Effects of thigh and abdominal muscles stimulation and lower limb stockings on the orthostatic hypotension responses in individuals with spinal cord injury

ผลของการกระตุ้นกล้ามเนื้อต้นขาและกล้ามเนื้อท้องและการใส่ถุงน่องขาต่อการตอบสนองกับภาวะความดันโลหิตตกขณะยืนในผู้ที่มีภาวะบาดเจ็บไขสันหลัง

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ABSTRACT

Background: No information comparing the effectiveness of thigh or abdominal muscle stimulation combined with stockings on the orthostatic hypotension responses in patients with spinal cord injury (SCI).

Objective: To compare the effects of three different interventions: lower limb stockings (LLS), thigh muscle stimulation, and a combination of the abdominal muscles stimulation and LLS on mean blood pressure (MBP) and heart rate (HR) during passive standing in patients with SCI.

Methods: A crossover design was used in this study. Thirteen patients with C3 to T1 SCI participated in the study. Participants were randomly tested during passive standing on a tilt table of the following three conditions: (1) the control (CON) using LLS (2) stimulation at the quadriceps and hamstrings (QH), and (3) stimulation at the abdominal muscle combined with LLS (Abd). The MBP and HR were measured at rest, 1 minute, every 3 minutes after tilting-up, and immediately after tilting-down. The tilting time up to 30 minutes was also recorded.

Results: Hypotension and faster HR occurred significantly after tilting-up when compared to resting in all three conditions. However, the MBP ($p=0.19$) and HR ($p=0.43$) after tilting up did not differ significantly among the three conditions. There were no significant differences in tilting time when comparing across these conditions (CON= 24: 06±11: 13; QH= 19: 35±11: 53; and Abd=21:08±11:48 minutes:seconds, $p=0.96$).

Conclusions: Stimulation only at the thigh muscles or the abdominal muscle combined with LLS, or using only LLS does not minimize cardiovascular responses during passive standing in patients with SCI.

Keywords: Blood pressure, Heart rate, Electrical stimulation, Spinal cord injury, Orthostatic hypotension

บทคัดย่อ

ที่มาและความสำคัญ: ไม่มีข้อมูลเปรียบเทียบประสิทธิผลการกระตุ้นกล้ามเนื้อต้นขาหรือกล้ามเนื้อหน้าท้องด้วยไฟฟ้าร่วมกับการใส่ถุงน่องขาต่อการตอบสนองกับภาวะความดันโลหิตตกขณะยืนในผู้ป่วยบาดเจ็บไขสันหลัง

วัตถุประสงค์: เพื่อเปรียบเทียบผลของการรักษาสามแบบ: การใช้ถุงน่องขา, การกระตุ้นกล้ามเนื้อต้นขา และการกระตุ้นกล้ามเนื้อหน้าท้องร่วมกับการใช้ถุงน่องขาต่อค่าเฉลี่ยความดันโลหิต และอัตราการเต้นของหัวใจในผู้ป่วยบาดเจ็บไขสันหลังขณะยืนบนเตียงปรับประดับ

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วิธีการวิจัย: การศึกษานี้ใช้รูปแบบ crossover ผู้เข้าร่วมการศึกษาเป็นผู้ป่วยบาดเจ็บไขสันหลังระดับ C3 ถึง T1 จำนวน 13 คน ผู้ป่วยถูกสุ่มเพื่อรับการรักษาสามแบบขณะยืนบนเตียงปรับประดับ คือ (1) กลุ่มควบคุม (CON) ใส่ถุงน่องขา (2) กลุ่มทดลองได้รับการกระตุ้นกล้ามเนื้อต้นขาด้านหน้าและด้านหลังด้วยไฟฟ้า (QH) และ (3) กลุ่มทดลองได้รับการกระตุ้นกล้ามเนื้อหน้าท้องส่วนล่างร่วมกับการใส่ถุงน่องขา (Abd) ทำการบันทึกค่าเฉลี่ยความดันโลหิต (MBP) และอัตราการเต้นของหัวใจ (HR) ขณะพัก นาทีที่ 1 และทุก 3 นาที หลังจากปรับระดับเตียงให้ตั้งขึ้น และทันทีหลังจากปรับเตียงลงในแนวราบ

