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Locomotor training with partial body weight support in spinal cord injury rehabilitation: literature review

Treino locomotor com suporte parcial de peso corporal em reabilitação de lesão medular: revisão de literatura

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Abstract

Introduction: The locomotor training with bodyweight support (LTBWS) has been used for approximately twenty years in the field of rehabilitation in patients who suffer from neurological pathologies. The LTBWS favors these improvements muscle, cardiovascular and osteo-psychological, because maximum residual potential develops the body, providing reintegration into the familial, social and professional. **Objective**: Identify the main methods of assessment and their parameters LTBWS with the purpose of contributing to the establishment of reliable evidence for the rehabilitation practice of people with spinal cord. **Materials and methods**: Original articles were analyzed, published between 2000 and 2011, involving gait training after spinal cord, with or without partial body weight support, and training assistance technologies such as functional electrical stimulation and biofeedback among others. **Results**: The majority of the participants of the studies was male; injury levels ranged from C3 to L3, ASIA had scores from A to D; injury times ranged from 0.3 months 33 years. Also it was noted that there is no consensus regarding LTBWS Protocol. **Conclusion**: The locomotor training with bodyweight support shows up, viable in the rehabilitation of patients who suffer from a neurological pathology such as the spinal cord, regardless of training protocol used the benefits relating to increases in muscular strength, maintaining or increasing bone density, decreased heart rate, increase in physical conditioning are present.

Keywords: Weight-bearing. Gait. Spinal cord injury.

Resumo

Introdução*: O treino locomotor com suporte de peso corporal (TLSP) é utilizado há aproximadamente 20 anos no campo da reabilitação em pacientes que sofrem de patologias neurológicas. O TLSP favorece melhoras osteomusculares, cardiovasculares e psicológicas, pois desenvolve ao máximo o potencial residual do organismo, proporcionando a reintegração na convivência familiar, profissional e social.* ***Objetivo****: Identificar as principais modalidades de TLSP e seus parâmetros de avaliação com a finalidade de contribuir com o estabelecimento de evidências confiáveis para as práticas reabilitativas de pessoas com lesão medular.* ***Materiais e métodos****: Foram analisados artigos originais, publicados entre 2000 e 2011, que envolvessem treino de marcha após a lesão medular, com ou sem suporte parcial de peso corporal, e tecnologias na assistência do treino, como biofeedback e estimulação elétrica funcional, entre outras.* ***Resultados****: A maioria dos participantes dos estudos era do sexo masculino; os níveis de lesão variavam de C3 a L3; ASIA teve pontuações de A a D; os tempos de lesão variaram entre 0,3 meses a 33 anos. Também se verificou que não há consenso em relação ao protocolo de TLSP.* ***Conclusão****: O treino locomotor com suporte de peso corporal mostra-se viável na reabilitação de pacientes que sofrem de uma patologia neurológica como a lesão medular. Independentemente do protocolo de treino utilizado, os benefícios referentes ao aumento da força muscular, manutenção ou aumento da densidade óssea, diminuição da frequência cardíaca e aumento do condicionamento físico estão presentes.*

Palavras-chave*: Suporte de carga. Marcha. Lesão medular.*

Introduction

Locomotor training with body weight support (LTBWS) has been proposed as an alternative option for the rehabilitation of people with spinal cord injury (SCI), in order to develop at most the body's residual potential and assist in the individual's reintegration into family, professional, and social daily life.

The early works in LTBWS were carried out by Lois Finch and Hugues Barbeau (1) and the Canadian researcher Hugues Barbeau (2) pioneered the use of LTBWS. The theoretical grounding for developing LTBWS comes from studies which studied the recovery of locomotion in cats with SCI (2, 3). Adult cats with a complete SCI and unable to move their hind legs after the injury, when put on the treadmill and encouraged to walk with a weight bearing, were able to take some steps with their hind legs after 7 months practicing LTBWS.

A feasible neurophysiological explanation for these motor responses may be that the continuous movement of the treadmill and the repetition of steps could stimulate neural circuits of locomotion control, which makes up the so-called central pattern generator (CPG) at the spinal level (4, 5).

