercises with the lower half of the body in an air-tight chamber surrounding the treadmill. The patient is integrated into this chamber, represented by an inflatable bag, using special shorts that enable zipping into the bag [24,25]. Before each session, the device is calibrated to the patient's weight and adjusted according to the patient's movement abilities. Speed, Inclination and BWS level are adapted to the recovery phase and gradually increased to prepare the patient for full load.

Data processing, filtration and analysis was performed using a custom-written script (MatLab R2010b, Mathworks, Inc., Narick, MA, USA). For the purpose of evaluating the relationship between BWS level and gait parameters, only records were used, during which zero inclination and a constant speed of 2 km/h were set. Similarly, the impact of speed settings on gait parameters was evaluated from exercises with set zero inclination and a constant BWS of 50%. A symmetry index was calculated for the gait parameters, which were recorded for each limb separately (stance time, step length, step time and swing time), based on the following equation:

$$Symmetry\ index = \left| \frac{(P_{Affected} - P_{Unaffected})}{0.5 \cdot (P_{Affected} + P_{Unaffected})} \cdot 100 \right|$$

[24,25]

Where P represents the respective gait parameter.

The significance and strength of the relationship was calculated using the Pearson correlation coefficient. The absolute value of the magnitude of the correlation coefficient defined the strength of the relationship [26]:

0.9 - 1.0 very high correlation

0.7 - 0.9 high correlation

0.5 - 0.7 moderate correlation

0.3 - 0.5 low correlation

< 0.3 little if any correlation

A level of $p < 0.05$ was considered statistically significant. Since the Shapiro-Wilk test showed a significant departure from normality, the data were presented as median (interquartile range).

Results

Of the total number of 1032 records, 405 met the conditions for analysis (Figure 1).

While in Table 1 it is rather difficult to find any pattern defining the development of gait parameters for individual ranges of BWS levels, in Table 2 an increasing (step length) or decreasing (cadence) tendency can be observed for some gait parameters.

This was confirmed by statistical analysis using the Pearson correlation coefficient (Table 3) which showed a statistically significant correlation between speed settings and all gait parameters except swing time of unaffected limb. The strength of the relationship between gait parameters and speed setting was evaluated as little too low. The impact of the speed setting on the calculated symmetry indices of all relevant gait parameters (stance time, step length, step time and swing time) was evaluated as statistically insignificant. The correlation between the BWS level setting and any of the gait parameters did not reach statistical significance. Likewise, the relationship between BWS settings and symmetry indices of all relevant gait parameters was insignificant.

The statistical significance of the relationship between the gait parameters and the speed setting can also be seen from the graphs in Figure 2. A comparison of the steepness of the trendlines shows that the value of the gait parameters is more significantly influenced by the speed setting than the body-weight support.

The differences in the individual gait parameters of the affected and unaffected limb can be seen in Tables 1 and 2. Stance time and step length parameters are lower, while step time and swing time are higher in the operated than in the healthy limb.

Discussion

This study retrospectively analyzed therapy records from multiple sites and demonstrated a significant effect of speed on gait parameters during the BWSTT, the impact of BWS was considered insignificant on all gait parameters. The effect of speed on the gait cycle in overground walking of

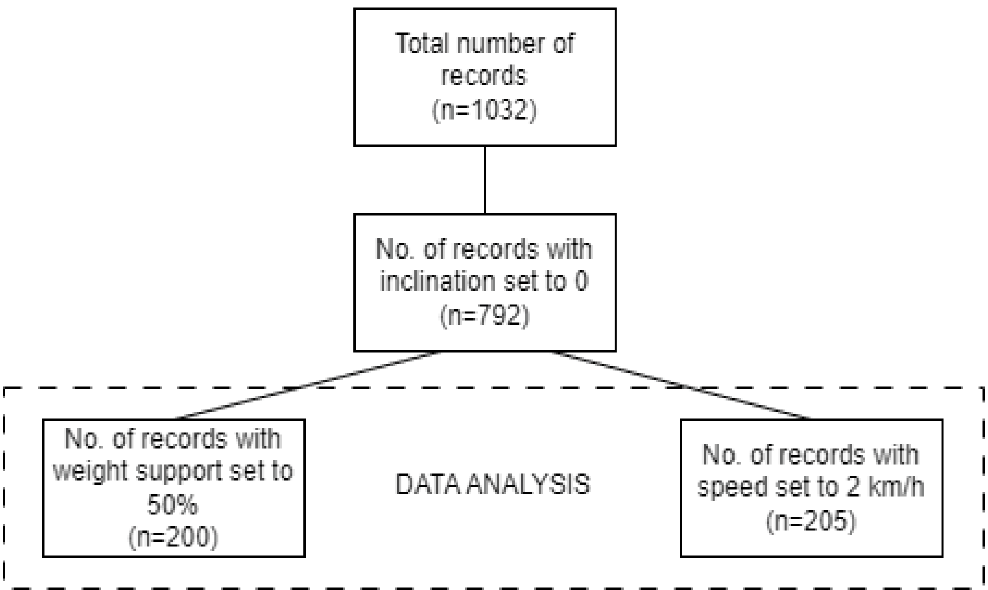

Figure 1: Diagram showing the process of data sorting and analysis.

