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Trunk kinematics during walking in persons with multiple sclerosis: The influence of body weight support

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Abstract.
BACKGROUND: Although body weight supported (BWS) treadmill training (TT) leads to some improvements in walking ability, it has not been proven that it is more effective than other walking therapies in persons with multiple sclerosis (PwMS). One possible explanation could be that BWSTT focuses on the cyclic movement of the lower extremities while the trunk is passively suspended in the harness.
OBJECTIVE: This study aimed to assess the 3 dimensional trunk and pelvis movements during BWS treadmill walking.
METHODS: 14 PwMS and 14 healthy persons (8 male/20 female; age 23 to 59 years) walked with 0%, 10%, 20%, 30%, 50% and 70% BWS. After a familiarization period, kinematic electromagnetic tracking (Polhemus Liberty™ 240/16) of the trunk and pelvis movements was applied. Statistical analysis consisted of a repeated measures ANOVA with simple contrasts (SPSS 20).
RESULTS: This study shows that BWS walking leads in general to smaller maximum trunk and pelvis movement amplitudes compared with walking without BWS, this with exception of the pelvis anterior-posterior movement in healthy subjects.
CONCLUSION: These data help to identify and isolate the effect of different BWS levels in PwMS and in healthy persons and suggest to use BWS lower than 30% for treadmill training.

Keywords: Body weight support, gait, gait analysis, kinematics, multiple sclerosis, pelvis, rehabilitation, treadmill, trunk, walking

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Abbreviations

BWS	body weight support
MS	multiple sclerosis
PwMS	persons with multiple sclerosis
CoM	center of mass

CoMt	centre of mass of the trunk
TT	treadmill training
BWSTT	body weight supported treadmill training
EDSS	Expanded Disability Status Scale
RoM	range of motion
TCT	Trunk Control Test
MAS	Modified Ashworth scale
MMSE	Mini Mental State Examination
VAS	Visual Analogue Scale
r.t.:	related to.

1. Introduction

Compared with over-ground gait training, treadmill training (TT) has advantages such as a larger number of steps during gait training and a controlled walking speed. Additionally, overhead body weight-support (BWS) systems can be utilized (Lee & Hidler, 2008). This allows therapists to initiate walking therapy before patients are able to bear their full body weight. BWS makes it possible to practise reciprocal stepping at faster speeds with greater safety and less fear of falling than early over-ground rehabilitation would permit (Dobkin et al., 2006) and discourages the development of compensatory strategies compared with walking aids (Visintin et al., 1998).

85% of persons with Multiple Sclerosis (PwMS) reported gait disturbance as their main complaint (Morris et al., 2002). During rehabilitation an adequate afferent input is necessary to activate the active spinal circuits (Dietz, 2009). Task-specific TT helps neuroplasticity after neurological damage and induces an expansion of the subcortical and cortical motor zones (Cramer et al., 2011).

Although BWS TT leads to some improvements in walking ability, it has not been proven that it is more effective than other walking therapies in neurological patients such as PwMS (Giesser et al., 2007; Lo & Triche, 2008; Pilutti et al., 2011; Swinnen et al., 2012; Swinnen et al., 2010). The lack of an added value for BWS may be explained by the fact that this training modality focuses on the cyclic movement of the lower extremities while the trunk is only passively suspended in the harness. Hereby the trunk and pelvis provide less input during the gait cycle.

The kinematics of the lower extremities during gait have often been discussed (Zajac et al., 2003). However, less attention has been spent to the trunk and pelvis movements despite the essence of these movements to maintain body balance, to make space on the gait path for the swing leg, to avoid excessive movement of the head and to decrease the vertical and lateral displacements of the centre of mass of the body (CoM) to save energy (Crosbie et al., 1997; Nymark et al., 2005; Saunders et al., 1953; Thorstensson et al., 1984). Only a few studies described some trunk movements during treadmill walking under BWS. Pintèr et al. (2006) studied the differential effect of 15 to 45% BWS on the thorax and pelvis rotations, and Aaslund et al. (2008) studied the differences in the thorax movements between 30% and 0% BWS. They found that a high percentage of BWS limited the inter-segmental coordination of pelvis and thorax (Pintèr et al., 2006) and restricted the accelerations of the body segments in all directions (Aaslund & Moe-Nilssen, 2008).

