Department of Veterans Affairs

Journal of Rehabilitation Research and Development Vol. 33 No. 4, October 1996
Pages 409–412

Chair rise strategy in the functionally impaired elderly

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Abstract—Many elderly people have difficulty with the common functional activity of rising from a chair. Previous work has identified different strategies that are used to assist the young, the healthy elderly, and the functionally impaired elderly subjects in this activity. For the young and the healthy elderly, modification of these strategies with decreased chair height has been examined. This study examined the changes in chair rise strategy in 18 moderately functionally impaired elderly as the difficulty with rising was increased. The results show that the functionally impaired elderly, when rising from their lowest successful chair compared to a chair of knee height, significantly increase peak hip flexion velocity (11°/sec, $p<0.01$) and time to rise (1.25 sec, $p<0.01$), and significantly decreased their mean center of mass/base of support (COM/BOS) separation at lift-off (1.96 cm, $p<0.05$). These alterations in strategy suggest that while the functionally impaired elderly attempt to increase their momentum in rising by increasing their hip flexion velocity, they simultaneously attempt to increase their stability by taking more time to rise and shortening the distance between their COM/BOS at lift-off. These changes suggest a more conservative strategy with increased difficulty, resulting in decreased success in rising from a chair.

Key words: *biomechanics, chair rise, elderly, function.*

This material is based upon work supported by the Department of Veterans Affairs Rehabilitation Research and Development Service, Washington, DC.

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INTRODUCTION

The ability to stand from the seated position is essential for independent living. Chair rise can be more biomechanically demanding than other activities of daily living, requiring more leg strength and greater joint ranges of motion than walking or stair climbing (1–3). Among the elderly, difficulty with rising from a chair is common, particularly when the seat height is below knee height. It has been estimated that over 2 million non-institutionalized elderly in the United States have trouble with transferring activities (4). Seats that are below knee height are commonly found in areas where elders would be expected to sit (5).

Previous work with young subjects and healthy elderly ones has identified a continuum of strategies for rising from a chair (6). One end of the spectrum has been called the momentum transfer strategy, in which subjects use momentum generated by the trunk to aid in rising (7). The other end of the spectrum has been called the stabilization strategy, in which very little momentum is generated and movements which increase stability are employed. The middle ground is spanned by a strategy that combines aspects of the momentum transfer and stabilization strategies to differing degrees. In controlled protocols, young subjects and healthy elderly subjects used predominantly the momentum transfer strategy (8).

Further work has focused on the compensatory changes in the strategy and biomechanics of rising when difficulty is increased by lowering the seat height (7–10). There is evidence that for some groups of subjects the strategy choice is unchanged with de-

creased seat height, but that the magnitude of the movements within a strategy is increased (6). For example, in the healthy elderly using the momentum transfer strategy, hip flexion angular velocity (a surrogate measure for momentum) was shown to increase with decreased seat height (11). Schultz et al. concluded that subjects who had more difficulty rising from a chair placed more importance on achieving postural stability than did those with less difficulty (12). Changes in chair rise strategies with increased difficulty are unexplored for the elderly with moderate functional impairment. Identifying changes in strategy for those having trouble rising from a chair could aid in determining why this group is failing, and also assist in designing interventions that would improve function.

The purpose of this study was to examine the changes in strategy when elderly persons with moderate functional impairments have difficulty rising from a chair. Based on our previous work, we hypothesized that this group would increase their momentum generation but would also attempt to increase stability as difficulty increased. Specifically, we hypothesized that at their lowest successful chair height, they would increase hip flexion angular velocity to increase momentum generation, and increase time to rise and decrease their center of mass/base of support (COM/BOS) separation at lift-off in order to simultaneously increase stability.

METHODS

Subjects

Subjects were recruited as a cohort of a larger study of the effects of strength training on the functionally impaired elderly. For this study, moderate functional impairment was defined as the inability to descend four consecutive stairs step-over-step, the inability to rise from a 0.33 m-high chair, and a lowest successful chair less than the subject's knee height. Exclusion criteria included blindness, lower extremity amputation; diagnosed neurological disease, such as Parkinson's, stroke with motor and sensory sequelae, or Alzheimer's; Folstein Mental Status score of less than 15 (13); or the inability to stand independently for 1 minute. A total of 100 subjects were recruited into the strength study, of which 59 completed the chair rise task. Of those, 18 fit the criteria of moderately functionally impaired.

Procedure

Following Institutional Review Board approval and signing an informed consent, the elderly group was asked to rise from a randomly ordered series of chairs of different heights to determine the lowest successful height of each subject. Subjects rose, with arms folded, from armless, backless, non-upholstered chairs. Chair heights ranged from 0.33 m to 0.58 m in 0.05 m increments. Knee height was determined by measuring the distance from the floor to the joint line of the knee. A successful trial was defined as the ability to rise to a standing position without unfolding the arms. A rise was called unsuccessful if the arms came unfolded, or if the subject rose from the chair and then fell back.

For the videotaped portion of the testing, all subjects wore outfits specially designed to allow visualization of the joints and not be restrictive to movements. Each subject had reflective markers placed on the skin on their right side at the fifth metatarsal head, lateral malleolus, joint line of the knee, greater trochanter, head of the humerus, temporomandibular joint, seventh cervical vertebra, midline of the forehead, and elbow. Subjects were videotaped with their right side to the camera. The subjects were barefoot, with a force plate under their feet. The original foot position was traced on paper placed over the force plate. The cue to begin to rise was a green light held at eye level. Subjects were given the following command before each trial: "When you see the light, stand up and remain standing," and tested rising from a chair at their knee height and from a chair at the lowest height from which they could rise.