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Table 1: Characteristics of the monitored gait parameters across the respective range of BWS levels at a constant speed of 2 km/h. Data are represented as median (interquartile range).

		BWS Level							
		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
Cadence		66 (11.25)	65 (8)	65 (2)	73 (13.75)	70 (13.75)	68 (8)	69 (7)	77 (9.75)
Stance Time	Unaffected Limb (ms)	1247 (153)	1421 (342)	1250 (35)	1087.5 (206.75)	1159 (192.5)	1197 (128)	1193 (138.5)	1229 (273)
	Affected Limb (ms)	1159 (144)	1346 (184)	1207 (31)	1050.5 (175)	1122 (219.75)	1155 (185)	1143 (196)	1219 (447.75)
	Symmetry Index (-)	5.27 (1.64)	5.24 (9.85)	1.13 (4.19)	4.06 (4.11)	4.93 (9.87)	7.26 (9.18)	7.34 (5.73)	4.10 (11.81)
Step Length	Unaffected Limb (cm)	54 (6)	45 (10)	54 (1)	48 (11)	48 (18)	50.5 (6)	51 (7)	41 (19.5)
	Affected Limb (cm)	57 (6.75)	43.5 (11)	51 (3)	49.5 (5.5)	48 (19)	49.5 (8)	50 (7.75)	33 (18.75)
	Symmetry Index (-)	2.06 (4.05)	3.57 (3.11)	5.50 (1.94)	1.80 (9.82)	2.99 (5.10)	4.26 (4.04)	4.26 (5.70)	11.32 (10.45)
Step Time	Unaffected Limb (ms)	738 (123.75)	864 (2)	873 (31)	798 (182.5)	805 (202.5)	826 (126)	803 (153)	881 (225)
	Affected Limb (ms)	780 (114.75)	879.5 (115)	886 (18)	802.5 (186.25)	794 (193.5)	856 (123)	852 (126.5)	865 (149.25)
	Symmetry Index (-)	3.99 (2.67)	6.43 (3.12)	1.48 (2.59)	3.97 (4.40)	5.62 (8.24)	5.36 (7.57)	6.59 (6.76)	2.74 (11.17)
Stride Length (cm)		111 (12.75)	89 (22)	105 (4)	97.5 (15.25)	97 (37.75)	100.5 (14)	102 (12)	74 (38.25)
Swing Time	Unaffected Limb (ms)	548 (105)	513 (30)	545 (5)	585 (109)	552 (145.25)	576.5 (91)	575 (132.75)	544 (201)
	Affected Limb (ms)	557 (1)	662.5 (124.5)	544 (15)	468.5 (201)	535 (169)	593.5 (156)	579 (124.75)	563 (95.25)
	Symmetry Index (-)	12.61 (5.61)	25.47 (2.82)	1.11 (1.27)	11.79 (20.13)	11.62 (18.96)	14.30 (19.81)	9.58 (13.12)	3.24 (29.41)

Table 2: Characteristics of the monitored gait parameters across the respective range of speed settings at a constant BWS level of 50%. Data are represented as median (interquartile range).

