Reliability of the sit-up test in individuals with spinal cord injury

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Objective: To determine the day-to-day reliability of blood pressure responses during a sit-up test in individuals with a traumatic spinal cord injury (SCI).

Design: Within-subject, repeated measures design.

Setting: Community outpatient assessments at a research laboratory at the University of British Columbia.

Participants: Five men and three women with traumatic SCI (age: 31 ± 6 years; C4-T11; American Spinal Injury Association Impairment Scale A-B; 1–17 years post-injury).

Outcome measure: Maximum change in systolic (Δ SBP) and diastolic (Δ DBP) blood pressure upon passively moving from a supine to seated position.

Results: The average values for Δ SBP were -11 ± 13 mmHg (range -38 to 3 mmHg) for visit 1, and -12 ± 8 mmHg (range -26 to -1 mmHg) for visit 2. The average values for Δ DBP were -9 ± 8 mmHg (range -21 to 0 mmHg) for visit 1, and -13 ± 8 mmHg (range -29 to -3 mmHg) for visit 2. The Δ SBP demonstrated substantial reliability with an intraclass correlation coefficient of 0.79 ($P = 0.006$; 95% CI 0.250 – 0.953), while the Δ DBP demonstrated almost perfect reliability with an intraclass correlation coefficient of 0.92 ($P < 0.001$; 95% CI 0.645 – 0.983). The smallest detectable differences in Δ SBP and Δ DBP were 7 mmHg and 6 mmHg, respectively.

Conclusion: Blood pressure responses to the sit-up test are reliable in individuals with SCI, which supports its implementation as a practical bedside assessment for orthostatic hypotension in this at risk population.

Keywords: Bedside testing, Blood pressure, Orthostatic hypotension, Reproducibility of results

Introduction

Orthostatic hypotension (OH) is highly prevalent in individuals living with a spinal cord injury (SCI), and is attributed to the disruption of the spinal vasomotor pathways and the loss of reflex vasoconstriction during an orthostatic challenge.¹ By definition, OH describes a decrease in systolic blood pressure (SBP) ≥ 20 mmHg or diastolic blood pressure (DBP) ≥ 10 mmHg, regardless of the presence or absence of symptoms, upon moving from a supine to upright position.² The tilt-table test is considered the gold standard assessment for OH³ and has demonstrated substantial day-to-day reliability in able-bodied individuals.⁴ However, this particular test requires specialized equipment, and

trained personnel, and therefore may not be applicable or available in many clinical settings. Claydon and Krassioukov⁵ demonstrated the presence of OH in individuals with SCI using a sit-up test, a simple bedside procedure which involved passively moving the individuals to a seated position. The reliability of this assessment, however, has yet to be determined. Therefore, the purpose of this study was to determine the day-to-day reliability of blood pressure responses during a sit-up test in individuals with a traumatic SCI. We hypothesized the blood pressure responses would demonstrate substantial reliability.

Methods

Participants

Eight individuals with traumatic, chronic (≥ 1 year post-injury) SCI were recruited from the community

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(Vancouver, British Columbia, Canada). The International Standards for Neurological Classification of SCI was used to determine the neurological level of lesion and American Spinal Injury Association Impairment Scale (AIS) classification.⁶ Participants were excluded if they were <18 years of age, or had any acute illness or cognitive or language barrier which prevented them from following English instructions. All procedures were reviewed and approved by the University of British Columbia Clinical Research Ethics Board, conforming to Helsinki Declaration of 1975, and written informed consent was obtained prior to participation. Participant characteristics are presented in Table 1.

Study Protocol

This study employed a within-subject, repeated measure design. Participants attended two testing sessions separated by an average of 1 day (range 1–3 days). Prior to each visit, participants were instructed to abstain from caffeine and alcohol for 12 hours, withhold medications, and to consume a light breakfast. Upon arrival to the laboratory, participants were asked to empty their bladders to minimize the influence of reflex sympathetic activation on peripheral vascular tone.