The aim of this study was to determine the maximal movement amplitudes of the relative movements of the trunk related to the pelvis and of the pelvis and the centre of mass of the trunk (CoMt) with respect to the global reference system. This study focused on the differences in mean maximal movement amplitudes between different BWS levels (10, 20, 30, 50 and 70%BWS) as compared with 0% BWS in a group of PwMS and in a group of healthy persons. The hypothesis of this study was that with increasing levels of BWS the range of motion of the trunk and pelvis will decrease.

2. Methods

2.1. Participants

14 PwMS (recruited from the rehabilitation centre) and 14 healthy persons participated. The selection criteria were: males or females between 20 and 60 years, an Expanded Disability Status Scale (EDSS) score between two (minimal disability in one functional system is present) and six (the person needs intermittent or unilateral constant assistance with a cane, crutch or brace to walk 100 meters with or without resting) (Kurtzke, 1983), no flare of the disease, no other neurological diseases or orthopedic problems affecting the gait pattern and they have to be cognitively able to understand and carry out the instructions. The inclusion criteria for the healthy persons were a normal range of motion (RoM) and no history of injury or surgery in the last 6 months. Persons with orthopaedic or musculoskeletal deformations, osteoporosis and anomalies of the lower extremities or trunk were excluded. The eligibility of the participants was checked using a standardized questionnaire (personal information, sports,

Table 1
Characteristics of the PwMS

PwMS	Type MS	Male/ Female	Time after diagnosis (years)	EDSS-score	MAS lower extremities				MMSE (max 30)	VAS SCORES (max 100 mm)		TCT (max 100)
					Flexors		Extensors			Pain	Fatigue	
					R	L	R	L				
1	SP	F	19	2.5	0	0	0	0	30	75	99	100
2	RR	F	18	3.5	0	0	0	0	28	0	87	100
3	SP	F	12	4	2	0	2	0	21	19	32	61
4	SP	M	12	4	0	0	0	0	22	*	*	74
5	PR	F	10	4.5	0	0	0	0	28	0	60	100
6	RR	F	4	4.5	0	0	0	0	29	0	71	100
7	RR	F	22	6	0	0	0	0	25	99	87	100
8	RR	M	2	5	2	3	0	0	29	0	16	100
9	PR	F	4	3.5	0	0	0	0	28	77	88	100
10	SP	F	22	6	0	0	0	0	29	2	51	100
11	PP	F	13	6	0	0	0	0	30	0	64	100
12	RR	M	5	6	0	0	0	0	29	0	23	100
13	RR	M	2	5.5	0	0	0	0	30	5	47	100
14	RR	F	0.5	6	0	0	0	0	28	52	50	100
Mean score			10.4	4.8	0.3	0.2	0.1	0	27.6	25.3	59.6	95.4
SD			7.7	1.2	0.7	0.8	0.5	0	2.9	36.7	26.4	12.1
Range			0.5–22	2.5–6	0–2	0–3	0–2	0	21–30	0–99	16–99	61–100

PwMS: persons with multiple sclerosis, MS: multiple sclerosis, SP: secondary progressive, RR: relapsing remitting, PR: primary progressive, EDSS: Expanded Disability Status Scale, MAS: Modified Ashworth Scale, L: left side, R: right side, MMSE: Mini Mental State Examination, TCT: Trunk Control Test, SD: Standard Deviation. *Not possible to measure.

Table 2
Characteristics of the participants

Characteristics of the participants	PwMS ($n = 14$)		Healthy persons ($n = 14$)	
	Range	Mean (SD)	Range	Mean (SD)
Age (years)	21–59	45.8 (10.9)	22–60	44.5 (12.2)
BMI (kg/m²)	20.1–31.9	24.3 (3.0)	19.0–28.7	22.4 (3.2)
Body mass (kg)	57–90	72.8 (9.3)	50–87	65.9 (10.9)
Body height (cm)	160–187	172.7 (8.7)	160–188	171.1 (8.6)

BMI: Body Mass Index, kg/m^2: mass in kilograms divided by squared height in meters, SD: standard deviation, n: number of participants, kg: kilogram, cm: centimeters.

diseases, problems with muscles and joints, surgery, medication and experience with walking on a treadmill and/or BWS system). For the PwMS the type and duration of the MS were registered.

Some additional clinical data of the PwMS were collected: the Trunk Control Test (TCT) to evaluate the trunk control of the patients (Verheyden et al., 2007); the Modified Ashworth scale (MAS) for the lower legs to determine the spasticity of the flexor and extensor muscles of the lower legs (Blackburn et al., 2002); the Mini Mental State Examination (MMSE) to detect cognitive problems (Swirsky-Sacchetti et al., 1992); and the Visual Analogue Scale (VAS) score for pain and fatigue (Table 1).

