Research Article

A preliminary study on the correlation of upper limb loading during seated push-up test and body compositions of individuals with spinal cord injury

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Abstract

Individuals with spinal cord injury commonly suffer from body composition decline, e.g., skeletal muscle mass (SMM) and bone mineral content (BMC), that could affect force generation and rehabilitation outcomes, as well as risk of secondary consequences and complications. However, the assessments for body compositions using a complex and costly machine could result in late detection on the abnormality occurred in these individuals. Therefore, this research investigated the correlation between the amount of upper limb loading (ULL) during a seated push-up test (PUT), and the amount of SMM and BMC in 20 individuals with SCI. Subjects were cross-sectionally assessed for the ability of ULL while completing a seated PUT, and SMM and BMC using DXA scan. The findings were analyzed using the Pearson's correlation coefficient (r) and Spearman's rank (r_s) correlation coefficients. The findings indicated significant correlation between the amount of ULL, and SMM and BMC of the subjects, not only for the arms, but also the legs and whole body (r_s, r=0.560-0.805, p<0.05). The current findings offer preliminary data on the use of ULL during seated PUT to monitor the change of body compositions of individuals with SCI. However, further studies in the large number of sample size with data analysis separately for those with complete and incomplete SCI may provide clear information to extend the benefit of seated PUT for these individuals.

Keywords: Bone mineral content, Skeletal muscle mass, Rehabilitation, Mobility, Press-up test

Introduction

Individuals with spinal cord injury (SCI) are commonly suffered from the alteration of body compositions, i.e., decreased skeletal muscle mass (SMM) and bone mineral content (BMC), that could affect ability of force generation and rehabilitation outcomes, as well as enhance risk of medical complications, such as osteoporosis and fracture of the patients. [1-3] This is particular important especially when individuals with SCI are those with obvious sensorimotor impairments and at a high risk of falls (39-75%). [4,5] Therefore, the change of SMM and BMC could affect optimal outcomes of the patients, and burden of care from family and society. Consequently, apart from the improvement of rehabilitation treatments, the ability of early detection on the change of SMM and BMC is crucial for the effectiveness of treatments and management for these individuals.

However, current assessments for body compositions are commonly executed using a complex and costly machine, such as bioelectrical impedance analysis (BIA), dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging (MRI) and computed tomography (CT). [6] Consequently, the assessments are prescribed for only those with obvious signs and symptoms of body composition decline that could enhance negative impacts and distort treatment effectiveness of the patients. [7] Therefore, further exploration for a simple, practical and standard assessment to detect and monitor body composition alteration may promote treatment effectiveness for the patients.

A seated push-up test (PUT) is a common rehabilitation strategy to promote independence of individuals with both complete and incomplete SCI. [8-10] The ability requires individuals to push both hands on the floor and lift the body up prior to bend the elbows to smoothly put the buttock down on the floor. [10] Such ability is highly demanding for upper limb and upper trunk muscles to increase substantial amount of upper limb loading (ULL, at least 80% of the body-weight), muscle force, and upper limb joint torque to successfully lift the body up from the floor. [8,9,11] Based on the concept of closed-association of the musculoskeletal system and global physiological change of the body systems [12,13], the researchers hypothesized that the amount of ULL while completing a seated PUT is associated with the amount of SMM and BMC of individuals with SCI. Therefore, this study investigated the correlation between the amount of ULL during a seated PUT and the body compositions, namely the SMM and BMC, of individuals with SCI.

Material and method

Subjects:

This preliminary study was conducted in 20 individuals with SCI, age at least 18 years. The individuals were excluded if they had signs and symptoms limiting the ability to complete the tests used in this study, e.g., unstable medical conditions, pain or inflammation in the muscles or joints (or more than 5 out of 10 on a visual analog scale), having other neurological disorders (e.g., brain lesions), etc. The eligible subjects needed to sign a written informed consent form that was approved by the Khon Kaen University Ethics Committees for Human Research, Khon Kaen, Thailand (HE611566) prior to participation in the study.