ผลการวิจัย: หลังจากปรับระดับเตียงให้ตั้งขึ้น พบภาวะความดันโลหิตต่ำ และอัตราการเต้นหัวใจเพิ่มสูงขึ้นเมื่อเทียบกับขณะพักเมื่อให้การรักษาทั้งสามแบบ อย่างไรก็ตาม ค่า MBP (p=0.19) และ HR (p=0.43) ขณะยืนบนเตียงปรับระดับไม่มีความแตกต่างกันระหว่างการรักษาทั้งสามแบบ ระยะเวลาที่อาสาสมัครยืนบนเตียงปรับระดับ ไม่แตกต่างกันเมื่อเทียบระหว่างการรักษาทั้งสามแบบ (CON=24:06±11:13; QH=19:35±11:53; และ Abd=21:08±11:48 นาที:วินาที, p=0.96)

สรุปผล: การกระตุ้นเฉพาะกล้ามเนื้อต้นขาด้วยไฟฟ้า หรือการกระตุ้นกล้ามเนื้อหน้าท้องร่วมกับการใส่ถุงน่องขา หรือการใส่เพียงถุงน่องขาไม่สามารถช่วยลดการตอบสนองการทำงานของหัวใจและหลอดเลือดที่เกิดขึ้นเมื่อผู้ป่วยบาดเจ็บไขสันหลังยืนบนเตียงปรับระดับ

คำสำคัญ: ความดันโลหิต อัตราการเต้นหัวใจ การกระตุ้นด้วยไฟฟ้า บาดเจ็บไขสันหลัง ความดันโลหิตตกขณะยืน

Introduction

Standing is an integral part of initial rehabilitation in individuals with spinal cord injury (SCI).[1] There are several benefits from standing such as reduced muscle tone, improved bowel function, and weight-bearing to prevent bone loss.[1] Most of the studies use passive standing on a tilt-table with 30-60 minutes standing times.[1] However, there are potential risks of lower limb fracture from bone demineralization and orthostatic hypotension (OH) that must be taken for standing treatment in SCI.[2-4]

In general, 74% of patients with SCI reported OH during sitting or standing positions.[2] This hypotension can be related to many physiological factors[5-12] such as the imbalance of sympathetic and parasympathetic activity[8], alteration of baroreceptor sensitivity[7,10], lack of skeletal muscle pumping activity[6,11,12], cardiovascular deconditioning[5], and others.[5-12] The symptoms of OH may discourage individuals with SCI from participating in activity daily living and rehabilitation.

Management of OH consists of pharmacological and non-pharmacological interventions such as lower limb stocking, abdominal binder, and neuromuscular electrical stimulation (NMES).[13] However, there was insufficient evidence for the effect of lower limb stocking and abdominal binder on cardiovascular responses to orthostasis in SCI.[13] From the meta-analysis, neuromuscular electrical stimulation (NMES) is the only non-pharmacologic treatment that showed some evidence in improving OH during upright position.[14] NMES has been used to reduce OH and increase standing time on a tilt table in patients with SCI.[11,12,15-17] Usually, the stimulation sites were quadriceps, hamstrings, gastrocnemius, and tibialis anterior during passive standing.[11,15,18,19] A single study reported a non-

significant difference in blood pressure (BP) when stimulated at the abdominal muscles or the lower limb muscles (quadriceps, hamstrings, and gastrocnemius), or through a combination of the abdominal and lower limb muscles when compared with a control during passive standing in patients with SCI.[20] There was no information about the electrode position for abdominal muscle stimulation in this single study.[20]

The transversus abdominis is one of the deep abdominal muscles which related to changes in intra-abdominal pressure, affected the venous return and BP.[21,22] To our knowledge, there is no information comparing the effectiveness of thigh muscle stimulation or abdominal muscle stimulation combined with stockings on the cardiovascular responses in patients with SCI. Considering this lack of evidence, this study sought to test the minimum number of stimulated muscles that could reduce the drop of blood pressure and allowed patients with SCI to stand on a tilt table for a longer duration.

