Effects of Different Chair Heights on Ground Reaction Force and Trunk Flexion during Sit-to-Stand in the Elderly

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Purpose: The purpose of this study was to analyze the coordination between trunk flexion and lower limb extension contributing to vertical propulsion during sit-to-stand (STS) at different chair heights in the elderly.

Methods: Ten elderly subjects were asked to stand up at their natural speed from different chair heights : (1) 90° knee flexion; (2) 100° knee flexion; (3) 110° knee flexion; and (4) 120° knee flexion. A standard chair without a backrest or armrests was used in this study. To remove inertial effects of upper limb movements, subjects were asked to stand up from a chair with their arms crossed at the chest. Mean of results of three trials were used in the analysis at different knee flexion angles. Distances moved by the shoulder for compensatory trunk movement was recorded by motion analysis and vertical force was recorded under foot using force plates. Distances moved by the shoulder and vertical ground reaction force measurements were analyzed using repeated ANOVA.

Results: Distances moved by the shoulder significantly decreased with higher chair ($p<0.05$). Vertical forces were not significant difference on chair heights ($p>0.05$), but results of pairwise comparisons for vertical force revealed significant difference between 90° knee flexion and 120° knee flexion ($p<0.05$).

Conclusion: Trunk movement is probably used as a compensatory mechanism at low chair heights to increase lift-off from sitting by the elderly.

Key Words: Sit-to-stand, Elderly, Ground reaction force

I. Introduction

The ability to stand up from a chair is essential for the elderly to enable independent living.[1–4] In the elderly, aging greatly decreases motor functions, such as, muscle strength and power.[5–9] Previous studies have reported that the elderly tend to exaggerate trunk flexion before lift-off when performing the sit-to-stand movement, as characterized by protracted sit-to-stand (STS) times. Thus, the ability to lift the body from sitting to standing can become a critical limiting factor of quality of life in the elderly.[10]

Upper and lower body segmental coordination is essential to maintain dynamic stability over a changing base of support (BOS) when performing STS successfully.[2,11] The basic kinematics of STS include flexion of the trunk and hips to bring the center of mass forward, followed by bilateral extension of the lower limb joints and trunk extension to raise the body mass in a vertical direction over the feet. Previous studies have suggested that STS is preprogrammed and that the selection of movement strategy reflects the mechanical requirements necessary to complete the task.[12,13] Specifically, both trunk positioning and movement are recognized to play key roles in STS strategies,[14] but might reflect significant compensation mechanisms during STS in various situations.[15]

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Several studies have also revealed that STS mechanical parameters vary with chair height.[7,16-19] Rodosky et al.[16] reported that higher chair positions reduce mechanical demand, as demonstrated by lower net extension moments at the knee and hip, as compared with those observed at lower chair heights. The majority of studies on the subject have examined two chair height effects, that is, high bench and low bench heights, and ground reaction forces. However, these studies did not explore the contribution made by coordination between trunk flexion and lower limb extension to vertical propulsion. Therefore, the purpose of this study was to analyze the contribution made by coordination between trunk flexion and lower limb extension to vertical propulsion during STS at four chair heights in the elderly.

II. Methods

1. Subjects

Ten healthy elderly volunteered to participate in this study. Participants did not report any serious neurologic or musculoskeletal condition. All participants received an explanation about the aims and procedures involved in the study and signed an informed consent form before enrollment. The study procedures were approved by the Institutional Review Board of our local ethics committee and were in accordance with the ethical standards of the Declaration of Helsinki.

2. Experimental methods

To examine the influence of chair height, vertical ground reaction forces and distances moved by the shoulder for trunk movement during STS performed at four chair heights adjusted to subjects' knee joint angles were measured. A standard chair without a backrest or armrests was used in this study. The STS was started by asking a participant to sit the chair with bare feet at 15° of dorsiflexion on the ground. The participant was then asked to stand up at their natural speed, stand still for 5 seconds, and sit down. The different chair heights were set (1) 90° knee flexion; (2) 100° knee flexion; (3) 110° knee flexion; and (4) 120° knee flexion. To remove inertial effects of upper limb movements, the participant was instructed to cross arms over his/her chest during the STS. Participants practiced STS twice and then performed three trials at each chair height. The mean value of three trials were recorded for the four different chair heights.