Research Protocols:

The eligible subjects were interviewed and assessed for their demographics (i.e., age, sex, body-weight, height, and underlying diseases [if any]), SCI characteristics (i.e., causes, post-injury time, level of injury, and severity of injury using the criteria from the American Spinal Injury Association Impairment Scale or AIS). Subsequently, they were assessed for the outcomes of the study, including the amount of ULL while completing a seated PUT, and the amount of SMM and BMC using DXA. Details of the assessments are described below.

Upper limb loading during a seated push-up test:

This test was executed using push-up loading devices (Model L6E3-C, 50 kg-3G, with the standard calibration method based on UKASLAB 14: 2006, accuracy up to <0.01 kg and measurement uncertainty of ±0.20 kg). Subjects were instructed to push both hands on the push-up loading devices, extend the elbows to lift the body up from the floor with bending the trunk forward to promote movement stability, then flex the elbows to lower the body smoothly down on the floor. [10] The amount of ULL was automatically generated by the push-up loading devices. Then the average maximum amount of ULL over the 3 trials was used for data analysis.

Dual-energy X-ray Absorptiometry:

Subjects were assessed for the body compositions, including the SMM and BMC using DXA, an accurate machine with an error margin to determine body compositions of 2-6%, at the Srinagarind hospital, Faculty of Medicine, Khon Kaen University. [14] The assessment was executed in a supine position on a DXA table with their arms by their sides. Subjects were instructed to not move any parts of the body while the DXA operated the data, then the amount of SMM and BMC was automatically reported by the machine. [14]

Statistical analyses:

The descriptive statistics were used to explain subjects' characteristics and findings of the study. The Pearson's correlation coefficients (r) and Spearman's rank correlation coefficient (r_s) were used to analyze the data. The level of statistical significance was set at $p<0.05$.

Results

Twenty subjects (10 subjects with motor complete SCI and the rest with motor incomplete SCI) with average age of 39.25±14.0 years old and normal body mass index completed the study. Most subjects were male (75%), having paraplegic (95%), and being at a chronic SCI (75%) with the average post-injury time more than 5 years (Table 1).

Table 1 Subject characteristics and their upper limb loading ability (n=20)

Variable	Total (n=20)
Gender: male: n(%)	15 (75)
Stage of injury: chronic: n(%)	15 (75)
Cause of injury: traumatic: n(%)	15 (75)
Level of injury: paraplegia: n(%)	19 (95)
AIS Classification: A: n(%)	10 (50)
Age[a] (years)	39.25±14.0 (21.0-65.0)
Body mass index[a] (kg/m^2)	22.30±3.2 (15.3-28.2)
Post-injury time[a] (months)	65.65+60.5 (2.0-186.0)
Upper limbs loading[a,b] (%body-weight)	84.61±7.6 (69.7-99.5)

Note: [a]The data are presented using mean±SD (range: min-max), [b]the data were assessed during performing a seated push-up test. Abbreviations: AIS=American Spinal Injury Association Impairment Scale.

The findings indicated that subjects had the average amount of ULL during performing a seated PUT of approximately 85% of their body-weight (Table 1). These data showed significant correlation to the amount of SMM of not only the arms but also the legs and total body SMM (r or r_s=0.565-0.805, p<0.05, Table 2). Moreover, the amount of ULL significantly correlated to the amount of BMC for arms, legs and total body BMC (r=0.560-0.676, p<0.05, Table 2).