		Speed Level					
		0.5 - 1	1.1 - 2	2.1 - 3	3.1 - 4	4.1 - 5	10.1 - 11
Cadence		80 (27)	69 (14)	75 (12)	84 (12)	121 (3)	94.5 (33)
Stance Time	Unaffected Limb (ms)	1390 (693)	1167 (226.5)	1079 (178)	963.5 (255)	685 (19)	1175 (158)
	Affected Limb (ms)	1341 (528)	1150.5 (222.25)	1022 (152)	912 (113)	660 (17)	937 (276)
	Symmetry Index (-)	3.93 (8.86)	5.53 (9.40)	4.52 (6.84)	4.30 (7.20)	3.15 (2.54)	23.13 (42.39)
Step Length	Unaffected Limb (cm)	31 (14)	43.5 (18)	54 (11)	67.5 (9)	69 (1)	42 (22)
	Affected Limb (cm)	30 (12)	43 (17)	53.5 (10)	64.5 (7)	68 (3)	46 (20)
	Symmetry Index (-)	3.28 (1.89)	3.81 (4.86)	2.07 (4.34)	2.84 (2.99)	0 (1.55)	10.25 (9.42)
Step Time	Unaffected Limb (ms)	757 (348)	771 (204.75)	734.5 (117)	660 (105)	483 (5)	705 (190)
	Affected Limb (ms)	804 (418)	767 (174.5)	752.5 (114)	701 (94)	480 (16)	782.5 (35)
	Symmetry Index (-)	6.02 (0.54)	6.43 (8.66)	3.81 (7.23)	2.47 (4.61)	1.47 (1.57)	11.27 (22.55)
Stride Length (cm)		60 (26)	87.5 (33.5)	107 (20)	131.5 (16)	136 (4)	88 (42)
Swing Time	Unaffected Limb (ms)	496 (264)	556.5 (147)	521.5 (123)	483.5 (121)	300 (3)	748.5 (387)
	Affected Limb (ms)	675 (874)	554 (136.5)	514 (119)	525.5 (193)	282 (6)	651.5 (167)
	Symmetry Index (-)	8.29 (24.72)	12.90 (18.43)	9.63 (15.21)	8.60 (13.99)	5.48 (2.25)	13.50 (22.37)

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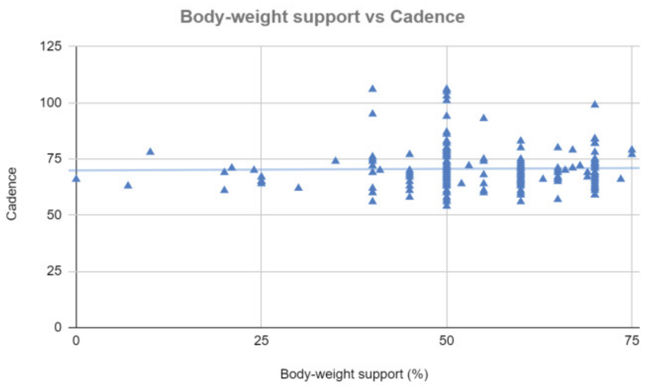
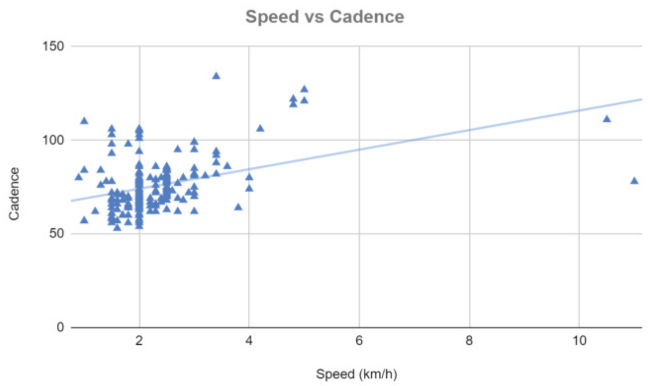
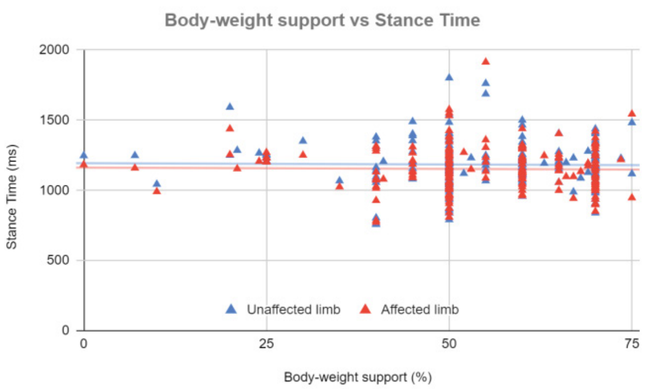
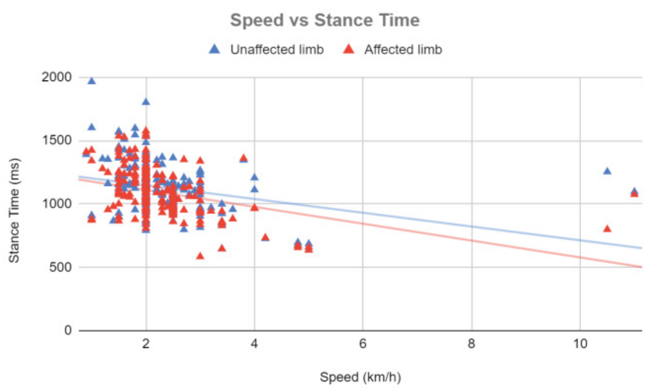
Table 3: Evaluation of statistical significance and strength of relationship between BWSTT settings (BWS and speed) and gait cycle parameters and their symmetry indexes. A level of $p < 0.05$ was considered statistically significant.