CPG is responsible for producing the cyclic gait pattern, even after SCI, as it is in the spinal cord (6, 7). CPG activation during training on the treadmill could favor the neural plasticity processes by regulating the interaction between CPG and peripheral reflex activity. Training stimulates neuronal activity and it produces a better activation of the spinal centers of locomotion control. Thus, synaptic and cell responses of the control circuits CPG may be more flexible or more appropriately modulated on the treadmill than on the floor (8).

LTBWS in patients with incomplete SCI may be an important ally in motor rehabilitation, especially through neural plasticity (9), something which allows learning a new gait pattern. This learning depends on specific sensory inputs associated to the fulfillment of a motor task and the repetitive practice of this task (10).

Motor learning brings improvements to the biomechanics of the lower limbs, such as the pelvis and ankle, by means of an increased range of motion of the joints involved and the strength of the lower limbs, ensuring greater stability during gait (11). These peripheral changes contribute to improve motor control, something which is reflected on an increased speed (12) and the independence of gait (13).

Besides motor gains, many studies point out the potential of LTBWS to provide an aerobic capacity gain (14), reducing the risk of cardiovascular diseases (15), improving self-image, self-esteem, and life satisfaction (16), and maintenance of bone mineral density due to the mechanical effect of muscle contraction (17, 18, 19), something which contributes to increase strength in the lower limbs (20). Also stand out the maintenance and increase in the resistance for practicing physical activity (21). It has been observed that the regular use of LTBWS brings benefits to the cardiovascular status, both central (heart) (22) and in the peripheral temperature (vessels) (23), reducing the risk factors for cardiovascular diseases (20), increasing the regulation of heart rate and blood pressure (21, 24), in addition to quality and functional independence (25). LTBWS in patients with incomplete SCI is critical to physical recovery, especially through neural plasticity (9) and by using stem cells (26).

Despite the implementation of LTBWS for rehabilitation of SCI has been proposed and studied for over 20 years, there is still no consensus with regard to the parameters for its application and all the effects it can produce. Indeed, there are methodological differences in the application of training and in the analyses carried out. For instance, passive movements required by LTBWS may be performed by a technician or robotically assisted by a robotic orthosis (27). LTBWS may be associated to techniques such as virtual reality (12) or functional electrical stimulation (2, 28). The protocols use different speeds, weight bearing ranges, and times, such as the speed of 2.7 km/h, 80% of body weight discharge, training time of 10 minutes (25), or the speed of 0.6 km/h, 60% of body weight discharge, and 60 minutes of training time (23).

Some authors devote themselves to study motor learning, i.e. they try to understand the way how people acquire motor skills. In contrast, other authors study the physical gains after training.

Due to the potential that LTBWS conventionally shows in the rehabilitation of SCI or even as an aid in stem cell therapy, we regard a literature review as relevant to constitute an overview on the effects of training observed in the literature and its association to the protocols used. This review article aims, therefore, to identify the main modalities of LTBWS and its evaluation parameters for the purpose of contributing to the establishment of reliable evidence for the rehabilitation practices of people with SCI.

Methods

The search for information was made on the bases Wiley Online Library, Science Direct, SciELO, BioMed Central, MedLine, LILACS, and Google Scholar. The selected languages were Portuguese and English, with the keywords: body weight-supported, treadmill training, spinal cord injury, gait training, robotic-assisted, *treino locomotor*, *suporte parcial de peso*, *lesão medular*, *treino de marcha*, and *terapia robótica assistida*.

We reviewed only original articles involving gait training after SCI, with or without partial body weight support, and training improvement technologies, such as biofeedback and functional electrical stimulation, among others.

We excluded the papers which aimed at locomotor training in pathologies which did not derived from spinal cord injury and articles which did not indicate the kind of evaluation. The time window searched was within 2000 and 2011. After conducting the search in the databases, the abstracts were read and duplications were eliminated. We extracted from selected studies information about the following topics: locomotor training with partial body weight support, gait training, electromyography, and spinal cord injury.

Results

Our synthesis was based on 43 references, used to prepare the tables addressing protocols with LTBWS. The total number of items used in the study was 44 distributed over the years, and 2005 and 2006 had the highest number of selected publications (8 articles each).