Sit-Up Test

The test protocol was modeled after the sit-up test previously employed by Claydon and Krassioukov.⁵ Throughout testing, discrete brachial blood pressures were taken every minute from the left arm using an automated device (Dinamap Pro 300 V2; GE Healthcare, Milwaukee, WI, USA), while heart rate was measured continuously using a single-lead electrocardiogram (Model ML-795; ADInstruments Inc., Colorado Springs, CO, USA). Following 10 minutes of rest in the supine position, the test began with 15 minutes of supine measurements, after which participants were passively moved to the sit-up position and supported while blood pressure and heart rate measurements were recorded for an additional 15 minutes. Supine and seated blood pressures and heart rates are reported as the average across each 15-minute interval. The maximum change in SBP (Δ SBP) was calculated as Δ SBP = minimum seated SBP-average supine SBP, while the maximum change in DBP (Δ DBP) was calculated as Δ DBP = minimum seated DBP-average supine DBP.

Statistical Analysis

Statistical analyses were performed using Statistical Package for Social Science software (Version 20.0; IBM Corp., Armonk, NY, USA). All data were assessed for normal distribution using Shapiro-Wilk tests and

Q-Q plot analyses. Day-to-day differences in supine and seated blood pressures and heart rates were assessed using paired *t*-tests. Reliability of the Δ SBP and Δ DBP were determined using Cronbach's alpha (α) and intra-class correlation coefficients (ICC). ICCs were interpreted as poor (0.00–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80) or almost perfect (0.81–1.00), while α values between 0.70–0.90 (moderate) or >0.90 (high) were deemed acceptable.⁷ The smallest detectable difference (SDD) was calculated using the equation, $SDD = 1.96 \times SEM \times \sqrt{2}$.⁷ Data are presented as mean $\pm$ SD, with $P < 0.05$ considered statistically significant.

Results

Supine and seated hemodynamic parameters for the entire group and according to the level of injury are presented in Table 2. There were no differences in supine or seated blood pressures or heart rates between visits. The Δ SBP demonstrated substantial reliability with an ICC of 0.79 ($P = 0.006$; 95% CI 0.250–0.953), and α of 0.88. The average values for Δ SBP were -11 ± 13 mmHg (range -38 to 3 mmHg) for visit 1, and -12 ± 8 mmHg (range -26 to -1 mmHg) for visit 2. The average values for Δ DBP were -9 ± 8 mmHg (range -21 to 0 mmHg) for visit 1, and -13 ± 8 mmHg (range -29 to -3 mmHg) for visit 2. The Δ DBP demonstrated almost perfect reliability with an ICC of 0.92 ($P < 0.001$; 95% CI 0.645–0.983), and α of 0.96. The SDD for Δ SBP and Δ DBP were 7 mmHg and 6 mmHg, respectively.

Discussion

In the present study, both SBP and DBP responses to the passive sit-up test demonstrated substantial day-to-day reliability. Previous reports suggest OH is present in up to 82% of persons with tetraplegia, and 50% of individuals with paraplegia.⁸ Additionally, OH has been documented in both the acute and chronic stages of SCI, making it an ongoing clinical concern.¹ The negative consequences of OH can include a reduction in the capacity to perform activities of daily living, deficits in cognitive performance, fatigue, and an increase susceptibility to pressure ulcers due to reduced tissue perfusion.^{1,8} Therefore, the diagnosis and proper management of OH is necessary to the overall health and quality of life for individuals living with SCI. While the tilt-table test is considered the gold-standard assessment for OH,³ its use of a specialized table makes it impractical for the clinical setting. The sit-up test has previously been shown to elicit OH in SCI.⁵ This finding in combination with our observation of

Table 1 Subject characteristics

Subject	Lesion Level	AIS	Time Post Injury (yr)	Age (yr)	Height (m)	Mass (kg)	Sex
1	C4	B	13	32	1.80	72.5	M
2	C5	B	7	25	1.88	72.7	M
3	C6	A	12	36	1.80	61.5	F
4	C6	B	8	39	1.58	63.9	F
5	T4	A	11	33	1.83	88.2	M
6	T4	A	17	32	1.78	57.9	F
7	T6	B	11	32	1.85	85.4	M
8	T11	A	1	20	1.80	73.2	M
Mean $\pm$ SD			10 $\pm$ 5	31 $\pm$ 6	1.79 $\pm$ 9.3	71.9 $\pm$ 10.8	

AIS, American Spinal Injury Association Impairment Scale.

its day-to-day reliability suggests the sit-up test provides a practical bedside assessment for OH, which could easily be implemented in the clinical setting.