This present study aimed to compare the effects of three interventions: a) the control condition using only lower limb stockings (CON), b) stimulation of quadriceps and hamstrings (QH) and c) stimulation of transversus abdominis muscles combined with lower limb stockings (Abd) on mean blood pressure (MBP), and heart rate (HR), and tilting time in patients with SCI. We hypothesized that the contraction of muscles in the QH or Abd condition might reduce hypotension during passive standing on a tilt table. Another consideration directing this study was using two-channel stimulators which provide co-contraction of muscles in each leg but not fully synchronized in both legs. If the two-channel stimulator approach is effective, it may be more readily available than a four-channel stimulator in the clinical setting.

Methods

Study design

A crossover design was used in this study. Patients were systematically random and tested in all conditions to counter any physiological factors affecting OH. The experiment was performed at the Rehabilitation Ward, Maharaj Nakorn Chiang Mai Hospital, Chiang Mai. This study was approved by the Ethics Committee of the Faculty of Medicine, Chiang Mai University (NONE-2557-02489). All patients could communicate and sign their signatures or fingerprints on the written informed consent before participating in the study. We certified that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

Participants

The sample size was calculated using the G*Power 3.1.9.4, based on a study design F-test, ANOVA: repeated measures, within-between interaction, with the effect size f=0.25, the level of significance of 0.05, and the power of 0.95. A total sample size was 39 (13 in each group). Thirteen individuals with traumatic SCI at C3 to T1 were recruited into this study. The inclusion criteria were ASIA impairment scale (AIS) A, B, or C; duration post-injury less than 5 months. Some

patients had tilt table standing treatments prior to the study recruitment and all of them had symptoms of OH such as dizziness or syncope while in a standing position. Patients were excluded if they had any cardiovascular problems, menstruation issues, or had a history of autonomic dysreflexia (AD). Any conditions that could trigger AD such as pressure ulcers, urinary tract infection, and heterotopic ossification were also excluded. The demographic data of all patients are presented in Table 1. A physiatrist's approval was required before commencing the passive standing treatment. All patients had no contraindications from using NMES. Their bladders were empty before commencing the procedures.

Table 1 Characteristics of study participants with traumatic spinal cord injury (n=13)

ID	Sex	Age (years)	Weight (kg)	Height (cm)	Lesion Level	AIS	Time since injury (day)
1	M	49	59.0	170	C4	A	65
2	M	44	58.0	168	C6	B	83
3	M	54	54.7	170	C3	B	56
4	M	23	60.3	165	C4	A	52
5	M	51	73.0	176	C4	A	75
6	M	22	47.3	175	C4	B	33
7	F	63	66.0	155	C4	B	49
8	M	57	61.0	168	C4	B	28
9	M	60	46.2	164	C5	B	27
10	M	58	51.5	172	C5	C	56
11	M	49	56.3	155	C3	A	123
12	M	56	58.0	175	C4	C	42
13	M	18	48.1	175	T1	B	72
Mean	-	46.46	56.88	168.31	-	-	58.54
sd	-	15.40	7.61	7.05	-	-	26.22

Note: AIS, American Spinal Injury Association (ASIA) Impairment Scale; F, Female; M, Male.

Termination criteria

The study would be terminated in the advent of a systolic and diastolic BP (SBP and DBP) of lower than 60 and 40 mm Hg[19], respectively. A self-perceived pre-syncope score of zero to four (0, no symptoms; 1, mild; 2, moderate; 3, severe symptoms; 4, syncope) was recorded. [19] A tilting trial was terminated if a patient-reported a pre-syncope score that was equal to three. [19] Any symptoms of AD such as a sudden increase in BP, severe pain in the neck and shoulder, headache, perspiration, or vomiting also led to study termination.