All participants were able to walk on a treadmill without a harness, a BWS system or holding their hands on the sidebars. The participants' body weight and height were measured before starting the protocol (Table 2).

The protocol was approved by the local ethical commission (BUNB14320084299) and the rehabilitation centre (OG033). All participants were informed about the purpose and protocol of the study, and they all signed the informed consent.

2.2. Test procedure

A motorized treadmill (Trimline) and suspension system (LiteGait MX300) (Frey et al., 2006) were used (Fig. 1). The suspension system has two suspension points, one at each side of the person in the frontal plane, separated 38 cm from each other (see Fig. 1). From each suspension point two belts, one on the front and one on the back of the person ensure the suspension. The harness was suspended at four points, two on the front (25 cm separated from each other) and two on the back side (21 cm separated from each other). Before

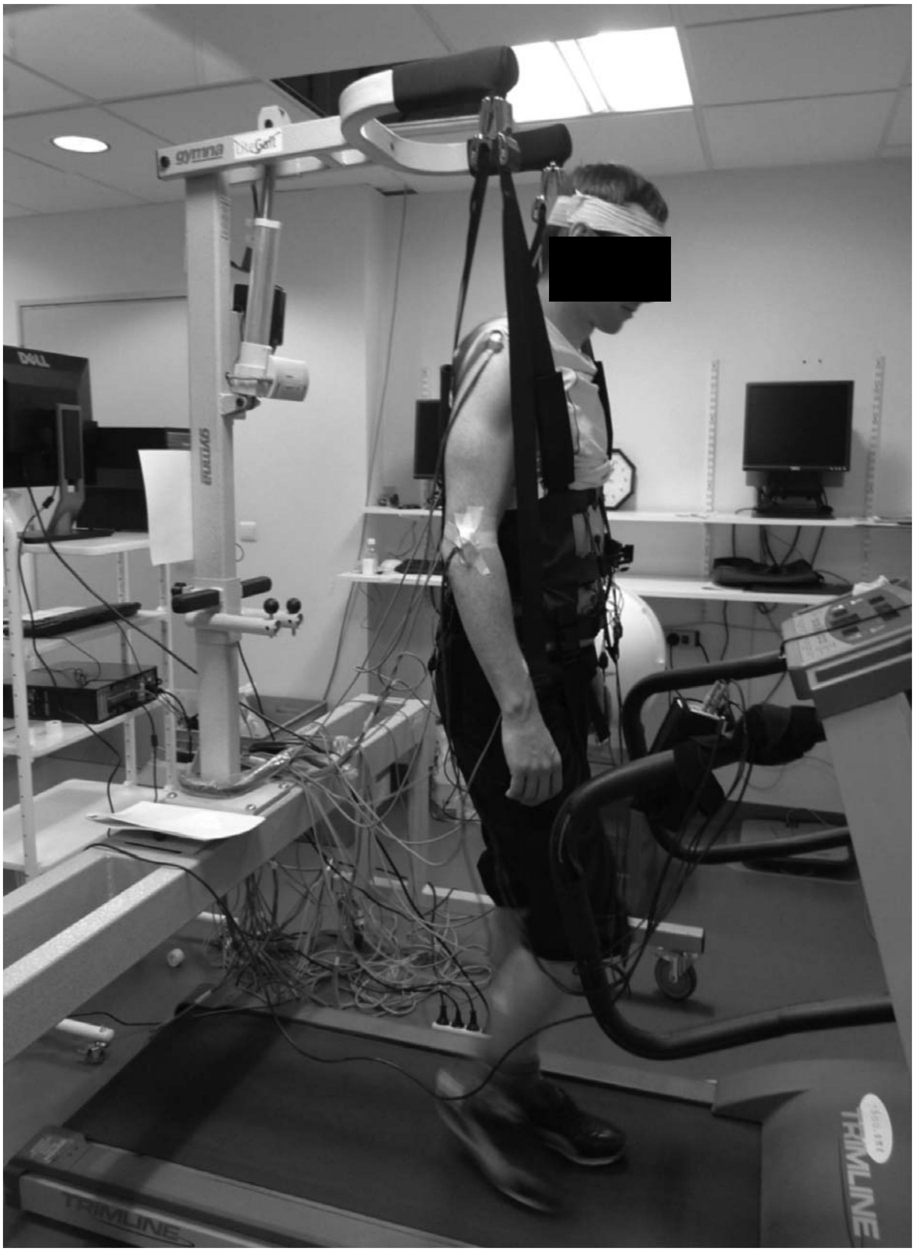

Fig. 1. Study equipment. A PwMS is walking on the treadmill with BWS system.