Supine blood pressures and heart rates were similar between visits, which suggest participants were in a similar resting hemodynamic state prior to the test. Based on the SBP criterion for OH, only one participant (13%) demonstrated OH. However, six of eight (75%) demonstrated OH based on the DBP criterion. This observation highlights the necessity to diagnose OH based on both blood pressure responses. Additionally, our observations are comparable to the prevalence rates previously reported in SCI⁸ with 100% and 50% of our patients with tetraplegia and paraplegia presenting with OH, respectively.

The SDD provides an objective cut-off value, whereby values above the SDD can be attributed to true changes

due to an intervention rather than day-to-day variability in the measurement itself. The severity of OH has been shown to change following an intervention. Specifically, Engelke *et al.*⁹ observed an attenuation of 12 mmHg in the Δ SBP following a single bout of exercise in individuals with paraplegia, while Wecht *et al.*¹⁰ observed a difference of 17 mmHg in Δ SBP following 10 mg of midodrine hydrochloride in individuals with tetraplegia. In the present study, the SDD for Δ SBP and Δ DBP were 7 mmHg and 6 mmHg, respectively, which are lower than the observed changes described above.

Conclusions

The sit-up test provides a practical bedside assessment that requires minimal equipment, and demonstrates substantial day-to-day reliability. The high prevalence of OH in individuals living with SCI makes its diagnosis

Table 2 Supine and seated hemodynamics based on injury level

Variable	Day 1	Day 2
Supine SBP (mmHg)		
Group	114 $\pm$ 10	113 $\pm$ 12
Tetraplegia	114 $\pm$ 6	113 $\pm$ 10
Paraplegia	115 $\pm$ 14	114 $\pm$ 16
Supine DBP (mmHg)		
Group	60 $\pm$ 8	59 $\pm$ 8
Tetraplegia	57 $\pm$ 4	58 $\pm$ 6
Paraplegia	63 $\pm$ 11	61 $\pm$ 10
Supine heart rate (bpm)		
Group	58 $\pm$ 4	61 $\pm$ 5
Tetraplegia	56 $\pm$ 4	60 $\pm$ 6
Paraplegia	60 $\pm$ 3	63 $\pm$ 4
Seated SBP (mmHg)		
Group	111 $\pm$ 15	110 $\pm$ 14
Tetraplegia	104 $\pm$ 14	103 $\pm$ 9
Paraplegia	119 $\pm$ 14	117 $\pm$ 16
Seated DBP (mmHg)		
Group	57 $\pm$ 10	55 $\pm$ 11
Tetraplegia	50 $\pm$ 8	48 $\pm$ 6
Paraplegia	63 $\pm$ 8	62 $\pm$ 10
Seated heart rate (bpm)		
Group	67 $\pm$ 6	70 $\pm$ 8
Tetraplegia	65 $\pm$ 9	70 $\pm$ 12
Paraplegia	68 $\pm$ 2	71 $\pm$ 2

Data are mean $\pm$ SD. Group (C4-T11, n = 8). Paraplegia (T4-T11, n = 4). Tetraplegia (C4-C6, n = 4).

and management a clinical priority. Both clinicians and researchers alike should consider implementing this technique in their assessments of individuals living with SCI.

Disclaimer statements

Contributors KDC contributed to the following aspects of the study: (1) analyzing the data, (2) interpreting the data, (3) writing the article in whole, and (4) revising the article. SCW contributed to the following aspects of the study: (1) obtaining ethics approval, (2) collecting the data, and (3) revising the article. DEW contributed to the following aspects of the study: (1) conceiving and designing the study, (2) interpreting the data, and (3) revising the article. AVK contributed to the following aspects of the study: (1) conceiving and designing the study, (2) collecting the data, (3) interpreting the data, and (4) revising the article.

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Conflicts of interest The authors declare that they have no conflict of interest.

Ethics approval Ethics approval was obtained from the University of British Columbia Clinical Research Ethics Board.

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