Measurement of MBP and HR

The SBP, DBP and HR were measured using an automated blood pressure cuff equipped with a pulse monitor on the left brachial artery (Omron® HEM-7117, Japan). The left upper arm was held at the heart level during the BP measurement.[19] All participants were in a supine position on a tilt table for at least 20 minutes before starting the BP measurement. The resting BP was measured at least three times. If the SBP or DBP varied more than 5 mmHg, measurements were repeated. All parameters were monitored at rest, 1 minute, 3, 6 and every 3 minutes after tilting-up,[23] and immediately after tilting down to the horizontal level. MBP was calculated from the SBP and DBP using the equation MBP= (SBP+ 2DBP)/3.[24] Changes of MBP have been reported as the most significant predictor of future cerebral blood flow in older adults.[25]

Intervention

All participants were tilted on an electronic tilt table (V.S. Engineering®) (speed 30 degrees in 24 seconds) in three different conditions: 1) the control condition which involved using only a pair of lower limb stockings (CON), 2) stimulation on both sides of the quadriceps and hamstrings (QH), and 3) stimulation at the transversus abdominis (Abd) while wearing a pair of lower limb stockings (Tubigrip®).

The angle of tilting was progressively set from 0° to 30° for 3 minutes (at 1 and 3 minutes), then was tilted from 30° to 45° for 15 minutes (at 6, 9, 12, 15, and 18 minutes) (see an X-axis in Figure 1 and 2). Each patient was tilted to either 45° or 60° (at 21, 24, 27, and 30 minutes) depending on the patient's condition. However, two subjects were tilted up to only 30° because of their resting BP being rather low (at about 95/60 mm Hg). Therefore, we did not test them at a more progressive angle. The maximum tilting time was 30 minutes, or until the BP or syncope score approached the termination criteria. Each condition was performed at about the same time, either in the morning or in the afternoon, on three separate days. Most of the patients were tested in three consecutive days or within five days from the starting day. The order of conditions was set by systematic random sampling; thus, each condition was tested equally on the first and second days of the experiment. Therefore, the effect of the previous intervention was balanced. It was found that there were no significant changes of BP from 0 to 40 sessions of locomotor training within the patients with cervical SCI.[26] Thus, the washout period of one day is sufficient to eliminate carryover effects because only a few treatments of standing on a tilt table in patients with SCI did not result in a significant change in BP.

Electrical stimulation

Two portable electrical stimulators (MediHighTec®, MH8000, Taiwan) with a biphasic pulsed current were used. The pulse duration was set at 300 μsec, with a current frequency of 35 Hz,[20] and on and off time of 10 seconds.[27] The current amplitude was about 1-1.5 times the motor threshold which provided a strong contraction of stimulated muscles. Self-adhesive electrodes (ENRAF-NONIUS entrode 50x90 mm) were placed on the pre-determined motor points of the rectus femoris and vastus medialis. For the sciatic nerve

or hamstrings stimulation, a self-adhesive electrode of the same size was placed in the middle of the posterior thigh and approximately five centimeters above the popliteal fossa. These electrode locations were over the sciatic nerve which runs along the posterior aspect of the thigh. For the Abd condition, two self-adhesive electrodes (50x90 mm) were placed on both sides at the anteromedial to the anterior superior iliac spine of the pelvis. [28] These positions were reported as a transversus abdominis stimulation site.[28]

Statistical Analysis

Data analysis was performed using the SPSS program. The Shapiro Wilks test was used to determine data distribution. MBP and HR data were analyzed using a mixed analysis of variance (ANOVA) (3 conditions x time (rest, 1, 3, 6, 9 minutes)) and the Tukey HSD were used as the statistical and post-hoc test, respectively. Changes of MBP and HR from the resting and tilting tolerance time were analyzed using the Friedman test and Wilcoxon Signed Ranks test were used as the statistical and post-hoc test, respectively. The p-value was set at 0.05, except for the Wilcoxon Signed Ranks test, while the Bonferroni correction adjusted the p-value to <0.017. The statistical test was intentionally compared with the time effect from rest to 9 minutes after tilting-up because the data showed closed mean and high standard deviation along with the time effect. The effect size or partial h_p^2 was also determined (0.02= small, 0.13= medium, and 0.26=large).[29]

Results

The current amplitude used in this study was in the same range as those used in other studies [15,28] Mean stimulation amplitude for the left and right thigh muscles were 52.86 ± 13.83 and 49.29 ± 13.23 mA for quadriceps; 53.14 ± 14.92 mA and 51.29 ± 15.31 mA for hamstrings, respectively. For the abdominal muscle, the current amplitude was 48.64 ± 13.60 mA.