starting the tests, the BWS system was calibrated and the height of the suspension fork was set for each person individually in the horizontal plane of the top of the head. In the harness openings were made for EMG electrodes (the EMG-data will be reported in a subsequent publication). The Polhemus Liberty$^{\text{TM}}$ (240/16) an electromagnetic tracking device (intra-trial reliability: CMD = 0.942 (Mills et al., 2007)), registered the 3D kinematics at 240 Hz (accuracy 0.08 cm for position and 0.15° for orientation). Before the research measurements, the electromagnetic device was tested for its accuracy to check for influences from the surrounding. No interference was detected of metal objects, such as the BWS system, the harness and the treadmill with the electromagnetic tracking system. The global frame was aligned with the orientation of the treadmill platform.

The sensors and wires were firmly affixed to the skin with tape to diminish sensor to skin motion artifacts and were not interfering with the harness.

Self-selected walking speed was determined during walking on the treadmill by varying the speed while the display was blinded for the participants. The PwMS walked with an average self-selected walking speed of 1.6 kmph (SD 0.5, range 1–2.5 kmph) and the healthy persons with a self-selected walking speed of 3.4 kmph (SD 0.5, range 2.5–4 kmph).

The PwMS walked 1 to 2 minutes and the healthy persons 2 to 4 minutes before each measurement (30 seconds) to get used to the new level of BWS. They were instructed to look forward and walk normally without using the sidebars. The participants were assigned to one of two groups by drawing lots. Both groups started walking on 0% BWS. For counterbalancing, one group walked with increasing levels of BWS (10, 20, 30, 50 and 70% BWS) and one group walked with decreasing levels of BWS (70, 50, 30, 20 and 10% BWS). If necessary, the patients could rest a few minutes between the different levels of BWS.

2.3. Data analysis and outcome measures

The sensors were used as position markers. Local embedded frames were defined following the recommendations of the International Society of Biomechanics (Wu et al., 2005). The pelvis segment was defined by the position of the sensors fixed on the right and left anterior superior iliac spine and the sacrum and the trunk segment was defined by the sensors on the sternum, the 7th cervical vertebra and the sacrum. The position of the CoM of the trunk (CoMt) was estimated at 37% proximally on the line connecting the sacrum and the 7th thoracic vertebra (Winter, 1990). Raw data were processed using a Savitzky-Golay smoothing filter, to eliminate small artefacts. This filter was chosen over traditional smoothing methods because of its data preservation properties, resulting in minimal time delay and amplitude attenuation (Guiñón et al., 2007).

The outcome measures were: (a) the RoM of the relative rotational movement of the trunk segment related to the pelvis segment, (b) the RoM of the rotational movement of the pelvis segment with respect to the global reference system oriented about the walking direction and (c) the RoM of the linear movement of the CoMt with respect to the global reference system. These outcome measures were calculated following an xyz Euler convention. The trunk movements (in degrees) were defined as lateral flexion (anterior-posterior axis), rotation (longitudinal axis) and flexion (frontal axis). The pelvis movements (in degrees) were defined as: lateral tilting (anterior-posterior axis), rotation (longitudinal axis) and anterior-posterior tilting (frontal axis). The CoMt movements (in centimeters) were in the direction of the3D axes. These outcome measurements were defined in terms of the gait cycle, based on the movement of the calcaneus of the left foot.

2.4. Statistical analysis

SPSS 20 was used to analyse the mean effects. A repeated measures ANOVA with simple contrasts was processed with the level of BWS as the within-subjects factor. The different levels of BWS were compared with the 0% level of BWS. The significance level was set at 5%.

3. Results

Table 3 presents the mean maximal movement amplitudes with their standard deviations during treadmill walking with different gradations of BWS.