Table 1 shows characteristics related to the sample and whether there was a control group. We divided the table according to the number of participants in each research, differing by sex, and data regarding the SCI, such as the classification by the American Spinal Injury Association (ASIA), level, and injury time.

We observe in Table 1 that most study participants were male; injury levels ranged from C3 to L3, characterizing paraplegic and also quadriplegic volunteers; ASIA classification had scores from A to D, with a higher frequency for C and D, which represent

Table 1 - Sample and sampling classification used in researches on LTBWS

continues

Author	Control group		Number of participants		Characteristics of SCI			
	Yes	No	M	F	ASIA	Level	Age	Injury time (months)
Behrman e Harkema (25)		X	4		A-C-D	C6-T9	20-45	3-120
Colombo et al. (26)	X		3	2		C4	24-70	
Colombo, Wirz e Dietz (29)		X	29	3	A-D		26-72	
Tordi et al. (30)		X	5				18-40	
Field-Fote (31)		X	13	6	C		31.7 ± 9.4	12-171
Wirz, Colombo e Dietz (32)		X	30	2	A-B-C-D	C4-T12	19-72	
Field-Fote e Tepavac (33)		X	9	5	C	T10	18-50	70 ± 47.6
Cikajilo, Matjacic e Bajd (34)		X	1		C	C4-C5	30	4
Dobkin et al. (35)	X		146		B-C-D	C4-L3	16-70	
Pepin, Norman e Barbau (36)	X		13	1	D	C5-T11	28-40	10-240
Jezernik et al. (37)		X	6			C3-L2	38-73	
Phillips et al. (38)		X	8	1	C	C4-T12		97-120
Hesse, Werner e Bardeleben (39)		X	3	1	C-D	C5-L2	44-62	3-180
Grasso et al. (40)	X		8	3	A-B-C	C7-L2		
Stewart et al. (41)		X	8	1	C	C4-T12		8 1±2.5
Behrman et al. (42)			1		D	C5-C6	55	
Carvalho e Cliquet Jr. (43)		X	20		A	C4-C7	33.8 ± 8.7	17-180
Ditor et al. (24)		X	6	2	B-C	C4-C5	27.6 ± 5.2	9.6 ± 7.5
Field-Fote, Lindley e Sherman (44)		X	27			C3-T10	22-63	12
Hicks et al. (45)		x	11	3	B-C	C4-L1	20-53	14-288
Hornby, Zemon e Campbell (46)		X	2	1	B-C	C6-T2	13-43	0.3-18
Wirz et al. (47)		X	18	2	C-D	C5-L1	40.5	240
Thomas e Garonassi (48)		X	8	2	C-D	C3-L1	29-78	8-336
Adams et al. (49)		X		1	B	C4	27	5
Carvalho e Cliquet Jr. (50)	X		20			C4-C8	33.8 ± 8.7	78.6 ± 56.2
Carvalho et al. (17)	X		21		B	C4-C8	31.9 ± 8.0	25-180
Dobkin et al. (51)			146		B-C-D	C5-L3	16-70	
Carvalho et al. (52)	X		11		A			
Effing et al. (53)			3		C-D	C5-C7	45-51	29-198
Lünenburger et al. (54)	X		19	3	A-B	C4-L1	21-67	2-396
Dobkin et al. (55)		X	107/38		C and D/B			
Phadke et al. (56)	X		16		D	C4-T1	51.4 ± 7.2	3-720
Prosser (57)		X		1	A	C4	5	10
Domingo, Sawicki e Ferris (58)	X		3	3	C-D	C4-T12	24-55	64-144
Dobkin et al. (55)		X	146		B-C-D	C5-L3		
Jayaraman et al. (59)		X	4	1	C-D	C6-T4	18-70	8-200
Lam et al. (60)		X	5	4	D	C4-L1	46-73	1.8-161.9
Musselman et al. (61)			2	2	C	C5-T12	24-61	12-276
Nooijen, Hoeve e Field-Fote (62)			75			T12		
Phadke et al. (63)	X		9	3	C-D	C3-T1	22-76	3-880

Table 1 - Sample and sampling classification used in researches on LTBWS

conclusion

Author	Control group		Number of participants		Characteristics of SCI			
	Yes	No	M	F	ASIA	Level	Age	Injury time (months)
Turiel et al. (22)		X	10	4			50.6 ± 17.7	
Protas et al. (64)		X	3		C-D	T8-T12	34-48	24-156

Legend: M = male; F = female; ASIA = functional classification of sensorimotor changes deriving from spinal cord injury, ranging from A (greater impairment) to E (normal).
Source: Research data.

