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Postural regulatory strategies during quiet sitting are affected in individuals with thoracic spinal cord injury

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ABSTRACT

Thoracic spinal cord injury (SCI) can have significant negative consequences, which can affect the ability to maintain unsupported sitting. The objectives of this study were to compare postural control of individuals with high- and low-thoracic SCI to able-bodied people and evaluate the effects of upper-limb support on postural control during quiet sitting. Twenty-five individuals were recruited into: (a) high-thoracic SCI; (b) low-thoracic SCI; and (c) able-body subgroups. Participants were seated and asked to maintain a steady balance in the following postures: (1) both hands resting on thighs; (2) both arms crossed over the chest; and (3) both arms extended. Center of pressure (COP) fluctuations were evaluated to compare postural performance between groups and different postures. Results showed that individuals with high- and low-thoracic SCI swayed more compared to the able-bodied group regardless of upper-limb support. No differences between the two SCI groups were observed, but the neurological level of injury was correlated to postural performance implying that those with higher injuries swayed more and faster. Unsupported sitting was more unstable in comparison to supported sitting posture, especially in the anterior-posterior direction. The velocity of postural sway was not different between groups, but the results suggest that postural regulation had unique effect during different postures in different groups. These results imply reduced postural stability after thoracic SCI. Overall, the way individuals with high-thoracic SCI achieved stability was different from that of individuals with low-thoracic SCI, suggesting different postural regulation strategies.

1. Introduction

Postural instability during sitting balance is a significant problem for individuals with spinal cord injury (SCI). Injuries above the mid-thoracic neurological level often result in motor and/or sensory impairment of the trunk muscles [1–3]. As a result, individuals with thoracic SCI compensate for the impairment by using non-postural muscles to maintain sitting, but their balance remains compromised [3]. They often utilize compensatory mechanism, which includes using their arms for support [4–6] and foot support [7].

It has previously been shown that trunk control is mostly responsible for the impaired sitting balance in individuals with SCI, whereas foot support provides passive forces [8]. Upright sitting posture is mostly maintained by modulating the tension of the posterior muscle chain. Grangeon et al. [5] compared sitting balance of individuals with SCI to able-bodied people during quiet sitting in various upper-limb support conditions. They showed that individuals with SCI have reduced stability irrespective of the upper-limb support during quiet sitting compared to able-bodied individuals. Moreover, they showed that upper-limb support can improve seated stability in individuals with SCI, especially in the anterior-posterior direction. Shirado et al. [9] showed that outstretching the arms over the thighs decreased anterior-posterior stability during quiet sitting, compared to sitting with hands supported on the thighs. This is likely because outstretching the arms typically shifts the center of mass superiorly and anteriorly with respect to the hip joint, creating greater postural oscillations [5,9]. Ability to maintain hands-free unsupported sitting is thought to be more difficult for individuals with high-thoracic and low cervical SCI compared to able-bodied people [6]. Paresis or paralysis of back and abdominal muscles minimizes the contribution of these postural muscles to sitting balance. Individuals with SCI often use upper extremities for support and when asked to elevate their arms they often have worse postural control, whereas individuals with low-thoracic SCI often have sufficient postural stability to maintain seated balance with

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Table 1
Participant age, height, weight, and clinical evaluations for the high-thoracic SCI (SCI_H), low-thoracic SCI (SCI_L), and able-body (AB) groups.