3.1. Kinematic differences compared with 0% BWS

3.1.1. PwMS (Fig. 2 A, B and C)

Compared with walking without BWS, the lateral displacement of the COMt decreased significantly during walking at 70% BWS (−32.33%; $p = 0.023$) and the vertical displacement decreased significantly during walking at 50 and 70% BWS (−32.55%; $p = 0.012$ and −36.07%; $p = 0.008$). Significant smaller movement amplitudes were found for lateral flexion of the trunk on the pelvis at 70% BWS (−27.8%; $p = 0.019$) and in the rotation of the trunk on the pelvis during walking at 50 and 70% BWS (−24.17%; $p = 0.029$ and −35.1%; $p = 0.005$). A significant decrease in rotation of the pelvis was found during walking at 10, 30, 50 and 70% BWS (−18.35%; $p = 0.006$, −28.19%; $p = 0.001$, −32.18%; $p = 0.001$ and −39.89%; $p < 0.001$).

3.1.2. Healthy persons (Fig. 3 A, B and C)

The anterior-posterior (−12.63%; $p = 0.001$, −19.19%; $p < 0.001$, −22.73%; $p < 0.001$ and −22.22%; $p = 0.002$) and cranio-caudal (vertical) displacement of the CoMt (−17.86%; $p < 0.001$, −27.5%; $p < 0.001$, −31.07%; $p < 0.001$ and −32.14%; $p = 0.001$) decreased significantly at 10, 20, 30 and 50% BWS. Significant smaller movement amplitudes

Table 3
Mean maximal movement amplitudes during treadmill walking with different BWS levels

Maximal movement amplitudes				0% BWS	10% BWS	20% BWS	30% BWS	50% BWS	70% BWS
Movement COMt (cm)	A-P	Healthy persons	Mean	1.98	1.73	1.6	1.53	1.54	1.97
			SD	0.32	0.24	0.28	0.32	0.57	0.95
		Persons with MS	Mean	2.99	3.21	3	2.68	2.52	2.5
			SD	1.04	1.43	1.27	1.22	1.01	0.91
	Lateral	Healthy persons	Mean	3.66	3.28	3.23	3.5	4.05	4.85
			SD	0.92	0.82	0.87	0.94	1.08	2.68
		Persons with MS	Mean	6.96	6.99	6.88	6.79	5.34	4.71
			SD	2.61	2.61	3.03	2.56	3.3	2.88
	C-C	Healthy persons	Mean	2.8	2.3	2.03	1.93	1.9	2.23
			SD	0.69	0.51	0.46	0.46	0.61	1.3
		Persons with MS	Mean	3.41	3.38	3.16	3.06	2.3	2.18
			SD	1.07	1.06	1.14	0.88	0.98	1.04
Movement trunk r.t. pelvis (°)	lat. flexion	Healthy persons	Mean	3.77	2.75	2.59	2.88	3.37	4.08
			SD	1.08	0.89	0.92	1.04	1.47	2.51
		Persons with MS	Mean	4.64	4.98	5.28	5.16	3.99	3.35
			SD	1.5	1.79	2.3	1.83	1.81	1.58
	rotation	Healthy persons	Mean	3.26	2.85	2.58	2.39	2.2	2.16
			SD	1.35	1.14	1.19	0.95	0.96	1.05
		Persons with MS	Mean	3.02	2.85	3.02	2.79	2.29	1.96
			SD	1.2	1.54	1.88	1.69	1.37	1
	A-P flexion	Healthy persons	Mean	2.13	2.28	2.17	2.36	2.13	2.04
			SD	0.73	0.93	0.82	0.91	0.77	0.76
		Persons with MS	Mean	2.62	2.55	2.59	2.49	2.23	2.19
			SD	1.12	1.02	1.14	0.98	1.42	1.07
Movement pelvis (°)	lat. tilting	Healthy persons	Mean	3.65	2.7	2.22	2.05	1.87	2.04
			SD	1.21	0.91	0.76	0.77	0.89	1.08
		Persons with MS	Mean	3.53	3.53	3.59	3.62	3.22	3
			SD	1.08	1.54	1.29	1.08	1.43	1.32
	A-P tilting	Healthy persons	Mean	5.25	4.93	5.46	6.42	7.76	9.11
			SD	1.53	1.86	2.05	2.53	2.65	3.66
		Persons with MS	Mean	8.08	8.43	8.66	8.77	7.99	7.44
			SD	2.88	2.49	3.11	2.83	2.34	2.7
	rotation	Healthy persons	Mean	2.78	2.63	2.04	1.96	2.06	2.1
			SD	0.71	1.47	0.55	0.59	0.69	0.79
		Persons with MS	Mean	3.76	3.07	3.13	2.7	2.55	2.26
			SD	0.9	0.77	1.18	0.83	0.83	0.63