SCIs; the injury times ranged from 0.3 months to 33 years (396 months).

It was observed that the experimental design, with a longitudinal nature (the collections are made over a long period), had a frequency eight times greater than cross-sectional studies, where data is collected within a given period of time, i.e. they are short-term studies.

Table 2 shows the parameters used in LTBWS in the last 10 years, highlighting the methodological differences in the implementation of training and in the analyses carried out.

We checked the weight percentage that each volunteer supported during gait training, noticing that a burden of 40% of body weight was the most frequently used. Most protocols (25%) were based on a training time of 30 minutes; the remainder (75%) varied training time between 10 and 90 minutes.

The resources for the conducting locomotor training were using a treadmill, floor (traditional gait training), or a mixture of both. The number of protocols which used the treadmill was around 4 times greater than the protocols using treadmill/ground. Some authors (6 among 44) did not report the type of training used, and they do not define whether training was performed only on the floor or otherwise.

In addition to the total training period applied to participants by means of the protocols, they were subdivided into weekly sessions, and the highest incidence (36.36%) of sessions was 5 times per week. LTBWS is put into practice through participants' gait movements, and these movements may be performed in an active way (by the participant her/himself without external assistance), assisted active (partially assisted by external mechanisms), and passive (entirely performed with external assistance). Since the passive motion may be done either in a manual way (a technician performs the impaired function), in a robotized way (an electromechanical orthosis performs the movement), using LTBWS with manual assistance was observed in 76.7% of the studies analyzed.

Discussion

Sampling characteristics

This article aimed at identifying the main modalities of LTBWS and its evaluation parameters for the purpose of contributing to the establishment of reliable evidence for rehabilitative practices of people with SCIs. Thus, we found out that LTBWS may be an important ally in the motor rehabilitation of SCI, something which allows us to know a new gait pattern, especially through neural plasticity (9). Such learning depends on specific sensory inputs, associated to the performance of a motor task and the repetitive practice of this task (10). The medulla integrates to the afferent supraspinal information and, with repetitive practice, it can improve the motor output. Therefore, activities specifically based on therapy provide an activation of the neuromuscular system below the lesion level, with the purpose to "retrain" the nervous system and resume specific motor tasks (70).

Based on the results, it was found out that the population of studies had an average injury time of 79.4 months, and the age group with the highest incidence was between 46 and 50 years, characterizing a population with age classification within the aging phase. In addition, there was a prevalence of participation of men in all these studies and, despite a study claimed that the distribution of gender is 3.8 men per 1 woman (71), corroborating the results, the findings regarding age at the time the injury occurred and the average age