Data Analysis

Videotape data were analyzed using the Peak Performance Motion Analysis System (Engelwood, CO). Each subject was modeled as four linked rigid bodies, one each representing the feet, lower legs, thighs, and trunk, arms, and head. All links moved only in the sagittal plane. The location of the COM and approximate percent of body weight for each segment were calculated from normative anthropometric data (15). The foot, lower leg, and upper leg mass percentages were doubled based on the assumption of left-right symmetry. The mass of the trunk segment includes the arms and head, as well as the trunk. To smooth digitizing noise, the raw kinematic data was filtered using a fourth order, zero lag, digital Butterworth filter with a 3 Hz cut-off frequency.

The time to rise was defined as the time from initiation of the light cue to the time when the COM

reached maximum vertical position. Hip angle was defined by the markers placed on the seventh cervical vertebra and the greater trochanter, and a horizontal line drawn from the greater trochanter. Hip flexion velocity was defined as the angular velocity of the hip angle, determined from differentiation of displacement data using a second order central difference algorithm. COM/BOS separation was defined as the horizontal distance between the location of the lateral malleolus and the whole body COM, minus 4 cm. If lowest successful height of the subjects was at or above their knee height, the data were not analyzed.

All statistical analyses were performed using the SAS statistical software system (SAS Institute, Cary, NC). Paired t-tests were used to compare differences between groups, with a significance level set at 0.05.

RESULTS

For the 18 subjects, the mean (sd) age was 74.8 yrs (±5.1), height 1.73 m (±0.10), and weight 83.3 kg (±10.2). The mean knee height of the subjects was 0.49 m, and the mean lowest successful height was 0.40 m.

As shown on **Table 1,** the mean time to rise was 2.44 sec for the knee height chair and 3.69 sec for the lowest successful chair. The subjects required significantly longer to rise from their lowest successful chair than from the knee height chair (mean=1.25 sec, $p<0.01$). Maximum hip flexion velocity was 76°/sec for the knee height chair and 87°/sec for the lowest successful chair. The maximum hip flexion velocity for lowest successful chair was significantly greater than for the knee height chair (mean=11°/sec, $p<0.01$). The COM/BOS separation at lift-off was 6.2 cm for the knee height chair and 4.3 cm for the lowest height chair. The COM/BOS separation was significantly smaller for the lowest height chair, (1.9 cm, $p<0.03$).

DISCUSSION

The results of this study indicate that elderly persons with moderate functional impairments compensate for increased difficulty in rising from a chair by simultaneously attempting to increase both momentum generation and stability. At their lowest successful chair height, the subjects generated momentum in their trunks by increasing their hip flexion velocity. This increase in momentum should help overcome the increased torque required to be generated by the knee musculature when rising from the lower chair. Increasing momentum generation with increased difficulty was also found in young subjects and healthy elderly subjects as seat height was decreased (11).

While at one time increasing their momentum, the elderly with functional impairment also attempt to increase their stability, as evidenced by increased time to rise and a trend toward decreased COM/BOS separation at lift-off. Increased momentum generation and increased stability are generally at odds, and together produce an inefficient strategy. The relative lack of success in this group appears, at least in part, to be the result of this inefficient strategy. However, whether this strategy is adopted because of physiological impairments (such as loss of strength or sensation) or to overcome physiological impairments is not clear.

Note that the hip flexion velocity was greater for the lowest successful chair, yet time to rise was increased. It would be expected that a lower chair would require more time to rise solely because the distance traversed would be greater. However, the mean differ-

Table 1.
Knee height vs. lowest successful height.

	Time to Rise (sec)	Hip Flexion Velocity (deg/sec)	COM/BOS Separation (cm)
Knee Height Chair: Mean (SD)	2.44 (0.60)	76.2 (17.8)	6.2 (4.9)
Lowest Successful Chair: Mean (SD)	3.69 (1.29)	87.2 (23.2)	4.3 (5.0)
Difference (p value)	−1.25 ($p<0.01$)	−11.0 ($p<0.01$)	1.9 ($p<0.03$)

COM = center of mass; BOS = base of support.

ence in height between chairs was 8.75 cm. If both rises were at the same speed, this difference in distance would account for only a small portion (16 percent, or <0.2 sec) of the difference in time to rise that was measured. Increased hip flexion angular velocity and increased time to rise imply that subjects spent more time repositioning before hip flexion and more time stabilizing afterward. With only a small but significant increase in momentum generation (hip flexion velocity), increased time to rise, decreased COM/BOS separation, and failure at a slightly more difficult chair height, it appears that the elderly with functional impairment place more value on their stability (or perceived safety) than on successfully rising from a chair. This conclusion concurs with that of Schultz with respect to healthy elderly and impaired elderly subjects (12).

Two main factors must be considered when interpreting the results of this study: the population studied and the limitations of the biomechanical analysis. The subjects in this study represent a specific segment of the elderly population, those with moderate functional impairments; therefore, conclusions about this group are not necessarily able to be generalized to the elderly as a whole. However, it is precisely these persons who have difficulty rising from a chair and have the best opportunity for improvement with intervention. As for the biomechanical model, the most important limitation is that the analysis was two-dimensional, and so left/right asymmetries could not be detected. However, asymmetry was minimized by excluding subjects with overt physical or neurologic conditions. Further, no grossly asymmetric movements were observed.

CONCLUSION

In conclusion, when the difficulty of rising from a chair is increased by decreasing the seat height, elderly persons with moderate functional impairments alter their rising strategy by simultaneously increasing their momentum and their stability. This results in a less efficient rising strategy, and therefore less success in rising from lower chairs. Whether this change in strategy is caused by physiologic impairments cannot be determined from the results of this work. However, these results provide a possible means for improvement in function with an intervention that fosters a less conservative strategy.

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