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REVIEW

Non-pharmacological management of orthostatic hypotension after spinal cord injury: a critical review of the literature

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Study design: Review.
Objectives: Identify and describe the body of literature pertaining to non-pharmacological management of orthostatic hypotension (OH) during the early rehabilitation of persons with a spinal cord injury (SCI).
Setting: Sunnaas Rehabilitation Hospital, Oslo, Norway.
Methods: Search strategy: a comprehensive search of electronic databases and cited references was undertaken. Selection criteria: case studies, parallel group trials and crossover designs using random or quasi-random assignments were considered. Participants with any level or degree of completeness of SCI and any time elapsed since injury were included. Interventions must have measured at least systolic blood pressure (BP), and have induced orthostatic stress in a controlled manner and have attempted to control OH during an orthostatic challenge. Data collection and analysis: studies were selected, assessed and described qualitatively. Meta-analysis was deemed inappropriate.
Results: Four distinct non-pharmacological interventions for OH were identified: application of compression and pressure to the abdominal region and/or legs, upper body exercise, functional electrical stimulation (FES) applied to the legs and biofeedback. Methodological quality varied dramatically between studies. Compression/pressure, upper body exercise and biofeedback therapies have proven inconclusive in their ability to control OH. During orthostatic challenge, FES consistently attenuates the fall in BP; however, its clinical application is less well established.
Conclusions: The clinical usefulness of compression/pressure, upper body exercise and biofeedback for treating OH has not been proven. FES of the legs holds the most promise.
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Introduction

Rehabilitation from spinal cord injury (SCI) is often complicated by orthostatic hypotension (OH). More than half of all patients will develop OH within the first month following an SCI.[1] Symptoms may present in as many as 73.6% of all physiotherapy treatments during early rehabilitation from SCI.[2]

The most commonly cited definition of OH was put forth by The American Autonomic Society in 1996.[3] The definition requires a clinician to observe at least a 20/10 mm Hg reduction in systolic/diastolic blood pressure (BP) within 3 min of standing, or after being raised greater than 60° on a tilt table, regardless of symptom presentation.

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The most common symptoms of OH observed by the reviewing authors and/or cited in the literature include; fatigue,[3] weakness,[3] light headedness,[3,4] dizziness,[3,4] blurred vision[3] and neck pain.[3,5] Overcoming the multifactorial orthostatic reaction[4] may allow stabilized SCI patients in early rehabilitation to achieve earlier mobility and progress more quickly through rehabilitation.[6] Accordingly, various management strategies have been developed, including functional electrical stimulation (FES) of the lower limbs,[7–12] application of compression/pressure devices to abdominal and leg regions,[13–15] various types of exercise[6,16] and biofeedback.[17,18]

Despite the growing body of literature, a critical review of each intervention's effectiveness has yet to be reported. The primary objective of this review is to identify and critique the body of literature pertaining to non-pharmacological management strategies of OH during SCI rehabilitation. The reviewing authors suggest that the interventions considered herein are most applicable to those patients in early rehabilitation who no longer experience acute spinal shock.

Methods

Data search
A comprehensive literature search of electronic databases and cited references was undertaken. The electronic search included MEDLINE/PubMed (1966 to April 2007), OVID-EMBASE (1980 to April 2007) and CENTRAL (issue 1, 2007). All references were retrieved and scanned for relevant citations to expand the data set. All titles and abstracts retrieved were then assessed against inclusion criteria. A log was maintained of all articles with reasons provided for any exclusion.

Study selection based on topic-related criteria
This review considered case studies, parallel group trials and crossover designs using random or quasi-random assignments. All studies must have been published in the English language. Study participants of any age or gender, with any level or completeness of SCI were included. No restrictions were placed on time elapsed since injury. Studies must have measured at least systolic BP under controlled and experimental conditions. Interventions were required to be applicable during rehabilitation from SCI to induce orthostatic stress in a controlled manner, to attempt to control OH during an orthostatic challenge and to be non-pharmacological in nature. Modifications in diet (that is, salt and water intake) were considered to be beyond the scope of this review.

Description of selected studies
Whenever possible, data describing the effect of an OH intervention on systolic and diastolic BP, patient perception and heart rate (HR) were extracted with the intent of drawing comparisons with a controlled condition. Additionally, the Downs and Black[19] checklist was used to describe the methodological quality of included references. The Downs and Black[19] checklist is suitable for assessing both randomized and non-randomized studies of health care interventions.