Table 2- LTBWS protocols and their respective results

continues

Author	Protocol								
	Support	Assistance	Session time (min)	Weight-bearing	Weekly frequency	Period (months)	Speed	FES	Results
Behrman e Harkema (25)	T/F	M	10	80	3-5	1-5	2.7-4.5 km/h		Improved gait on treadmill.
Colombo et al. (26)	T	M/R	10-60	25-50	5	36	1.5-2 km/h		Automated training lengthens therapy.
Colombo, Wirz e Dietz (29)	T	M/R	20	30-50			1.9 km/h		There was no significant difference in the EMG signal of the lower limbs when compared to robotic training and LTBWS.
Tordi et al. (30)		M	30		3	1			Increased strength of lower limbs.
Field-Fote (31)	T/F	M	90	30	3	3	0.23 m/s	X	Increased strength of lower limbs.
Protas et al. (64)	T	M	60	40	5	3	0.16 km/h		Increased gait speed.
Wirz, Colombo e Dietz (32)	T	M	15	80	5	4.5	1.5 km/h		Increased EMG signal in the lower limbs.
Field-Fote e Tepavac (33)	T	M	90		3	3	1 km/h	X	Improved intra-limb coordination.
Cikajilo, Matjacic e Bajd (34)	T	R	30	70	1 training session	NI	1.9 km/h		Increased amplitude of the EMG signal in the lower limbs.
Dobkin et al. (35)	T	NI	NI	NI	NI	NI	NI	X	Increased stability in the balance phase.
Pepin, Norman e Barbau (36)	T	M	90	NI	5	3	80 m/min		Increased independence for walking.
Jezernik et al. (37)	T	M	20		1 training session		0.1-1 m/s		Increased EMG amplitude.
Phillips et al. (38)	T	R	10	50	1 training session		1.7-1.9 km/h		Increased rehabilitation of locomotion.
Hesse,Werner e Bardeleben (39)	T	M	NI	NI	NI		0.27-1.52 m/s		Increased EMG signal with regard to the increased gait speed on a treadmill.
Grasso et al. (40)	T		25		5	1		X	Positive effect on gait parameters.
Stewart et al. (41)	T	M	25	65	3	6	0.6 km/h		Improved regulation of blood glucose.
Behrman et al. (42)	T	Electromechanical	20-25	10; 15	5	1.1	2.5 km/h	X	Improved walking capacity.
Carvalho e Cliquet Jr. (43)	T	M	30	75	5	3	2-3 km/h		Improved walking capacity.
Ditor et al. (2005) 24	T	M	10	65	3	6	0.6 km/h		Increased muscle fiber size.
Field-Fote, Lindley e Sherman (44)	T	NI	NI	NI	NI	NI	NI	NI	The EMG signal was higher when executing alternate movement with the lower limbs.

Table 2- LTBWS protocols and their respective results

continues

Author	Protocol								
	Sup-port	Assis-tance	Session time (min)	Weight-bearing	Weekly frequency	Period (months)	Speed	FES	Results
Behrman et al. (42)	T	M	75-90	10	5	2.1	1 m/s		Improved walking capacity after LTBWS.
Carvalho e Cliquet Jr. (43)	T		20	30-50	2	3	0.5 km/h	X	Decreased blood pressure.
Ditor et al. (24)	T	M	60	70	3	6	0.5 km/h		Maintenance of the ability to make positive changes in cardiovascular autonomic regulation without aggravating orthostatic intole-rance.
Field-Fote, Lindley e Sherman (44)	T/F	M/R	60	30	5	2	0.32 km/h	X	Increased gait speed.
Hicks et al. (45)	T		60	60	2	12	0.6 km/h		Improved walking capacity on the treadmill.
Hornby, Zemon e Campbell (46)	T	R	30	59	3	5	2-2.5 km/h		Increased range of motion, gait speed.
Wirz et al. (47)	T	R	45		3;5	2	0.66 m/s		Improved gait on the floor.
Thomas e Garo-nassi (48)	T	M	60	70	5	1	1.5 km/h	X	Increased maximum motor potential.
Adams et al. (2006) 49	T	M	15	59	3	4	1 a 2.5 km/h		Decreased muscle atrophy.
Carvalho e Cliquet Jr. (50)	T	M	20	60-70	2	6	1 km/h	X	Increased bone formation rate and aerobic capacity.
Carvalho et al. (17)	T	M	20	30-50	2	5	1 km/h	X	Increased concen-trations of bone formation markers and decreased bone reabsorption markers.
Dobkin et al. (51)	T/F	M	30	40	2	6	1.07 m/s		There was no significant difference between LTBWS and training on the floor.
Carvalho et al. (52)	T	M	20	60-70	2	6	1 km/h	X	Increased aerobic capacity.
Effing et al. (53)	T	M	30	50	5	4	0.1 km/h		Positive effects on the healthy functional status – increased quality of life.
Lünenburger et al. (54)	T	R	60	70	NI	NI	0.5-2.5 km/h		Increased degree of co-activation of the tibialis anterior and the gastrocnemius.
Dobkin et al. (55)	T	M	30	40	5	2	1 km/h		Increased body pro-prioception, increased body control.