C-C: cranio-caudal, A-P: anterior-posterior, lat.: lateral, SD: standard deviation, °: degrees, cm: centimeters, COMt: centre of mass of the trunk, r.t.: related to.

were found in lateral displacement of the CoMt at10 and 20% BWS (−10.38%; $p = 0.030$ and −11.75%; $p = 0.038$) and larger movement amplitudes (10.66% and 32.51%, but not significantly) were seen at 50 and 70% BWS compared with 0% BWS. Compared with 0% BWS the lateral flexion of the trunk on the pelvis decreased significantly at 10 to 50% BWS (−27.06%; $p = 0.008$, −31.3%; $p = 0.002$, −23.61%; $p = 0.001$ and −10.61%; $p = 0.005$), but increased significantly at 70% BWS (8.22%; $p = 0.019$). Significant smaller movement amplitudes were found in rotation of the trunk on the pelvis at 10 and 20% BWS (−12.58%; $p = 0.001$ and −20.86%; $p = 0.005$). Lateral tilting (−39.18%; $p < 0.001$, −43.84%; $p < 0.001$, −48.77%; $p = 0.001$ and −44.11%; $p = 0.002$) and rotation of the pelvis (−26.62%; $p = 0.001$, −29.5%; $p = 0.001$, −25.9%; $p = 0.007$and −24.46%; $p = 0.009$) decreased significantly at 20 to 70% BWS and anterior-posterior tilting increased significantly at 30 to 70% BWS (22.29%; $p = 0.043$, 47.81%; $p < 0.001$ and 73.52%; $p = 0.001$).

4. Discussion

The aim of the present study was to measure the trunk and pelvis movements during treadmill walking with different BWS levels in PwMS and in healthy persons. Only two previous studies were found in literature in which the trunk and pelvis kinematics were measured during BWS walking (Aaslund & Moe-Nilssen, 2008; Pintèr, et al., 2006). To the best of our knowledge, this is the first study that gradually investigated in five levels – from 10% up to 70% BWS - the influence of BWS on

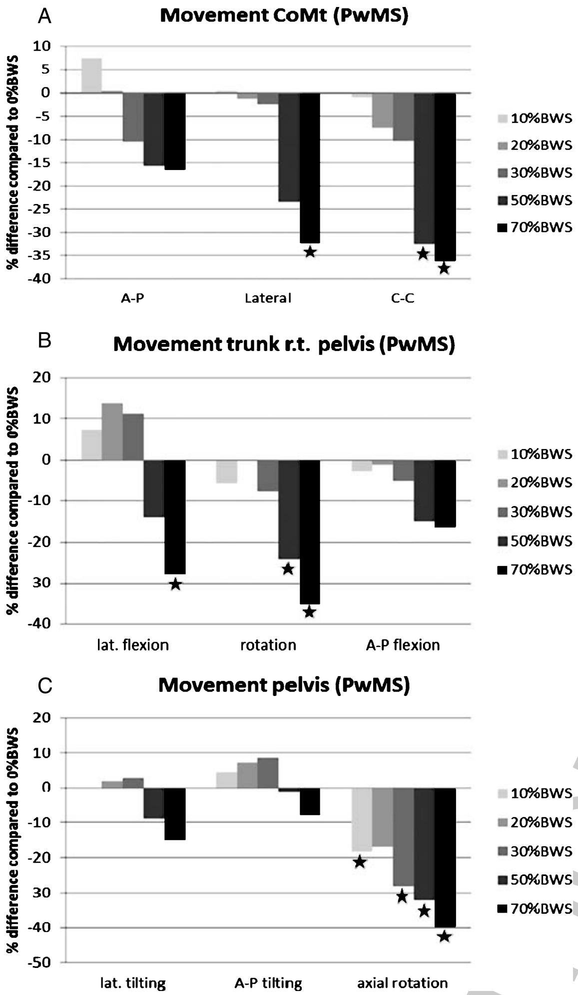

Fig. 2. Differences in % compared with 0% BWS in PwMS. A. movement of CoMt, B. movement trunk related to pelvis, C. movement pelvis. A-P: anterior-posterior, C-C: cranio-caudal, lat.: lateral, r.t.: related to, *: significant difference compared with the 0% BWS level.