Data analysis
Owing to the clinically diverse nature of OH interventions identified in this review, coupled with an under reporting of central tendency measures, statistical comparison (meta-analysis) was deemed inappropriate. Instead, descriptive comparisons are drawn below. The effectiveness of each intervention is outlined in Tables 2–6.

Results

Results of search strategy
The search strategy identified 115 potentially relevant references. Of these, 100 were identified using the electronic search strategy. The remaining 15 were identified using a cited reference search of primary articles. Screening of the titles and abstracts eliminated the vast majority of these, leaving 34 potentially relevant references. Of these 34, 19 did not meet the initial inclusion criteria. Further review of the remaining 15 references identified the possibility that two references[20,21] may have reported findings that had been derived from previously published experiments.[16,7] Suspicions of one study[20] were subsequently confirmed by an American Physiological Society investigation. To avoid the possibility of double counting participants and unfairly weighting results from these authors, the two studies in question[20,21] were excluded from this review. A total of 13 references were included for review.[6–18]

Participants
Detailed participant information is displayed in Table 1. A total of 138 participants with SCI were enrolled, seven of whom were female. Mean ages ranged from 29 to 41 years. The mean time since injury was reported in nine studies, of which four recruited acute patients 3–9 weeks postinjury,[6,10,12,13] and 5 studies recruited chronic patients 77 months to 12 years postinjury.[7,8,12,14,16,17] Sixty-four percent (89/138) of participants had cervical lesions and 36% (49/138) had thoracic lesions.

Interventions
Systematic review of the literature identified the following four distinct non-pharmacological interventions for OH: application of compression and pressure to the abdominal region and/or legs,[13–15] upper body exercise[6,16] FES applied to the legs[7–12] and biofeedback.[17,18]

The effectiveness of each compression/pressure intervention is detailed in Table 2. The use of an abdominal corset[13] and leg splints[13] attenuated the fall in BP through 45° of head-up tilting (HUT) versus control conditions; however, HR increased similarly across all conditions. The application of a gait harness during sitting significantly ($P<0.05$) increased diastolic BP, but caused no change in systolic BP or HR.[14] The addition of an anti-g-suit through 60° of HUT significantly ($P<0.005$) attenuated the fall in BP and the rise in HR versus control conditions.[15]

The effects of FES during an orthostatic challenge are presented in Table 3. When OH was induced using a controlled HUT,[8,10,12] FES consistently attenuated the fall in BP. However, one study[9] reported an increase in systolic BP during both the controlled and experimental HUT. When the easy stand system was used to induce OH, the fall in BP was also attenuated after FES application versus control conditions.[7] When lower body negative pressure was used to induce OH, BP rose during the control condition and rose again during FES application.[11] The effect of FES application on HR during orthostatic challenge was not clear. Four studies observed no change, or a decrease in HR versus controls,[7–9,11] and two observed an increase.[10,12]

The effects of exercise on OH are presented in Table 4. Maximal arm cranking exercise performed 24 h before a 70° HUT test significantly ($P=0.017$) attenuated the fall in

Table 1 Participant information by OH intervention

Reference	*N (138)*	*Mean (± s.d.) age*	*SCI classification*	*Mean (s.d.) time since injury*
Compression/pressure				
Huang *et al.*[13]	27	32 (13)	27 cervical	47 (22) days
Krassioukov and Harkema[14]	12	31.8 (11.3)	6 cervical, 6 thoracic	5.8 (8.3) years
Vallbona *et al.*[15]	17	16–43 (range)	12 cervical, 5 thoracic	3–48 months
Functional electrical stimulation				
Chao and Cheing[8]	16	37.3 (13.78)	16 cervical	118.87 (104.2) months
Davis *et al.*[9]	8	32.4 (2.7)	8 thoracic	—
Eldoka *et al.*[10]	5	29 (4.3)	2 thoracic, 3 cervical	3 (0.7) weeks
Faghri *et al.*[7]	14	35 (9)	7 thoracic, 7 cervical	77.3 (64.4) months
Raymond *et al.*[11]	8	41.3 (6.5)	8 thoracic	3–39 years
Sampson *et al.*[12]	6	30.3 (11.8)	5 cervical, 1 thoracic	Acute: 8.6 (1.1) weeks Chronic: 12 (2) years
Exercise				
Engelke *et al.*[16]	10	36 (4) s.e.	10 thoracic	118 (21) months
Lopes *et al.*[6]	12	26–54	11 cervical, 1 thoracic	7.7 weeks
Biofeedback				
Brucker and Ince[17]	1	31	1 thoracic	3 years
Ince[18]	2	23–32 (range)	2 cervical	15–18 months