		BWS (speed=2, n=205)			Speed (unweighting=50, n=200)		
		Relationship strength	Pearson coefficient	P-value	Relationship strength	Pearson coefficient	P-value
Cadence		little positive	0.019	0.784	low positive	0.4	<0.001
Stance Time	Unaffected Limb	little negative	-0.015	0.829	little negative	-0.298	<0.001
	Affected Limb	little negative	-0.016	0.822	low negative	-0.388	<0.001
	Symmetry Index	little positive	0.108	0.124	little positive	0.059	0.407
Step Length	Unaffected Limb	little positive	0.116	0.097	little positive	0.298	<0.001
	Affected Limb	little positive	0.105	0.136	low positive	0.318	<0.001
	Symmetry Index	little positive	0.1	0.151	little negative	-0.029	0.674
Step Time	Unaffected Limb	little negative	-0.038	0.586	little negative	-0.216	0.002
	Affected Limb	little positive	0.036	0.607	little negative	-0.187	0.008
	Symmetry Index	little positive	0.124	0.076	little negative	-0.121	0.087
Stride Length		little positive	0.111	0.115	low positive	0.309	<0.001
Swing Time	Unaffected Limb	little positive	0.116	0.098	little negative	-0.088	0.218
	Affected Limb	little positive	0.182	0.116	little negative	-0.153	0.031
	Symmetry Index	little positive	0.015	0.831	little negative	-0.118	0.095









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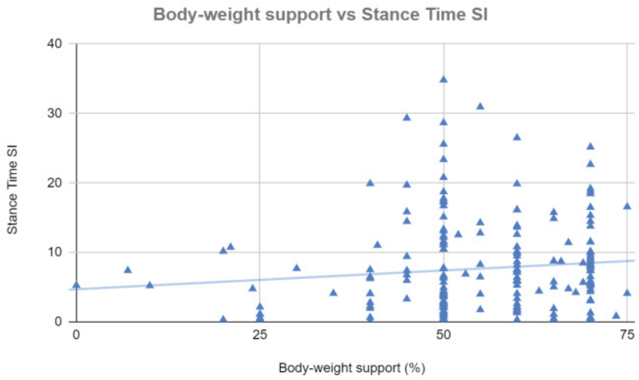