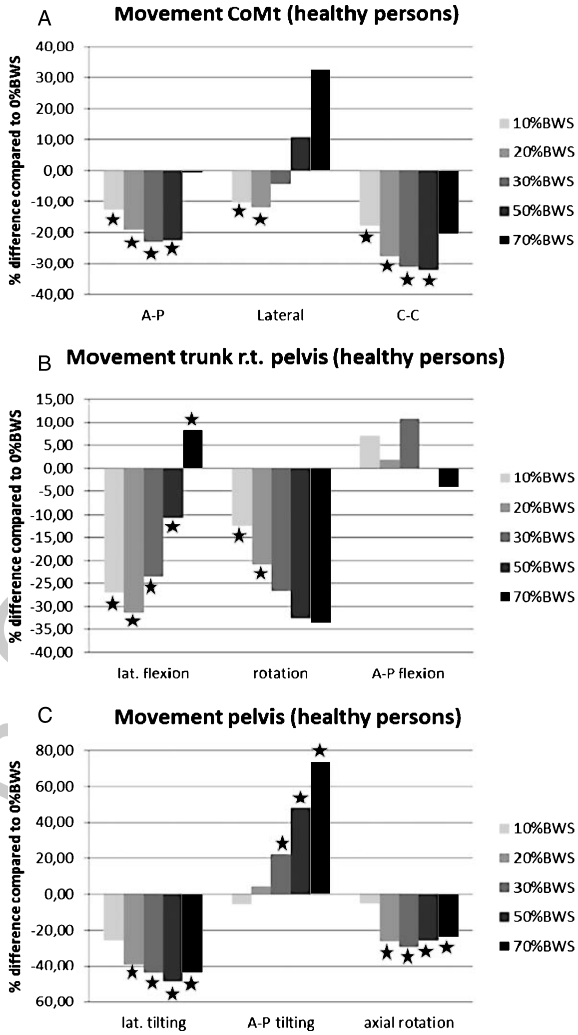

Fig. 3. Differences in % compared with 0% BWS in healthy persons. A. movement of CoMt, B. movement trunk related to pelvis, C. movement pelvis. A-P: anterior-posterior, C-C: cranio-caudal, lat.: lateral, r.t. related to, *: significant difference ($p \leq 0.05$) compared with the 0% BWS level.

the 3D trunk and pelvis movements; and the first study in which trunk and pelvis movements were measured in neurological patients during walking at different BWS levels.

4.1. Movements of the trunk and pelvis

As hypothesized in this study, in PwMS and in healthy persons, in general, walking with BWS led to a significant decrease in trunk and pelvis movement amplitudes in comparison with walking without BWS.

The pelvis movements were strongly influenced by the BWS during walking, especially during the highest levels of BWS where smaller movement amplitudes of the pelvis appeared with increasing levels of BWS, this with exception of the anterior-posterior movement of the pelvis. During high levels of suspension the trunk and pelvis are fixated in the BWS system, it is possible that there is a compensation of the pelvis movements in antero-posterior direction. The pelvis movements are essential during gait in order to move the lower extremities and to transfer the body weight from one side to the other.

The pelvis and trunk lateral movements and rotations are important to move the feet forwards without excessive trunk and CoM displacements (Krebs et al., 1992). Pintèr et al. (2006) demonstrated a decrease of the trunk rotation related to the pelvis at 45% BWS. They stated that this induced a more synchronic movement between trunk and pelvis (Pintèr, et al., 2006). This study also revealed a significant decrease of the trunk rotation on the pelvis in the PwMS and in the control group.

Taken together, the pelvis rotation and lateral tilt are responsible for a decrease in excessive body movements to lower the energy consumption (Inman, 1993; Saunders, et al., 1953). In this study, the CoMt displacements in vertical and anterior-posterior direction significantly decreased at 10% to 50% BWS and in lateral direction at 10% and 20% as compared with 0% BWS in the control group. These small movement amplitudes of the CoMt in combination with the small amplitudes in lateral tilting and rotation may indicate a less active participation in balance regulation during gait caused by the suspension and/or the harness. With increasing levels of suspension, Finch et al. (1991) noted a decrease in relative time of the stance phase and bipedal phase (Finch et al., 1991). An increase of the bipedal phase refers to an increased need of balance during gait. As such, it is possible that TT with high BWS levels could result in less need of balance, causing less task specific balance rehabilitation.