Abbreviations: OH, orthostatic hypotension; SCI, spinal cord injury.

Table 2 compression and pressure interventions versus no treatment

Outcome measure	*Huang et al.*[13]		*Krassioukov and Harkema*[14]	*Vallbona et al.*[15]
Control				
OH	0–45° HUT		Harness application during passive sitting	60° HUT
BP in mm Hg (SBP/DBP)	Fell from 113/71 to 77/52		Cervical—86/54 Thoracic—106/65	81/49
Patient perception	—		—	—
HR (b.p.m.)	Rose from 70 to 94		—	92
Intervention				
OH intervention	Corset 0–45°	Leg splints 0–45°	Sitting with harness	Anti-g-suit
BP in mm Hg (SBP/DBP)	Fell from 114/71 to 101/69	Fell from 113/72 to 94/62	Cervical—99/*65 Thoracic—111/*77	105/71
Patient perception	—	—	—	—
HR in b.p.m.	Rose from 74 to 90	Rose from 72 to 86	No significant change in HR	82

Abbreviations: BP, blood pressure; b.p.m., beats per minute; DBP, diastolic BP; HR, heart rate; HUT, head-up-tilting; OH, orthostatic hypotension; SBP, systolic BP. *Significant difference ($P<0.05$).

systolic BP versus a control condition, while HR rose similarly under both conditions. Alternatively, reciprocal bilateral elbow flexion during HUT over 10 sessions facilitated the fall in BP versus a control condition.[6]

The effects of biofeedback training on systolic BP are presented in Table 5. Two case studies using similar biofeedback protocols were able to greatly attenuate the fall in systolic BP during orthostatic challenge.[17,18]

A comparison of each intervention is presented in Table 6. Biofeedback interventions caused the greatest attenuation in the fall of BP, followed by compression/pressure, maximal exercise 24 h before HUT and FES. The results from two studies were not included in this comparison, because the percentage change in BP due to an intervention could not be determined.[6,9]

Discussion

The aim of this review was to objectively identify and critique the body of literature pertaining to non-pharmacological management of OH during rehabilitation from SCI. Key findings are critically discussed below by intervention.

Compression/pressure interventions for OH

Four distinct compression interventions were identified in this review, including leg splints, anti-g-suit, abdominal corset and gait harness.

Pneumatic leg splints pressurized to 65 mm Hg significantly ($P<0.01$) attenuate the fall in BP during orthostatic challenge in acute patients with cervical lesions C5-7.[13] Although this finding added credibility to the earlier insights

Table 3 FES of the legs interventions versus no treatment

Outcome measure	Chao and Cheing[8]	Davis et al.[9]	Elokda et al.[10]	Faghri et al.[7]	Raymond et al.[11]	Sampson et al.[12]
Control						
OH	0–90° HUT	0–70° HUT	0–60° HUT	Sit to stand	LBNP	0–90° HUT
BP in mm Hg (SBP/DBP)	Fell from 105/66 to 85/57	Rose 9–15	Fell from 118/70 to 90/60	Fell from 108/75 to 99/68	Rose from 123/72 to 129/ 76	Fell from 115/65 to 92/56
Patient perception	75% report symptoms at 90°	—	—	—	—	—
HR mean (b.p.m.)	Rose from 65 to 86	Rose from 73 to 96	Rose from 74 to 105	Rose 20%[a]	Rose 5–6 b.p.m.	Rose from 70 to 96
Intervention						
OH intervention	FES+0–90°HUT	FES+ HUT	FES+HUT	FES+sit to stand	LBNP+FES	HUT+FES
BP in mm Hg (SBP/DBP)	Fell to 93/59	SBP rose > 9–15	Fell to 98/61	109/78	132/78	100/65
Patient perception	46% report symptoms at 90°	—	—	—	—	—
HR mean (b.p.m.)	82	Fell 4–12	112	Rose 10%[a]	No change	115

Abbreviations: BP, blood pressure; b.p.m., beats per minute; FES, functional electrical stimulation; HR, heart rate; HUT, head-up tilting; LBNP, lower body negative pressure; OH, orthostatic hypotension; SBP, systolic BP; DBP, diastolic BP.
[a]Absolute values were not published by the original authors.