Table 2- LTBWS protocols and their respective results

continues

Author	Protocol								
	Support	Assistance	Session time (min)	Weight-bearing	Weekly frequency	Period (months)	Speed	FES	Results
Phadke et al. (56)	T/F	M	30	40	1 training session	0.1	0.5 km/h		Increased H-reflex.
Prosser (57)	T	M	20-30	80	3-5	6	0.98 m/s		Increased movement inhibiting factor of lower limbs, walking index increased from 0 to 12.
Domingo, Sawicki e Ferris (58)	T	M	40	30-60	1 training session	NI	0.18-1.07 m/s		The amplitudes and profiles of normalized muscle activity in subjects with spinal cord injury were similar to training with and without manual assistance.
Forrest et al. (65)	T	M	60	60	3	9	0.71 m/s		Decreased total metabolic bone disease, increased lean mass in the lower limbs.
Jayaraman et al. (59)	T/F	M	30	40	5	2	2 -2.8 km/h		Increased muscle size, improved voluntary activation, and the ability to generate torque peak.
Lam et al. (60)	T	R	1				1 -1.9 km/h		Increased proprioceptive input.
Lucareli et al. (66)	T		30	40	2	4	NI		Increased spatiotemporal gait parameters.
Gorassini et al. (67)	T	M		40	5	2	0.2 -0.6 m/s		Increased length of the EMG activity of specific muscles are associated to functional recovery of gait.
Musselman et al. (61)	T	M	60	41	5	3	1 m/s		Increased ability to walk free from obstacles and climbing stairs.
Nooijen, Hoeve e Field-Fote (62)	T/F	M/R	45	30	5	3	2.6-3.2 km/h	x	Improved gait quality.
Phadke et al. (63)	T	M	20	40	1 training session	0.1	1.2 m/s		Depression in the H-reflex significantly increased after training.
Winchester et al. (68)	T	M/R	60	40	3	3	2.5-3 km/h		Prospective prediction of gait speed at 4.15 ± 2.22 cm/s.
Fox et al. (69)	T/F		40		3	12			Improved gait function.

Table 2- LTBWS protocols and their respective results

conclusion

Author	Protocol								
	Sup-port	Assis-tance	Session time (min)	Weight-bearing	Weekly frequency	Period (months)	Speed	FES	Results
Turiel et al. (22)	T	R	60	30-50	5	1.2	2 - 2 . 5 km/h		Improved sensorimotor and diastolic left ventricular functions.
Protas et al. (64)	T	M	20	40	5	3	0.16 km/h		Improved gait in individuals with incomplete spinal cord injury.
Cotie et al. (23)	T	R	60	60	3	1	0.6 km/h		LTBWS increased skin temperature, but there was no significant difference in blood flow of the lower limbs.

Legend: T/F = treadmill or floor; M/R = manual or robotized assistance; T = session time, in minutes; % SP = percentage of partial body weight support by the individual; WF = weekly frequency; S = speed; FES = functional electrical stimulation; NI = not informed.
Source: Research data.

of patients with spinal cord injury were 33 years, contradicting the results obtained in this literature review.

Protocols and results

Based on this literature review, it was found out that LTBWS is a technique which benefits patients with SCIs, regardless of age and injury time.

LTBWS can change the ankle biomechanics, especially in the plantiflexors, influencing gait. A study carried out tests with healthy volunteers (n = 15), and the measures were taken by means of electromyography of leg muscles and kinematic analysis (72). During LTBWS, there was no change in muscle activity at any speed applied (0.4 m/s to 1.6 m/s), with 3 levels of body weight support, 0%, 20%, and 40%. The loss of kinematics of the plantiflexors at high speeds supporting 40% of body weight can compromise motor re-learning in healthy volunteers. These results agree those from another study, which recommends that LTBWS is performed with the minimum percentage of support, generating a gait similar to the healthy pattern (73). These studies showed negative results for the percentage of 40%, however, the results were negative for healthy volunteers, without confirmation of the same event for volunteers with SCI.