Group	Age (years)	Height (m)	Weight (kg)	Neurological level of injury	AIS	ASIA Motor (/100)	ASIA Sensory (/224)	Time since Injury (years)
SCI_H	45.8	1.8	80.0	T7	A	50	117	12.1
	55.8	1.8	73.9	T7	A	50	112	0.4
	36.5	1.7	67.9	T6	A	50	53	6.9
	53.2	1.8	84.7	T4	A	50	-	27.9
	50.2	1.7	70.2	T7	C	52	88	5.5
	60.7	1.7	62.3	T5	A	50	92	38.3
	39.4	1.8	84.8	T6	C	50	166	9.0
Mean	**48.8**	**1.8**	**74.8**			**50.3**	**104.7**	**14.3**
SD	**8.8**	**0.1**	**8.7**			**0.8**	**37.6**	**13.7**
SCI_L	34.6	1.9	-	T12	C	56	162	9.2
	35.4	1.8	101.7	T11	C	54	182	2.8
	29.7	1.9	73.0	T12	A	50	154	11.9
	41.7	1.5	66.5	T8	B	50	134	11.0
	24.1	1.8	54.0	T11	A	66	160	0.1
	53.9	1.8	110.7	T9	A	50	132	20.0
	37.6	1.9	83.5	T10	A	50	138	2.4
	57.1	1.8	85.3	T12	A	55	168	25.0
	61.2	1.9	102.4	T10	A	50	140	6.3
	54.0	1.7	73.6	T12	B	63	172	10.2
Mean	**42.9**	**1.8**	**83.4**			**54.4**	**154.2**	**9.9**
SD	**12.8**	**0.1**	**18.7**			**5.9**	**17.4**	**7.8**
AB	31.9	1.7	57.9					
	43.5	1.7	100.8					
	34.2	1.8	93.6					
	59.8	1.8	68.9					
	42.8	1.8	78.1					
	50.2	1.9	76.2					
	27.8	1.7	54.8					
	54.8	1.9	71.0					
Mean	**43.1**	**1.8**	**75.2**					
SD	**11.4**	**0.1**	**15.9**					

both arms elevated [6].

Chen et al. [1] compared sitting balance performance of individuals with high- and low-thoracic SCI during static balance (i.e., quiet sitting) and dynamic balance (i.e., weight transfer) tasks. Individuals with low-thoracic SCI demonstrated better dynamic stability, compared to high-thoracic SCI. However, there were no differences in static sitting balance between individuals with high- and low-thoracic SCI [1]. Also, neurological injury level did not correlate well with static sitting stability among individuals with thoracic SCI, but it was correlated with dynamic stability performance [1]. However, Chen et al. [1] compared only one measure related to the postural performance (i.e., related to the amount of sway) and did not have sufficient outcome measures to fully characterize postural control mechanisms in the context of static sitting balance [4]. Furthermore, they did not examine the effects of upper-limb support on sitting balance nor compare sitting balance of individuals with thoracic SCI to the able-body control group. Previous investigations [1,9] also did not account for the effects of foot support on postural stability, which has been shown to influence sitting balance [7,8].

To date, there is no clear understanding of how postural control differs in individuals with high- and low-thoracic SCI and how upper-limb support influences sitting balance in these individuals. Therefore, the objectives of this study were to: (1) compare quiet sitting postural control of individuals with high- and low-thoracic SCI as well as able-bodied individuals; and (2) evaluate the effect of upper-limb support on postural control. We hypothesized that postural control will be impaired in individuals with thoracic SCI and that upper-limb support will have different effects on individuals with high- and low-thoracic SCI.

2. Methods

2.1. Participants

A total of twenty-five participants were recruited into: (a) high-thoracic SCI (SCI_H); (b) low-thoracic SCI (SCI_L); and (c) able-body (AB) subgroups (Table 1). Individuals were recruited in the SCI groups if they had a motor and/or sensory incomplete or complete thoracic SCI American Spinal Injury Association (ASIA) Impairment Scale (AIS) A to C, and could independently maintain unsupported sitting. Individuals with SCI were excluded if they had secondary complications, pressure sores, or other impairment, which may limit their ability to perform the experiment. Individuals were recruited in the able-bodied group if they had no history of impairments that could affect their sitting balance or performance of the experiment. All participants gave written informed consent in accordance with the Declaration of Helsinki. The experimental procedures were approved by the local institutional Research Ethics Board.

2.2. Experimental protocol

Participants were seated upright such that their thigh-trunk angle was at approximately 90°. They were seated on a height-adjustable chair without back support and with their feet parallel and flat on the ground. The height of the chair was adjusted for each participant such that the knees were flexed at about 75–85° and were seated centrally with 75% of their thighs supported on the seating surface (Fig. 1).