Hypotension (Figure 1) and faster HR (Figure 2) occurred significantly after tilting-up when compared to resting. A mixed ANOVA was conducted to compare MBP and HR between three conditions across time: at rest, 1, 3, 6, and 9 minutes. There were no significant main effects of condition ($F(2, 165) = 1.681$, $p = 0.19$, $h_p^2 = 0.020$ for MBP; $F(2, 165) = 0.847$, $p = 0.43$, $h_p^2 = 0.010$ for HR) or interaction effect ($F(8, 165) = 0.243$, $p = 0.98$, $h_p^2 = 0.012$ for MBP; $F(8, 165) = 0.110$, $p = 0.99$, $h_p^2 = 0.005$ for HR). However, significant main effect of time was observed ($F(4, 165) = 18.630$, $p < 0.001$, $h_p^2 = 0.311$ for MBP; $F(4, 165) = 3.698$, $p = 0.007$, $h_p^2 = 0.082$ for HR). Turkey HSD indicated significant differences in MBP at 1, 3, 6, and 9 minutes compared with resting ($p \leq 0.005$), and at 1 minute compared with 6 and 9 minutes ($p \leq 0.004$). For HR, a significant difference was found between resting and at 3 and 6 minutes ($p \leq 0.04$). A comparison of the changes of MBP from the resting value in each subject across conditions demonstrated the same drop of MBP across conditions. At 6 minutes after tilting-up, the MBP dropped 25.00±13.92, 26.85±14.71, and 26.71±14.86 mmHg from resting for the CON, QH,

and Abd, respectively (Friedman test, p= 0.72), and HR increased 8.73±8.58, 13.76±11.24, and 10.63±7.91 bpm (Friedman test, p= 0.15) from resting for the CON, QH, and Abd, respectively.

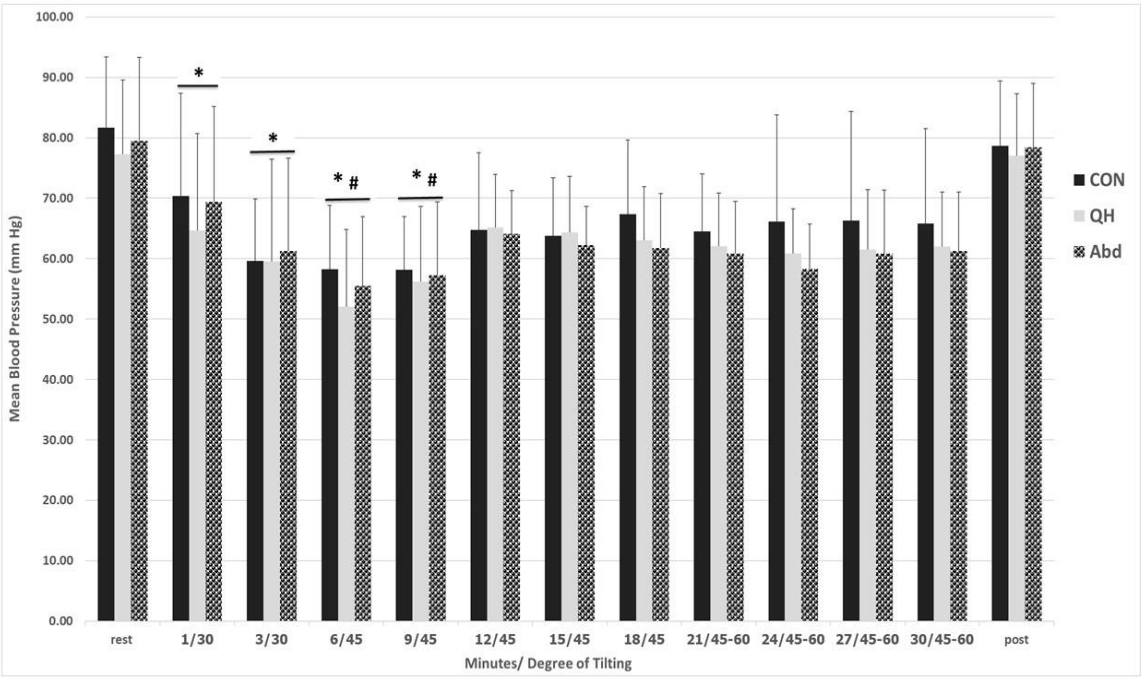

Figure 1 The mean blood pressure (mm Hg) in three conditions. CON = stockings only, QH = quadriceps and hamstrings stimulation, Abd = abdominal muscle stimulation with stockings