During STS at different chair heights, maximum vertical ground reaction force was measured using a force plate (AMTI, Advanced Mechanical Technology Inc., USA) by sampling at 1000 Hz. Distances moved by shoulders were collected at 100 Hz using six infrared camera of Motion Analysis System (EGL-500, Motion Analysis Corp., USA) during STS with different chair height. Reflective markers were positioned on participants according to the Helen Hayes protocol. Marker motion data was smoothed using a 4 Hz, fourth-order, Butterworth filter, and imported into Visual 3D software (C-Motion Inc., USA) for inverse dynamic calculations.

3. Statistical analysis

The statistical package SPSW ver. 15.0 for Windows was used for the statistical analysis. Demographic data, including age, height, and weight, were analyzed using descriptive statistics. Ground reaction force measurements and distances moved by shoulders were analyzed using reapeated ANOVA. P values of < 0.05 were considered statistically significant.

III. Results

The age of the 10 participants was 71.10 ± 2.81 years and their heights and weights were 161.63 ± 9.99 cm and 64.13 ± 9.09 kg, respectively.

We found statistically significant decrease in distance moved by the shoulder according to ($p<0.05$). Also, there was significant differences between 90° and 120° of knee flexion in hocpairwise comparison ($p<0.05$).

In addition, vertical ground reaction force were not found to depend significantly on distances moved by shoulders ($p>0.05$). However, pairwise comparison showed that vertical reaction force had significantly increased at 90° than 120° of knee flexion ($p<0.05$).

IV. Discussion

In the current study, we analyzed the contribution made by coordination between trunk flexion and lower limb extension

Table 1. Ground reaction forces and distances moved by the shoulder at four chair heights.

	90° knee flexion	100° knee flexion	110° knee flexion	120° knee flexion
Ground reaction force (%BW)	106.80 ± 7.28	103.70 ± 4.85	102.30 ± 6.60	100.90 ± 4.23
Distances moved by the shoulder (㎜) *	456.50 ± 62.09	408.10 ± 55.33	388.90 ± 70.16	370.40 ± 62.79

Values are expressed as the mean±SD. The asterisk (*) indicates significance (p<0.05).

to vertical propulsion during STS at different chair heights in the elderly. Our results show that vertical ground reaction force was not significantly affected by chair height in elderly subjects. However, moved distance of the shoulder was significantly increased on decreasing chair heights in elderly subjects. Our results show trunk flexion could be used as a compensatory mechanism for coping with low chair heights during the lift-off phase of the STS by the elderly.

According to several previous studies, decreasing chair height increases the difficulty of initiating lift-off.[20] Further, functionally impaired elderly require maximum isometric knee strength to rise from lowest successful chair heights.[16] Decreasing chair height lowers initial center of gravity relative to the knee joint, which makes the initiation of lift-off mechanically more demanding.[16,21] Thus, the present results showed that moved distances of the shoulder increased with decreasing chair heights in elderly subjects.

Many studies have reported that STS movement becomes slower during aging due to decreases in the functions of muscles required for hip joint extension,[22] that is, muscles of the erector spine and thigh related to extension and flexion of the hip joint.[23] It is inferred that functional decreases of these muscle groups largely affects movement characteristics, in addition to decreasing physical activity and increasing the risk of fallin.8 As a result, STS tasks initiated with a more vertical thigh orientation and/or a more horizontal shank orientation can be used as a facilitation strategy for patients who need to unload the hips (e.g., patients with osteoarthritis) and/or with limited strength of hip extensor muscles. A more vertical thigh segment orientation can be achieved by using a higher seat height or by adding cushions to a chair.[24] Thus, it appears that momentum transfer may be used as a mechanism for compensating for low chair heights and lift-off difficulties.

The clinical implication of our finding is that low chair heights increases trunk flexion but does not affect vertical ground reaction force in elderly subjects. However, the present study has some limitations. First, our results cannot be generalized due to the small sample size. Second, we cannot explain the other variables, such as, strength and momentum. Therefore, further studies are needed to clarify the situation, and to clarify the relative contributions of strength and momentum in subjects who have difficulty with the STS task.

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