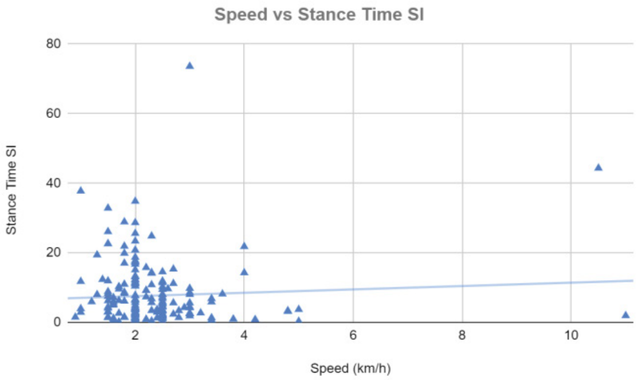

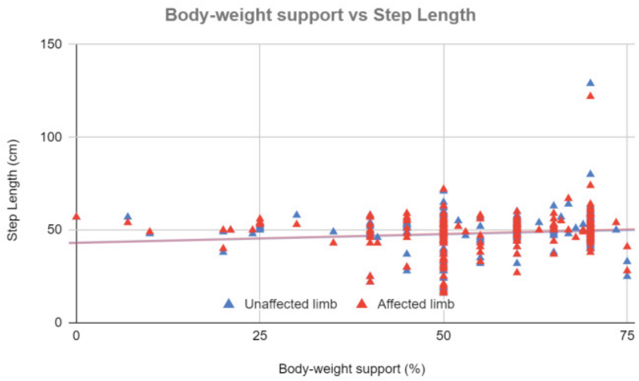

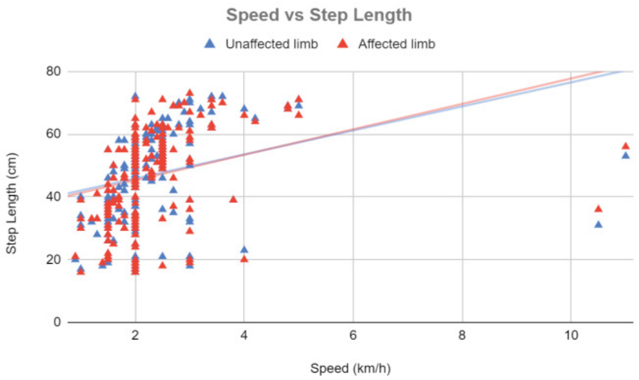

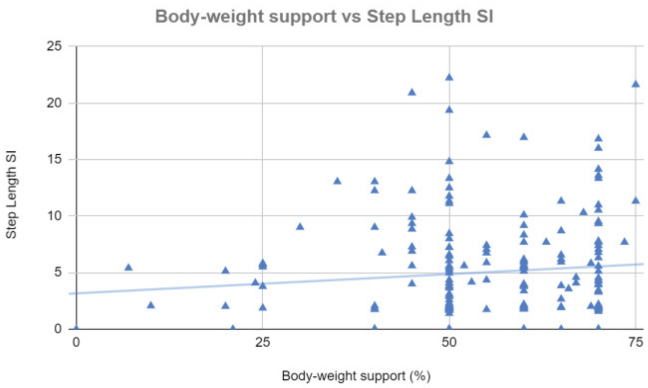

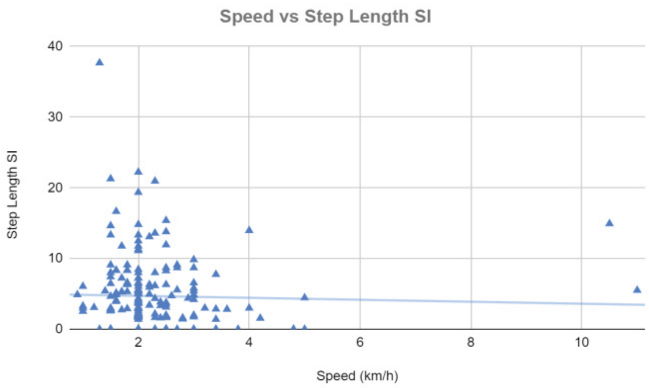

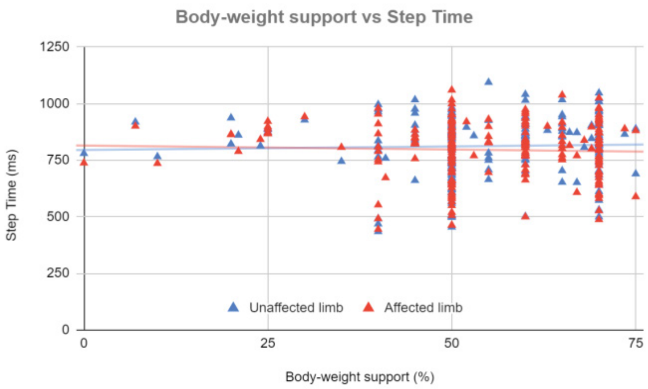

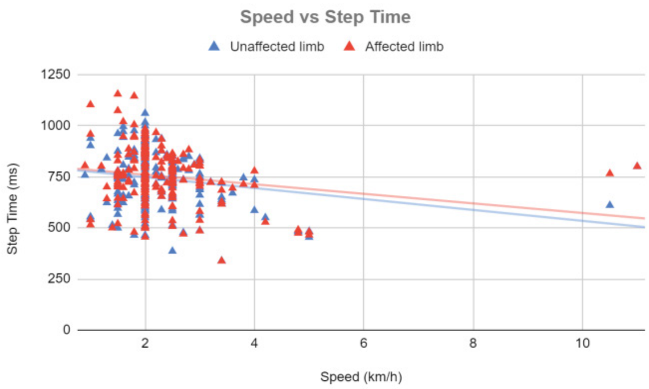

Body-weight support vs Step Time SI

Speed vs Step Time SI

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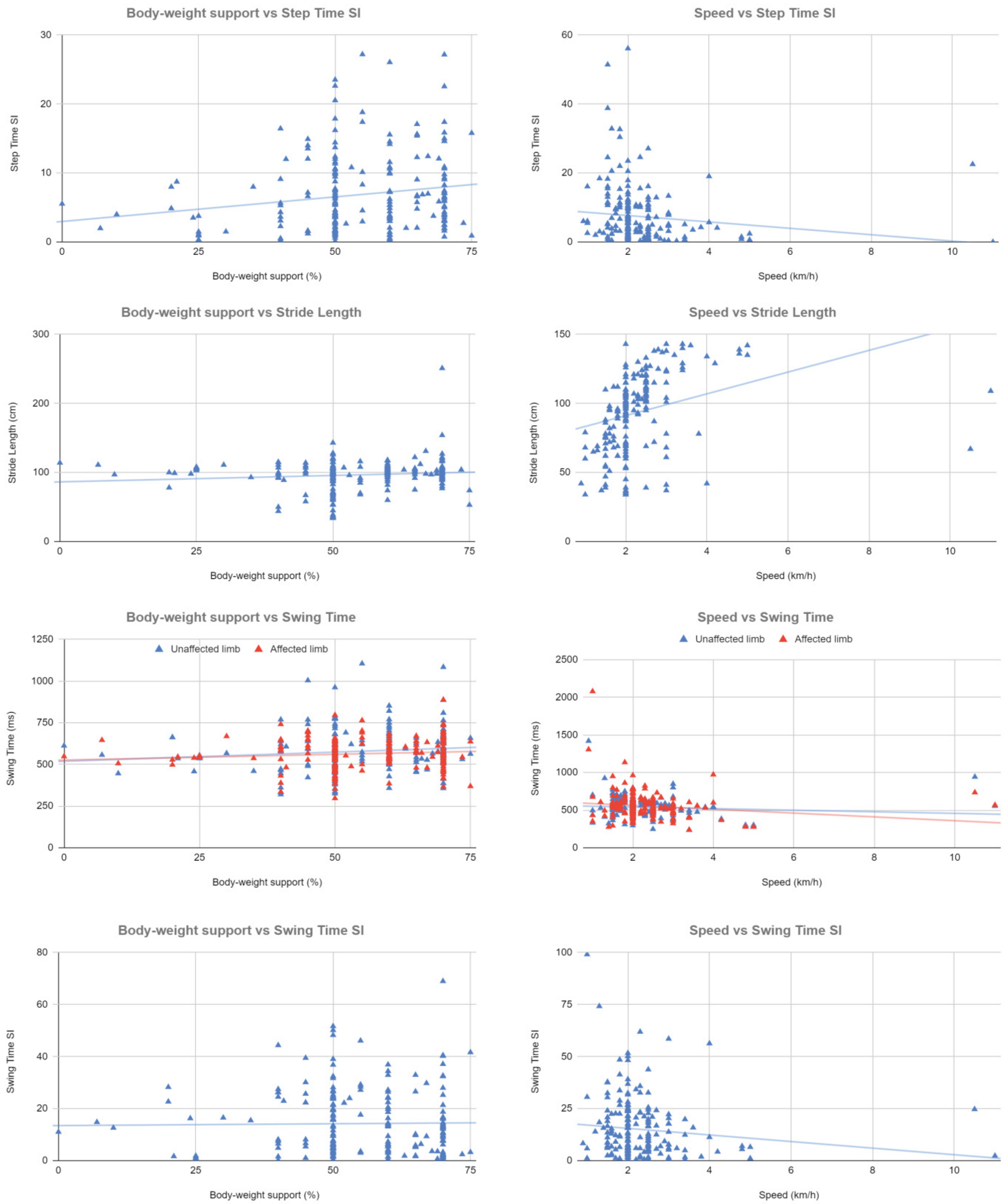

Figure 2: Graphs showing the dependence of measured gait parameters and their calculated symmetry indexes (SI) on BWS and speed settings as scatter plots interspersed with trendlines. The steepness of the trendlines determines the strength of the relationship between the parameter displayed on the x-axis and the therapy setting on the y-axis.

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healthy subjects was previously analyzed by Fukuchi et al. [27]. Impact was evaluated as significant across all monitored parameters in a positive direction for cadence, step length and stride length and in a negative direction for stance time, which is in accordance with the present trial. This conclusion leads to the assumption that the effect of speed is expected in both overground and BWSTT training and thus from the point of view of the walking cycle, during BWSTT therapy, patients undergo walking training in similar conditions as in regular overground practice. No negative effect of BWS was observed and, on the contrary, several benefits arise from the principle of BWSTT compared to overground rehabilitation. During exercise, patients are weight-supported, so they do not overload the joints and other parts of the locomotor system with their entire weight, which enables the involvement of the limb in the early recovery phase after injury or surgery.

Comparison with the conclusions of the existing clinical evidence investigating the influence of the BWSTT setting on gait patterns is not completely unambiguous. Firstly, the studies that investigated the effect of BWSTT used a device working on the principle of a suspension system, and secondly, these studies differ slightly in their conclusions. While Fischer and Wolf did not confirm the effect of BWS on gait curvature, Barela et al. [17], van Hedel et al. [18] and Threlkeld et al. [19] found a significant impact on spatiotemporal gait parameters [1]. In addition, it can be assumed that the principle of the suspension vest will influence walking parameters in a completely different way than in the case of lower-body positive pressure.