Table 4 Exercise interventions versus no treatment

Outcome measure	Engelke et al.[16]	Lopes et al.[6]
Control		
OH	70° HUT	10 sessions of 70° HUT
BP in mm Hg (SBP/DBP)	SBP fell from 118 to 106, or 10% ($P=0.025$). DBP not altered.	Only the mean BP at termination angle for 10 sessions of 70° HUT could be determined (122/70)
Patient perception	—	—
HR mean (b.p.m.)	Rose by 29 b.p.m. ($P<0.001$)	Mean HR at termination angle for 10 sessions of 70° HUT was 63
Intervention		
OH Intervention	maximal exercise 24 h before 70° HUT	Upper arm exercise+70° HUT (10 sessions)
BP in mm Hg (SBP/DBP)	SBP fell from 116 to 113, or 2.5%. DBP not altered	Only the mean BP at termination angle for 10 session of 70° HUT could be determined (117/76)
Patient perception	—	—
HR mean (b.p.m.)	Rose by 30 b.p.m. ($P<0.001$)	Mean HR at termination angle for 10 sessions of 70° HUT was 67

Abbreviations: BP, blood pressure; b.p.m., beats per minute; DBP, diastolic DP; HR, heart rate; HUT, head-up tilting; OH, orthostatic hypotension; SBP, systolic BP.

Table 5 Biofeedback interventions versus no treatment

Outcome measure	Brucker and Ince[17]	Ince[18]
Control		
OH	Sit to stand	Lowering legs
BP in mm Hg (SBP/DBP)	SBP fell to 50 mm Hg after 2 min of standing	C2/3—fell from 110/70 to 75/40 C5—fell from 101/62 to 85/60
Patient perception	—	—
HR mean (b.p.m.)	—	—
Intervention		
OH intervention	Biofeedback	Biofeedback training
BP in mm Hg (SBP/DBP)	SBP fell to 88 mm Hg after 5 min of standing	C2/3—was able to raise and maintain SBP 120 C5—raised and maintained SBP between 110 and 120
Patient perception	—	—
HR mean (b.p.m.)		

Abbreviations: BP, Blood pressure; b.p.m., beats per minute; DBP, diastolic BP; HR, heart rate; HUT, head-up tilting; mm Hg, millimeters of mercury; OH, orthostatic hypotension; SBP, systolic BP.

of Ragnarsson[22] who suggested in 1975 that a pneumatic orthosis may well reduce the tendency for OH in patients with SCI, few studies have since provided validation. In fact, findings by Hopman *et al.*[23] provided an alternate view point. After assessing the effectiveness of anti-embolism stockings on blood redistribution in persons with chronic quadriplegia ($n=5$) and paraplegia ($n=4$) during seated exercise, Hopman *et al.*[23] concluded that the stockings had an insignificant effect on BP. It is, however, likely that the disparity can be attributed to the lower pressure used in Hopman's stockings (10–30 mm Hg)[23] versus Huang's leg splints (65 mm Hg).[13] In any case, Hopman's research raises interesting questions that have not been addressed concerning the dose–response relationship between the pressure applied to the lower body and the gain in orthostatic tolerance.