Note: * All interventions show significant differences compared with resting (p≤0.005), # All intervention show significant differences compared with 1 minute (p≤0.005)

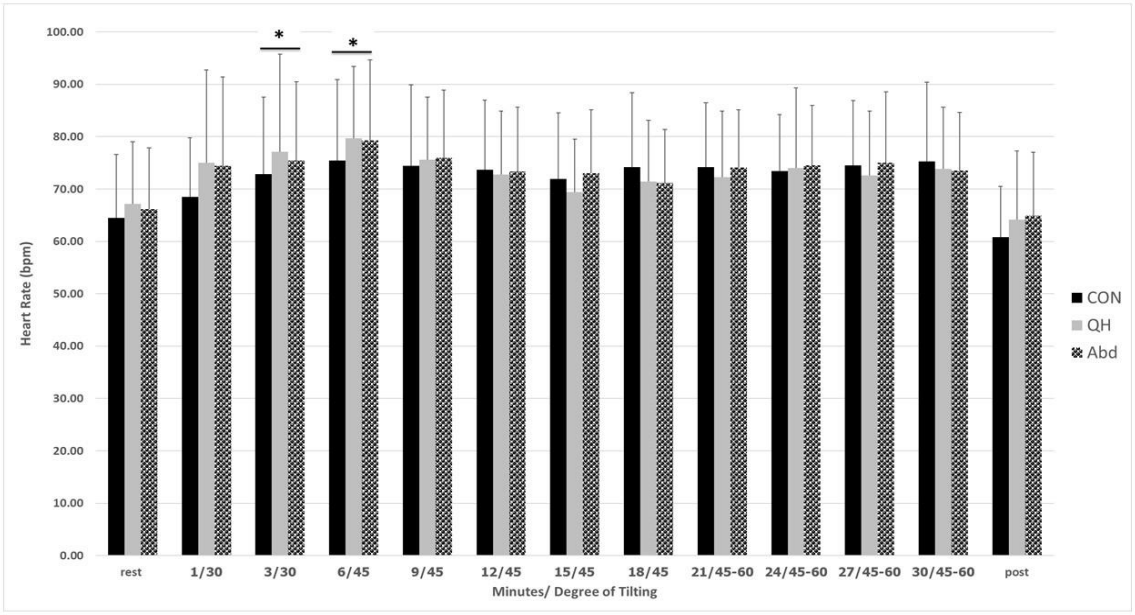

Figure 2 The heart rate (beat/minute; bpm) in three conditions. CON = stockings only, QH = quadriceps and hamstrings stimulation, Abd = abdominal muscle stimulation with stockings

Note: * All intervention show significant differences compared with resting (p≤0.004)

The tilting tolerance time also showed no significant difference among conditions (24: 06±11: 13, 19: 35±11: 53, and 21: 08±11: 48 minutes: seconds for the CON, QH, and Abd, respectively) (Friedman test, p= 0.96). Figure 3 shows the number of patients at each tilting angle and the tilting time. Despite the non-significant tolerance times, 10 patients in the CON could stay on a tilt table for 30 minutes compared to seven and eight patients in the QH and Abd conditions, respectively (Table 2). Only subject ID 4 (Table 2) could stay for 30 minutes and having a tilt angle of 60°. In contrast, subjects ID 10 and 11 showed tolerance times of 30 minutes, but the tilt angle was only 30°. Subjects ID 2, and 13 had the 30 minute tolerance time only in CON condition, and subject ID 5 had the 30 minute tolerance time in both CON and Abd conditions.