Another aim of this research was to find out if the BWSTT setting affects one of the main indicators of walking symmetry - the symmetry index. This indicator was calculated for the gait parameters stance time, step length, step time and swing time, which enable separate monitoring for each limb. The results of the Pearson correlation coefficient analysis showed that there is no significant relationship between the symmetry index of any gait parameter and the BWSTT (speed, BWS) setting. Such finding brings a promising aspect in monitoring the progress of gait symmetry restoration during BWSTT. Since the impact of any monitored therapy setting on this indicator was not proven, the symmetry index recorded directly during the BWSTT can be used to evaluate the improvement of asymmetry in patients recovering after lower limb impairment.

Comparison of data for the affected and unaffected limb showed that the injured lower limb recorded a shorter stance time and step length and a longer step time and swing time. This trend is consistent with the evidence on patients recovering from total hip arthroplasty and tibial fracture [28,29].

Some limitations of this research must be acknowledged. Since the data were analyzed retrospectively from therapies performed as part of the rehabilitation routine, records with settings typical for the recovery of post-operative conditions of the musculoskeletal system were dominantly represented - speed settings in the range of 0.5 - 4 km/h and BWS 40 - 70%. For this reason, a small amount of data outside the therapeutic range was analyzed. For the sake of simplifying the research, only records with zero inclination were analyzed and therefore the impact of inclination on gait parameters and symmetry indices cannot be evaluated.

Despite these shortcomings, this is unique research of BWSTT working on the lower-body positive pressure principle and the first study investigating the dependence of BWSTT settings and the gait symmetry parameter. Further research should continue to investigate the influence of inclination on the gait cycle and its symmetry.

Conclusion

The present study concluded that body-weight supported treadmill walking is, in terms of gait parameters, comparable to regular overground walking. In addition, the unweighting element enables performing the same movement with a lower load on the lower extremities and thus might be more suitable for gait recovery after surgery or injury of the locomotor system. Symmetry index was evaluated as a suitable tool for monitoring the process of gait symmetry restoration during therapy on a body-weight supported treadmill.

References

1. Fischer AG, Wolf A. Assessment of the Effects of Body Weight Unloading on Overground Gait Biomechanical Parameters. Clinical Biomechanics (Bristol, Avon) 30 (2015): 454461.
2. Plummer P, Behrman AL, Duncan PW, et al. Effects of Stroke Severity and Training Duration on Locomotor Recovery after Stroke: A Pilot Study. Neurorehabilitation and Neural Repair 21(2007): 137-151.
3. McCain KJ, Pollo FE, Baum BS, et al. Locomotor Treadmill Training With Partial Body-Weight Support Before Overground Gait in Adults with Acute Stroke: A Pilot Study. Archives of Physical Medicine and Rehabilitation 89 (2008): 684-691.
4. Miller EW, Quinn ME, Seddon PG. Body weight support treadmill and overground ambulation training for two patients with chronic disability secondary to stroke. Physical Therapy 82 (2002): 53-61.
5. Sullivan KJ, Knowlton BJ, Dobkin BH. Step Training with Body Weight Support: Effect of Treadmill Speed and Practice Paradigms on Poststroke Locomotor Recovery. Archives of Physical Medicine and Rehabilitation 83 (2002): 683-691.