4.2. Methodological considerations

The changes of the maximal movement amplitudes during different levels of BWS walking in comparison with 0%BWS were often significant, but the absolute values were overall small. Previous research described different possibilities in local frame definition of the trunk: a thorax definition in terms of the acromiae and sacrum (Nymark, et al., 2005) or as in this study a thorax definition based on a proximal point on the spine, the sternum and the sacrum (Vogt et al., 2002). Estimated movement amplitudes will be larger if a thorax frame comprising the acromiae is used compared with a frame build up with points on the spine and sternum due to the relative movements of the scapulae (i.e. acromiae) with respect to the thorax segment induced by the arm-swing during gait (Inman, 1993).

The different BWS levels were compared with the 0% BWS level. The question remains if the results were influenced by the gait on a treadmill and/or by the harness that is worn even without suspension. Gait on a treadmill results in a decrease of pelvis lateral tilt and rotation, trunk lateral flexion (Riley et al., 2007; Vogt, et al., 2002) and an increase in lumbar anterior flexion compared with over-ground walking (Aaslund & Moe-Nilssen, 2008; Nymark, et al., 2005). These differences are very small and Riley et al. concluded that the gait analysis on a treadmill is functionally equivalent to measurements over ground (Riley, et al., 2007). Wearing a harness leads to a decrease in the vertical acceleration of the CoM of the body and linear and rotational trunk movements, which can lead to a decrease in shock absorption by the trunk. Most of the shock will therefore have to be absorbed by the legs to avoid excessive cranial movements (Aaslund & Moe-Nilssen, 2008). A limitation is that within this study the individual influence of the treadmill and the harness was not investigated separately.

The BWS system used in this study had two suspension points. However, some other systems have only one suspension point. As is the case in most rehabilitation centres, this study encompassed a passive system where the suspension varied during the gait cycle (Finch, et al., 1991). Hence, the results of this study cannot be extrapolated to other suspension systems.

4.3. Participants

In the PwMS different questionnaires and tests were completed. The MAS was taken to evaluate the spasticity in the lower extremities. A high level of spasticity has influence on postural control (Sosnoff et al., 2010) and the gait pattern (Balantrapu et al., 2012) in the PwMS. In this study only in two of the 14 included persons some low level of spasticity was found. Control of the trunk motion is related to disorders of the gait pattern (Verheyden et al., 2006). Therefore, a TCT evaluation was included in this study. The PwMS scored 95,4% ($\pm$12,1) at average, revealing good trunk control. On the MMSE, all participants scored between 21 and 30. Two participants had a score lower than 24, reported in literature as the limit for dementia (Swirsky-Sacchetti, et al., 1992), but they were all able to understand and carry out the given instructions. At the beginning of the protocol, four PwMS presented a high fatigue score on the VAS-scale. Therefore, the opportunity was given to take a rest break between the different trials. In this study only PwMS were included with an EDSS score between 2 and 6 to be able to compare them with a 0%BWS reference.

4.4. Clinical implementations

The optimal BWS level is the percentage that allows a maximum load on the legs in stand phase, based on the ability to make heel contact, but where enough support is given to patients who cannot stand independently (Finch, et al., 1991). Van Hedel et al. (2006) noted that many persons have problems standing squarely on their feet and walking normally with 70% BWS (van Hedel et al., 2006). Based on the kinematics of the lower extremities, literature generally advices the use of a BWS level lower than 30% (Threlkeld et al., 2003; van Hedel, et al., 2006) or 50% (van Hedel, et al., 2006). Also in this study the most significant and larger differences in movement amplitudes were found for 30, 50 and 70% BWS compared with the 0% BWS level.

5. Conclusions

This study helped to identify and isolate the effect of different BWS levels in PwMS and in healthy persons. The data show that walking with BWS, especially with high levels of BWS, leads to generally smaller maximum movement amplitudes of the trunk and pelvis compared with walking without BWS. This is with exception of the anterior-posterior movement of the pelvis in the healthy subjects, where an increase in movement amplitude was found during walking with the highest levels of BWS. These data suggest to use BWS lower than 30% for gait training on a treadmill.

Institutional review

The Ethical Committees of the University Hospital UZ Brussels (BUN B14320084299) and the National Multiple Sclerosis centre at Melsbroek (OG033) approved the protocol. The tests were carried out at the National Multiple Sclerosis centre, Melsbroek, Belgium. Written informed consent was obtained from all study participants.

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Declaration of interest

The authors have declared that no competing interests exist.

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