Table 2 Correlation between the amount of upper limbs loading (ULL) during a seated push-up test and the amount of skeletal muscle mass (SMM) and bone mineral content (BMC)

Segments	Body compositions from dual-energy X-ray absorptiometry		Levels of correlation between ULL and body compositions			
	SMM[a] (g)	BMC[a] (g)	SMM	p-value	BMC	p-value
Arms	5,664.86 (1,926.2)	344.45 (83.1)	0.662[b]	0.001*	0.676[c]	0.001*
Legs	11,115.24 (2267.7)	668.18 (154.9)	0.565[c]	0.009*	0.560[c]	0.010*
Total	41,094.18 (7934.25)	2,233.94 (412.4)	0.805[c]	<0.001*	0.655[c]	0.002*

Note: [a]The data are presented using mean (SD), [b]The data were analyzed using Spearman's rank correlation coefficient, [c]The data were analyzed using Pearson's correlation coefficient, * indicate significant correlation.

Discussion

A seated PUT has been widely used as a rehabilitation treatment to promote independence of many individuals, including those with SCI. However, there is little evidence regarding the use of this test as a clinical measure for these individuals. Thus this study investigated the correlation between the amount of ULL while completing a seated PUT, and the amount of SMM and BMC from DXA. The findings indicated the moderate to high correlation between the amount of ULL during a seated PUT, and the SMM and BMC, not only for the arms, but also legs and total body (r or r_s=0.560-0.805, $p<0.05$, Table 2).

The findings support the high demand of the PUT, global physiological change of the body systems, and the concept of closed-association of the musculoskeletal system. [12,13] The ability of seated PUT requires individuals to push both hands on the floor and lift the body up. [10] Such ability is highly demanding for upper limb and upper trunk muscles to increase substantial amount of upper limb loading, muscle force, and upper limb joint torque that are largely depending on the amount of SMM. [8,9,11] Previous studies also found the correlation between knee extension strength test, as determined using one repetition maximum (1RM), and the SMM of many subjects such as healthy individuals, frail older adults, post-menopause women, and individuals with knee osteoarthritis. [15-18] The correlation is clearly seen in the upper limbs as they are major parts responsible for the task (r_s=0.662, Table 2). Nevertheless, the correlation found in the legs and total SMM (Table 2) may suggest the global physiological effects of exercise, disuse, aging and any abnormality found in both humans and experimental animal models. [8,13,19,20] Although individuals with SCI have obvious sensorimotor deterioration below the levels of injury, some studies also reported the musculoskeletal decline in individuals with SCI above the lesion site due to disuse and hormonal effects. [21,22] This evidence is clearly seen in those with long post-injury time as the subjects in this study (>5 years post-injury). Therefore, the amount of ULL during a seated PUT, that is mainly responsible by the upper limb and upper trunk muscles, showed significant correlation of not only the arms, but also the legs and the whole body of the subjects with SCI (Table 2).

The closed-association of the musculo skeletal system due to mechanical loading is a key mechanism linking the amount of SMM and bone tissue with the central aim to promote mobility. [12] Some studies also revealed closed-functional and alteration relationship between SMM and BMC. [12,13] Therefore, apart from SMM, the amount of ULL was correlated to the BMC of the subjects (Table 2).

The present findings provide preliminary data to extend clinical benefit of a seated PUT, apart from being a rehabilitation strategy to promote independence of individuals with SCI. The test can be used to monitor the change of SMM and BMC of individuals with SCI overtime, not only for the arms, but also legs and total body compositions. However, these data were arisen from a small number of subjects with both complete and incomplete SCI. Moreover, the body compositions were considered only in terms of SMM and BMC. Therefore, further studies in a large number of subjects with data analysis separately for individuals with complete and incomplete SCI, and the verification for the benefit of the test to determine other crucial issues for these individuals are needed.

Conclusions

The findings preliminary suggested the use of amount of ULL while completing a seated PUT to monitor the change of SMM and BMC of individuals with SCI. The assessment can be clinically determined using digital bathroom scales on a hard and even surface. Therefore, the current findings extend clinical utility of the seated PUT not only as a rehabilitation treatment but also a monitoring tool for the SMM and BMC of individuals with SCI in various clinical and home-based settings.

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