6. Sousa CO, Barela JA, Prado-Medeiros CL, et al. Gait Training with Partial Body Weight Support During Overground Walking for Individuals with Chronic Stroke: A Pilot Study. Journal of Neuroengineering and Rehabilitation 8 (2011): 48.
7. Ganesan M, Sathyaprabha TN, Gupta A, et al. Effect of Partial Weight-Supported Treadmill Gait Training on Balance in Patients with Parkinson Disease. PM & R: The Journal of Injury, Function and Rehabilitation 6 (2014): 22-33.
8. Ganesan M, Sathyaprabha TN, Pal PK, et al. Partial Body Weight-Supported Treadmill Training in Patients with Parkinson Disease: Impact on Gait and Clinical Manifestation. Archives of Physical Medicine and Rehabilitation 96 (2015): 1557-1565.
9. Lucareli PR, Lima MO, Lima FP, et al. Gait Analysis Following Treadmill Training with Body Weight Support versus Conventional Physical Therapy: A Prospective Randomized Controlled Single Blind Study. Spinal Cord 49 (2011): 1001-1007.
10. Covarrubias-Escudero F, Rivera-Lillo G, Torres-Castro R, et al. Effects of Body Weight-Support Treadmill Training on Postural Sway and Gait Independence in Patients with Chronic Spinal Cord Injury. The Journal of Spinal Cord Medicine 42 (2019): 57-64.
11. Lotfian M, Dadashi F, Rafieenazari Z, et al. The Effects of Anti-gravity Treadmill Training on Gait Characteristics in Children with Cerebral Palsy. Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference 2019 (2019): 5256-5259.
12. Mattern-Baxter K. Effects of Partial Body Weight Supported Treadmill Training on Children with Cerebral Palsy. Pediatric Physical Therapy: The Official Publication of the Section on Pediatrics of the American Physical Therapy Association 21 (2009): 12-22.
13. D Prunerova A. Comparison of Therapeutic Progression Using Anti-Gravity Treadmill for Different Postoperative and Post Injury Conditions. J Clin Exp Orthopr 9 (2023): 401.
14. Hesse S, Werner C, Seibel H, et al. Treadmill Training with Partial Body-Weight Support after Total Hip Arthroplasty: A Randomized Controlled Trial. Archives of Physical Medicine and Rehabilitation 84 (2003): 1767-1773.
15. Webber SC, Horvey KJ, Yurach Pikaluk MT, et al. Cardiovascular Responses in Older Adults with Total Knee Arthroplasty at Rest and with Exercise on a Positive Pressure Treadmill. European Journal of Applied Physiology 114 (2014): 653-662.
16. Palke L, Schneider S, Karich B, et al. Anti-Gravity Treadmill Rehabilitation Improves Gait and Muscle Atrophy in Patients with Surgically Treated Ankle and Tibial Plateau Fractures after One Year: A Randomised Clinical Trial. Clinical Rehabilitation, 36 (2022): 87-98.
17. Barela AMF, Gama GL, Russo-Junior DV, et al. Gait Alterations During Walking with Partial Body Weight Supported on a Treadmill and Over the Ground. Sci Rep 9 (2019): 8139.
18. van Hedel HJ, Tomatis L, Müller R. Modulation of Leg Muscle Activity and Gait Kinematics By Walking Speed and Bodyweight Unloading. Gait & Posture 24 (2006): 35-45.
19. Threlkeld AJ, Cooper LD, Monger BP, et al. Temporospatial and Kinematic Gait Alterations During Treadmill Walking with Body Weight Suspension. Gait & Posture 17 (2003): 235-245.
20. Błaszczyk JW, Plewa M, Cieślinska-Swider J, et al. Impact of Excess Body Weight on Walking at the Preferred Speed. Acta Neurobiologiae Experimentalis 71 (2011): 528-540.
21. Lee SJ, Hidler J. Biomechanics of Overground vs. Treadmill Walking in Healthy Individuals. Journal of Applied Physiology (Bethesda, Md.: 1985) 104 (2008): 747-755.
22. Hassid E, Rose D, Commisarow J, et al. Improved Gait Symmetry in Hemiparetic Stroke Patients Induced During Body Weight-Supported Treadmill Stepping. Journal of Neurologic Rehabilitation 11 (1997): 21-26.
23. Council of Europe. Convention for Protection of Human Rights and Dignity of the Human Being with Regard to the Application of Biology and Biomedicine: Convention on Human Rights and Biomedicine. Kennedy Institute of Ethics Journal 7 (1997): 277-290.
24. Patterson KK, Gage WH, Brooks D, et al. Evaluation of gait symmetry after stroke: a comparison of current methods and recommendations for standardization. Gait & Posture 31 (2010): 241-246.
25. Queen R, Dickerson L, Ranganathan S, et al. A Novel Method for Measuring Asymmetry in Kinematic and Kinetic Variables: The Normalized Symmetry Index. Journal of Biomechanics 99 (2020): 109531.
26. Mukaka MM. Statistics Corner: A Guide to Appropriate Use of Correlation Coefficient in Medical Research. Malawi Medical Journal: The Journal of Medical Association of Malawi 24 (2012): 69-71.

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DOI:10.26502/josm.511500127

27. Fukuchi CA, Fukuchi RK, Duarte M. Effects of Walking Speed on Gait Biomechanics in Healthy Participants: A Systematic Review and Meta-Analysis. Syst Rev 8 (2019): 153.

28. Dolatabadi E, Taati B, Parra-Dominguez GM, et al. A Markerless Motion Tracking Approach to Understand Changes in Gait and Balance: A case study (2013).

29. Larsen P, Laessoe U, Rasmussen S, et al. Asymmetry in Gait Pattern Following Tibial Shaft Fractures - A Prospective One-Year Follow-Up Study of 49 Patients. Gait & Posture 51 (2017): 47-51.