In 1963, Vallbona *et al.*[15] published findings from a sample of 12 participants (all male) with quadriplegia and five participants (two women) with paraplegia who wore an anti-g-suit through 60° of HUT. During the orthostatic challenge,

Table 6 Comparison of % BP changes between all interventions

Intervention (reference)	*Percentage and actual (mm Hg) attenuation of systolic BP fall with orthostasis*	*Percentage and actual (mm Hg) attenuation of diastolic BP fall with orthostasis*
Leg splints (Huang *et al.*)[13]	12%** (16 mm Hg) at 20°	11%** (5 mm Hg) at 20°
	23%** (17 mm Hg) at 45°	24%**(10 mm Hg) at 45°
Abdominal corset (Huang *et al.*)[13]	11%** (16 mm Hg) 20°	0 at 20°
	18%* (23 mm Hg) 45°	16%* (17 mm Hg) at 45°
Gait harness (Krassioukov and Harkema)[14]	0% (thoracic)	20%* (thoracic)
	15% (cervical)	20%* (cervical)
Anti-g-suit (Vallbona *et al.*)[15]	Rose 22%** (24 mm Hg)	30%** (30 mm Hg)
FES (Chao and Cheing)[8]	8.6% (8 mm Hg)	3% (1 mm Hg)
FES (Davis *et al.*)[9]	Rose >9–15 mm Hg	Rose >9–15 mm Hg
FES (Elokda *et al.*)[10]	7%* (8 mm Hg)	1% (2 mm Hg)
FES (Faghri *et al.*)[7]	9% (11 mm Hg)	0
FES (Raymond *et al.*)[11]	2% (3 mm Hg)	2% (2 mm Hg)
FES (Sampson *et al.*)[12]	8% (8 mm Hg)	13% (11 mm Hg)
Maximal exercise (Engelke *et al.*)[16]	7.5% (9 mm Hg)	—
Upper body exercise (Lopes *et al.*)[6]	Unable to determine	Unable to determine
Biofeedback (Brucker and Ince)[17]	43% (38 mm Hg)	—
Biofeedback (Ince)[18]	Approximately 34% (range: 30–45 mm Hg)	—

Abbreviations: BP, Blood pressure; b.p.m., beats per minute; DBP, diastolic BP; HR, heart rate, HUT, head-up tilting; OH, orthostatic hypotension; SBP, systolic BP.
**significant at $P<0.01$; *significant at $P<0.05$.

systolic and diastolic BP significantly increased ($P<0.005$) compared to BP observed during 60° HUT with no anti-g-suit.[15] The anti-g-suits' effectiveness became more apparent when it was deflated at 60° HUT. The authors observed an abrupt fall in both systolic and diastolic BP by 19 and 11 mm Hg, respectively, followed by a compensatory rise in HR. Adding support to these findings, Pitetti *et al.*[24] assessed the effectiveness of an anti-g-suit (pressurized to 50–75 mm Hg) during seated exercise in eight persons with chronic quadriplegia and two with paraplegia. Although OH was not induced and systolic/diastolic BP not reported, a significantly higher ($P=0.042$) cardiac output was observed when the anti-g-suit was worn. The authors concluded that the anti-g-suit augmented exercise capacity by preventing the redistribution of blood to the lower extremities. This finding was subsequently supported by Hopman *et al.*[23] who found a significant increase ($P<0.01$) in systolic/diastolic BP when an anti-g-suit was worn during seated exercise, although an orthostatic challenge was not imposed.

Descriptions of abdominal binders began to rise in the years following Vallbona's investigation of the anti-g-suit in 1963.[15] In 1968, McCluer[25] described the characteristics of a cloth abdominal binder that was purported to serve as a temporary method of controlling OH in patients with quadriplegia. One year later, Jones and Burniston[26] improved upon McCluer's design by describing a more durable, inflatable plastic splint. However, as with McCluer's design, Jones' new model was recommended out of clinical experience rather than systematic experimentation. Nearly 13 years later, Huang *et al.*[13] provided evidence that an abdominal corset could significantly ($P<0.01$) attenuate the fall in BP during orthostatic challenge in acute patients with cervical lesions at C5-7. However, Huang *et al.*[13] described six patients who were unable to complete the study due to symptoms of OH, even with the support of abdominal compression. Similarly, in 1986 Goldman *et al.*[27] evaluated the effect of abdominal binders on breathing in persons with chronic quadriplegia and found that three out of seven participants could not tolerate HUT greater than 50°, despite wearing an abdominal belt. Furthermore, in 1995, the evaluation of an abdominal binder, by Kerk *et al.*,[28] during exercise in highly trained athletes with paraplegia (T3-6) failed to find a significant effect on cardiovascular variables during sub-maximal and maximal exercise. Disconcertingly, symptoms of OH seem to persist despite abdominal compression, as evidenced by Huang *et al.*,[13] Goldman *et al.*[27] and Kerk *et al.*[28] Until further research is conducted to validate the findings of Huang *et al.*,[13] a definitive answer regarding the abdominal binders' effectiveness in both reducing the fall in BP and perceived symptoms of OH during orthostatic challenge remain elusive.