The application period of the LTBWS protocol more frequently adopted was over 3 months, however, 12 studies did not report the period of the protocol application. Variability in the duration of training was relatively large (from 1 to 36 months), something which shows the absence of consensus with regard to the time of locomotor training protocol application. Perhaps, the 3-month period is the most used to minimize sampling losses, since long-term studies have limitations regarding such losses, and this fact is routine (74). Also with regard to the training period, an important issue to be taken into account is the weekly frequency, due to the participants' physical fitness their muscle fatigue; in this article, we found out that most researchers opted for the frequency of 5 times per week, and there was no report of muscle fatigue.

Recovering gait is a difficult and costly task, patients are often unable to produce the muscle strength required to keep posture and walk (1). Resuming the ability to walk requires various techniques and it usually demands considerable assistance from the physiotherapist to hold the patient's weight and increase her/his balance. In conventional gait training, often the result does not satisfy the patient, with asymmetrical patterns of movement and, especially, undergoing difficulty to walk through greater distances (75). LTBWS on a treadmill is more effective for training gait skills when compared to locomotor training on the floor (61). A study investigated the effect of LTBWS, and that of the locomotor training on the floor, on the modulation of H-reflex in the soleus muscle of 8 individuals with SCI, finding out that LTBWS helps normalizing the H-reflex, when compared to training on the floor, pointing out that the average amplitude of the H-reflex in the soleus muscle (male/female ratio) was 33% lower in the supporting phase and 56% lower in the balancing phase during gait on a treadmill, and the male/female ratio was significantly higher in the support and balancing phases (p = 0.001 and p = 0.007, respectively), when compared to healthy individuals (63). In contrast, there was a study which found out no conclusion when comparing LTBWS and exercises on the floor with regard to improvement in the functional gait (76).

In the articles analyzed, manual assistance for conducting locomotor training was the most frequently used. A study evaluated LTBWS with traditional gait training for 12 weeks in patients with SCI (n = 146) (76). The tests were carried out with (1) speed, (2) walking distance, and (3) the independence measure for locomotion (FIM-L). The results showed no significant difference between the kinds of training, denoting that all of them have the same results with regard to gait improvements in patients with SCI. The results of another study denote the effectiveness of manual assistance, indicating a high incidence of studies which applied manual assistance (76). An advantage of this assistance is enabling the gait of people with SCI at higher speeds, something which they cannot fulfill without manual assistance (66,58). Conversely, coach's effort is great, thus, robotized locomotor training has been proposed, because with this kind of assistance the coach works less (46), but there is a limitation with regard to the range of motion during the execution of robotized gait, since the orthoses stems are fixed.

It has also been found out that LTBWS constitutes a feasible alternative option for the rehabilitation of patients who underwent stem cell application, due to the neural remodeling caused by repetitive stimulation deriving from locomotor training; however, further research is needed.

LTBWS also shows results going beyond motor mobility, such as those of a study with patients with incomplete SCIs (ASIA C), which evidenced that after 6 months of treatment (3 sessions/week) there was an improvement in the lipid profile with decreased low-density lipoprotein (LDL), increased area of muscle fiber type I and IIa, but it showed no change in body fat mass (45). In patients with incomplete SCI, improved regulation of blood glucose (glucose tolerance) and increased insulin sensitivity have been observed (38).

Although a study claims that LTBWS does not seem to prevent bone density loss both in the acute and chronic phases of SCI (77), the results (Table 2) of this article contradict this assertion, i.e. LTBWS prevents bone density loss in SCI (17,21).

LTBWS also showed decreased energy expenditure, expressed by means of oxygen consumption, from 1.96 to 1.33 mL/kg m^{-1} (66), and a decreased heart rate after training, from 180 to 131 beats/min (39). This leads to less chance of a traumatic event, such as cardiac arrest or shortness of breath during training, as well as less fatigue during and after training (77).

In addition to the traditional benefits, such as musculoskeletal, kinematics, psychological, and cardiorespiratory improvements, LTBWS leads to improved sensory system (sensory and proprioceptive), which works by coordinating motor control, lipid profile, decreased heart rate after training (77), besides improved blood flow in the legs, preventing pressure ulcers (23).

Conclusion

LTBWS leads shown to be feasible for the rehabilitation of patients suffering from a neurological pathology, such as SCI; regardless of the training protocol adopted, the benefits related to increased muscle strength, sustained or increased bone density, decreased heart rate, and increased physical fitness are observed.

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