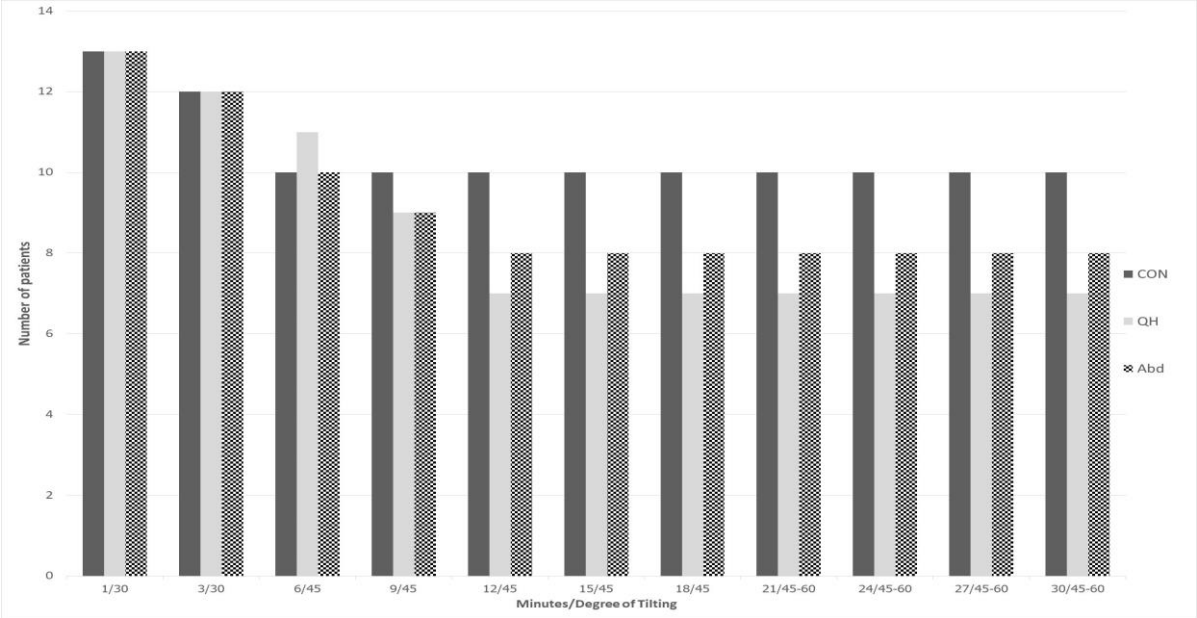

Figure 3 The number of patients at each tilting angle and the tilting time. CON = stockings only, QH = quadriceps and hamstrings stimulation, Abd = lower abdominal muscle stimulation with stockings.

Note: that 2 patients had a maximum tilt angle of 30° only.

Discussion

This study showed a significant drop in MBP and faster HR during tilting-up when compared to the resting condition for all three interventions: CON, QH, and Abd. These responses are in accordance with the response of passive standing in patients with tetraplegia. To our knowledge, during quiet standing gravitation force induces hydrostatic pressure to approximately 90 mmHg at the ankle, depending on the body height. [30] After spinal cord lesion, venous pooling occurs in the lower extremities and splanchnic area due to impairment of sympathetic activity. [31] Therefore, the use of electrical stimulation to facilitate muscle contraction may be an adjunctive treatment to minimize cardiovascular change during upright position in SCI patients. Similarly, using lower limb stocking also may decrease the venous pooling in lower extremity.

Table 2 Tilting time and the final tilt angle in each participant (n=13)

ID	Tilting time (minutes: seconds)			Final tilt angle
	CON	QH	Abd	(°)
1	5:50	6:41	5:30	45
2	30:00	11:53	12:00	45
3	30:00	30:00	30:00	45
4[a]	30:00[a]	30:00[a]	30:00[a]	60
5[b]	30:00	10:00	30:00	45
6	4:30	7:50	5:30	45
7	30:00	30:00	30:00	45
8	30:00	30:00	30:00	45
9	3:00	5:00	3:50	45
10[c]	30:00	30:00	30:00	30
11[c]	30:00	30:00	30:00	30
12	30:00	30:00	30:00	45
13	30:00	3:15	8:00	45
Mean	24:06	19:35	21:08	43.85
sd	11:13	11:53	11:48	7.40