Application of a gait harness during sitting significantly improved ($P<0.05$) diastolic, but not systolic BP in persons with chronic cervical and thoracic SCI.[14] However, participants were not moved from supine to sitting or from sitting to standing, so the effectiveness of the gait harness in controlling OH with position change could not be determined.

Functional electrical stimulation interventions for OH

When OH was induced under control conditions, BP (systolic/diastolic) fell on average from 114/72 mm Hg to 89/58 mm Hg; however, when FES was applied, systolic BP only fell to an average of 97/62 mm Hg (Table 3).[7,8,10–12]

Interpretation of these results requires a discussion of variations between each FES study. Between and within studies, participant groups varied substantially in lesion level (range: C3–T12) and completeness of injury. Only a minority of references classified participants using the American Spinal Injury Association (ASIA) impairment scale.[8,12] Several references combined participants with high and low levels of spinal cord lesions.[10,12] Time since injury varied dramatically from 3 weeks to 12 years.

A further source of variation was found in the electrical stimulation protocol. Many references frequently adjusted FES intensity to achieve a visible contraction. It is interesting to note that a dose–response relationship between FES intensity and BP response has been established by Sampson *et al.*[12] in 2000. Additional variation was found in the number of electrodes used, which ranged between two and four per participant and the electrode placement; however, it has been suggested that the latter may be less relevant an issue.[12]

The equipment used to induce OH adds an additional source of variation. Use of a lower body negative pressure chamber has poor external validity, but more importantly, its ability to induce OH is questionable. When Raymond *et al.*[11] used lower body negative pressure to induce OH, participant systolic, diastolic and mean arterial BP slightly increased from resting values. Alternatively, the use of an easy-stand system by Faghri[7] seems to possess a higher external validity than the pressure chamber of Raymond *et al.*[11]; however, when participants assume an upright position the easy-stand system features an abdominal pad that may apply pressure to the splanchnic area. This added pressure may confound comparisons of BP response between subject of different heights, and also in comparison with other methods that induce OH. A tilt table was used to induce OH in the majority of references; however, the tilting protocol varied between references in terms of the time spent at each angle of HUT, the absolute angle achieved and the increments between each tilt angle.

Despite variations in experimental protocols, FES has consistently proven to attenuate the fall in BP by approximately 8/4 mm Hg during an orthostatic challenge under experimental conditions. However, its clinical application in early SCI rehabilitation is less evident due to heavy reliance upon chronic[7,8,11,12] versus acutely[10,12] injured study participants.

Exercise interventions for OH

Two distinct exercise interventions were identified in this review, including low intensity upper body exercise[6] and maximal upper body exercise.[16] When participants (T1-L2) undertook low intensity upper body exercise during HUT, they were unable to cope as well as when they were tilted without exercise. The authors intuitively attributed the lower BP in the experimental group to vasodilation and a normal response to continuous exercise. However, both groups significantly increased their orthostatic tolerance from the first to the 10th training session. The increases in orthostatic tolerance appeared to be hindered by upper body exercise and facilitated by repeated tilting. In fact, the beneficial effects of tilting therapies in persons with SCI have been documented as early as 1969.[29] The study by Lopes *et al.*[6] more effectively validates repeated tilting, and not continuous exercise, as an intervention for OH in persons with SCI.

A single bout of maximal upper body exercise eliminated OH without affecting HR response during a HUT test 24 h after maximal exercise was undertaken.[16] Despite the combined analysis of persons with both upper and lower thoracic SCI, an appreciable difference was observed in the experimental group. Unfortunately, only a range of individual patient lesion levels were provided (T1-12). These findings may be more applicable in persons with low-level paraplegia, where more of the sympathetic outflow that regulates BP remains intact and a larger motor functionality is present. The applicability of maximal arm cranking ergometry as an intervention for OH during early rehabilitation of SCI declines as the lesion level increases due, in large part, to a loss in motor functionality with higher lesions.

Despite these findings, certain types of exercise may yet prove useful as an intervention for combating OH. For example, Petrofsky[30] investigated BP and HR responses to isometric hand grip exercise in persons with high and low thoracic SCI and found a linear increase in systolic and diastolic BP among all participants. Future research may focus on the effect of isometric exercise during orthostatic challenge in persons with SCI.

Biofeedback interventions for OH

Three patients from two case studies were taught to raise and lower their BP with the use of visual and auditory feedback.[17,18] In both case studies, the procedure consisted of learning sessions of several weeks where patients were instructed to effect change in their BP without skeletal or respiratory involvement. BP was continuously monitored and reported to the patient with positive verbal reinforcement. OH was induced using a sit-to-stand movement at the end of every session,[17] or by reducing knee extension from 180 to 90°.[18]

Biofeedback interventions produced an average increase of 39% in systolic BP versus control conditions. The evidence provided by the case study of Brucker and Ince[17] demonstrated one patients' ability (lesion level at T3) to increase his BP willingly when seated; however, its effect during orthostatic challenge remains questionable. Out of 11 sessions where the patient moved from a sitting to a standing posture, with and without attempts to increase BP, only data from the ninth training session were presented. It might be considered, however, that the passage of time itself, during the training period, might have modified the response to orthostasis. However, evidence provided by Ince[18] lends support to the findings of Brucker in that patients with high level SCI (above T6) may be able to produce marked increases in BP with biofeedback training.

Commenting on the definition of OH

The current definition of OH as provided by The American Autonomic Society requires at least a 20/10 mm Hg reduction in systolic/diastolic BP within 3 min of standing, or after being raised greater than 60° on a tilt table, regardless of symptom presentation.[3] However, the presence or absence of symptoms can influence patient participation in daily rehabilitation.

For example, in some patients visual signs and perception of OH (that is, syncope) may occur before BP falls to its predefined level of 20/10 mm Hg.[2] These patients may be unable to take part in rehabilitation; but, OH would not be diagnosed. Additionally, some patients may experience a large fall in BP before reaching 60° of HUT. These patients would also remain undiagnosed. Knowing this, many clinicians monitor patient perception of OH rather than BP during mobilization treatments.[2]

Through careful review of the literature, we have identified specific inadequacies with the current definition of OH as set forth by the American Autonomic Society.[3] The reviewing authors are in general agreement with recent comments made on the definition;[31] however, we place greater emphasis on patient perception of syncope due to any fall in BP.

Limitations

Some limitations were encountered during the development of this study. The scope of this review was limited to the efficacy of each intervention; thus, ignoring the assessment of equipment costs, training and the clinical time required in performing a given intervention. Also, the Downs and Black[19] scale is in many aspects a subjective tool for assessing methodological quality of both randomized and non-randomized studies. A source of bias may have been introduced when one assessor with minor training in the Downs and Black[19] scale conducted the assessment of methodological quality. Furthermore, the assessor was not an expert in the field of OH and SCI. Another source of bias was introduced when the search strategy was undertaken by only one assessor. However, the impact of this bias was minimized through the use of objective search terms and inclusion criteria. Despite these threats to internal validity, the methodological rigor applied in this critical review is far superior to that of the traditional narrative review; therefore, the findings herein can provide a novel update to the field of SCI rehabilitation.

Conclusions

This literature review identified four classes of interventions for the non-pharmacological management of OH in persons with SCI: compression/pressure applied to the lower limbs and abdominal region, FES applied to the lower limbs, exercise and biofeedback.

Compression and pressure therapies have proven inconclusive in their ability to control OH in persons with SCI. This is not to diminish the significant findings of individual studies, but rather to draw attention to the lack of randomized control trials and validating investigations that are required in an era of evidence-based medicine. The same can be said for the use of exercise and biofeedback interventions for OH.

Despite the variations that exist between FES protocols, two reasonably well-designed, randomized control trials have shown that FES can consistently attenuate the fall in BP during an orthostatic challenge. To this point, however, its clinical application is less well established due to an under-reporting of patient perception during orthostatic challenge and a limited amount of research conducted in acutely injured patients with SCI. The authors of this review feel that it is reasonable to conclude that the use of FES cannot be supported clinically until further research is undertaken using a representative population sample.

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