Note: CON, stockings; QH, quadriceps and hamstrings stimulation; Abd, abdominal stimulation and stockings, [a] Tilted angle was up to 60°, [b] Difficulty of finding a motor point of the hamstrings, [c] Having low resting blood pressure, tilting angle was only 30°

To the best of our knowledge, our study is the first to select thigh muscle stimulation compared with lower limb stocking. Previous studies stimulated both thigh and leg muscles and showed significant results, but it is different in control groups. [11,15,18,19] Some studies did not use lower limb stockings or used healthy individuals in the control group.[11,12,15,17] Therefore, it was difficult to compare the result with this study. In this study, a similar drop of MBP in all conditions may be due to not strong enough muscle contraction or the treatment effect of leg stocking in the control group. Additionally, the patient characteristics were also different between studies. Some previous studies recruited both tetraplegia and paraplegia[11,15,17], in acute phase[17] or chronic phase. [11,15] Because OH tends to occur in the acute rather than the chronic stage. [9,32] This present study recruited patients from 27 to 123 days post-injuries. Therefore, other factors such as baroreceptor sensitivity[7,10] and cardiovascular deconditioning[5] may vary when compared with other studies. In addition, our subjects were traumatic SCI who presented higher incidences of SCI medical complications such as orthostatic

hypotension compared with the non-traumatic lesions.[33]

The results of stimulation at the transversus abdominis while wearing a pair of lower limb stockings (Abd) showed a non-significant drop of MBP when compared to wearing lower limb stockings (CON). The mechanism behind abdominal muscle stimulation was to increase intra-abdominal pressure and promote venous return. [34] West and coworkers[34] reported a strong but non-significant trend towards an increase in MBP by using an abdominal binder. Abdominal binder-induced increase venous return by translocating blood from splanchnic bed during increasing intra-abdominal pressure. [34] They also found that compression force was essential and demonstrated a positive dose-dependent improvement in cardiorespiratory function in individuals with cervical SCI. [34] This refers to our study that the stimulated current intensity may be not sufficient to decrease the OH symptoms. The contribution of abdominal muscle contraction to venous return is beyond the scope of this study. Future studies to explore this relation are needed.

The average duration of tilting tolerance time was no significant difference among interventions. However, a few patients in the CON condition had longer but not significant tolerance times than other conditions. Although this study was the cross-over design, all contributing factors from patients were the same across three interventions. A non-significant tilting tolerance time across three interventions may be due to other physiological factors and the fluctuating conditions of patients with traumatic SCI in the subacute phase. Moreover, we found that it was difficult to find the motor point of the hamstrings of a single patient (ID 5). This difficulty might result in poor contraction of the hamstrings and a short duration of tilting time in the QH intervention.

Many factors should be considered by the therapist while applying muscle stimulation to reduce OH in SCI. First, stimulation might cause muscle fatigue over time. [35] Therefore, venous pooling may gradually increase. From our knowledge, no evidence is available that compared the different electrical parameters such as pulse duration, current frequency, and on-time/off-time on the MBP and HR during passive standing in SCI. However, this study used the same current frequency[20] and on time/off time[27] as these previous studies. Limitations of this study were, firstly, this study used constant current amplitude which may not be a maximal contraction throughout the period of passive standing due to muscle fatigue. Secondly, muscle contraction was determined from visual observation and palpation. Thirdly two-channel stimulators which can provide co-contraction of quadriceps and hamstrings muscles of each leg, but not synchronously of both legs was used. Thus, not only the number of stimulated lower extremity muscles, that is stimulation of quadriceps, hamstrings, tibialis anterior and gastrocnemius) but also the co-contraction of muscles of both legs may be another important factor to alleviate the cardiovascular responses during passive standing. Future studies may compare the effect of different stimulation

frequencies and different duration of on-time and off-time to determine the optimal current parameters.

Conclusion

There were no MBP, HR, and tilting time differences among the three interventions. These results suggest that using only lower limb stockings, stimulation only at the quadriceps and hamstrings, or a combination of abdominal muscle stimulation with lower limb stockings are not sufficient to minimize MBP and HR changes during passive standing in individuals with acute SCI.

Conflict of interest

All authors declare no conflicts of interest relating to any aspect of this study.

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