Effects of Body Weight Squats on Balance and Upright Mobility in Participants with Incomplete Spinal Cord Injury

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Background: Few exercise interventions have been designed to improve the lower body strength of individuals with incomplete spinal cord injury (SCI). Such improvements could improve balance and upright mobility. **Objective:** To determine the effects of a 6-week resistance training program using body weight squats (BWS) on measures of balance and upright mobility in participants with SCI. **Design and Setting:** A single-case design with no between subjects comparison was utilized. Testing and training occurred in an exercise facility used by participants with SCI. **Subjects:** Three males and one female with incomplete SCI participated in the case report. Two of the males and the female were classified as American Spinal Injury Association (ASIA) functional category C and the other male was classified as functional category D. **Intervention:** Participants trained 3 days/week for 6 weeks using 3 sets of 10 reps of BWS. **Measurements:** The three outcome measures included a modified Timed Up and Go Test (mTUG), the Berg Balance Scale, and the Sit to Stand Test. **Results:** All participants completed the training, attending a minimum of twice per week, without injury or complaint of pain. Each participant demonstrated marked improvement in all outcome measures. **Conclusion:** Resistance training using BWS can improve lower body strength in individuals with incomplete SCI which in turn can improve their balance and upright mobility.

The health and performance benefits of resistance training are particularly important for populations with limited mobility, including those with spinal cord injury (SCI). Persons with SCI, for the most part, are extremely inactive and consequently at great risk for cardiovascular disease.[1] While those with SCI adapt well to both aerobic and resistance training programs,[2] their access to different training modes and facilities is usually limited. Moreover, arm ergometry and wheelchair ergometry, the most common modes of training among those with SCI, require expensive equipment and often cause upper extremity injuries that impair one's ability to perform daily activities.[3]

A challenge for health professionals who work with those who have SCI is to identify modes of training that are safe and accessible. When first working with individuals with SCI many are surprised by the considerable heterogeneity that exists in the functioning ability of those with incomplete SCI. For example, higher motor functioning individuals with SCI are capable of engaging in functional strength training activities that do not require the use of expensive equipment or skilled technicians.[4] One such activity that paraplegics in American Spinal Injury Association's (ASIA) impairment category D (and some in impairment category C) can perform is the arm assisted body weight squat (BWS). This activity requires rising out of a chair while pulling on bars in front of the chair and lowering oneself back to the seated position using the arms as little as possible. It is hypothesized that the lower body strength gained from BWS would not only facilitate chair transfers but could also improve ambulation with a walker and several other active daily living (ADL) tasks requiring balance. Therefore, the purpose of

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this study is to examine the effectiveness of arm assisted BWSs among those with SCI in improving performance in rising out of a chair, ambulating using a walker, and maintaining balance in selected ADL activities. Should this exercise prove to have the functional benefits expected, it could be an important activity to include in a comprehensive fitness program for selected individuals with incomplete SCI.

Methods

Participants

Three males and one female with chronic (>2 years since injury), incomplete SCI volunteered for the study. To be included in this study, a participant needed to be medically stable, and be able to rise from their wheelchair to a walker with some assistance. Thus, participants needed to belong to impairment categories C or D as defined by the ASIA's Standards for Neurological Classifications. Category C implies motor function is partially preserved below the neurological level and more than half the key muscles below the neurological level have a muscle grade of less than 3, while Category D implies that motor function is partially preserved below the neurological level and at least half the muscles below the level have a grade of 3 or more. Participants were informed of the purpose, benefits, and protocol of the study. Subjects completed an informed consent form, which along with the protocol, was approved by the University of Miami Medical Sciences Subcommittee for the Protection of Human Subjects. Relevant descriptive characteristics are presented in Table 1.

Testing Procedures and Instrumentation

The testing protocols consisted of three ADL performance measures conducted in the following order: a) the Modified Timed Up and Go Test (mTUG); b) the Berg Balance Scale; and c) the Sit to Stand Test. The Modified Timed Up and Go Test measured the time required to rise out of a chair, walk 5 m, turn around, and return to the starting line using a walker. The Berg Balance Scale assessed the ability to maintain balance while performing 14 common, everyday tasks, including moving from sitting to standing, transferring from a chair, turning to look back, etc. The Sit to Stand Test measured the ability to rise out of their chair while relying as little as possible on the use of their arms. The contribution of the arms was assessed using mounted dynamometers.

Training Intervention

Participants underwent 6 wk of functional resistance training, performed three times weekly on non-consecutive days. The participants worked up to a target of 3 sets of 10 repetitions of the BWS. The exercise was performed from the participant's chair which was situated in the Seated Dip Station of the Equalizer 7000 Multi-Station Exercise System. The station was modified by inverting the vertical bars so that they pointed upward and would give the participants upright bars to hold. We instructed the participants to gently grasp the vertical bars, rise out of the chair relying mostly on the legs and pulling minimally with the arms.

Results

All participants completed the six weeks of resistance training, attending a minimum of twice per week, without injury or complaint of pain, and demonstrating marked improvement throughout the training.

Participant 1. Participant 1 had the lowest level of motor functioning which prevented him from completing the mTUG test. However, on the pretest he required considerable help in rising from the chair and was unable to take a single step, but on the posttest he was able to get out of the chair unassisted and take a few steps. While difficult to quantify the improvement, it was notable. Participant 1's initial score on the Berg Balance Scale was 7 and his posttest score was 19, which reflected an improvement in the quality and quantity of tasks performed. As expected, the greatest improvement was observed on the Sit to Stand Test. On the pretest, the participant was only able to rise from the chair depending heavily on the use of the arms with the knees at an angle of 125 degrees of extension. On the posttest, he was able to rise from the chair at an angle of 110^{o} of knee extension with a significant reduction in the pulling force of the arms (i.e. 86.5 lb on the ascent and 55 lb on the descent).

Participant 2. Participant 2 had a pretest time of 2 min and 3 s on the mTUG and on a posttest time of 1 min and 32 s (25% improvement). The participant's score on the Berg Balance Scale improved from a pretest score of 11 to a posttest score of 14. The pretest scores on the Sit to Stand Test were not compared to the posttest scores because the investigators realized, after the fact, that participant 2 had used a technique on the pretest which greatly underestimated the score.

Participant 3. Participant 3's pretest time on the mTUG test was 1 min and 25 s and her posttest time was 1 min and 13 s (14% improvement). The participant's pretest score on the Berg Balance test was 12 and the posttest score was 21. As expected the greatest improvement was seen in the Sit to Stand Test. The participant demonstrated 18% and 12% improvements on the ascent and descent, respectively.

Participant 4. Participant 4 had a pretest time of 1 min and 29 s on the mTUG test and a posttest time of 1 min and 11 s (20 % improvement). His pretest score on the Berg Balance Scale was 25 and his posttest score was 43. On the Sit Up and Stand pretest, he began with a combined pulling force of 20 lb on the ascent and 26 lb on the descent. On the posttest, he showed marked improvement using only an average of 7 lb on the ascent and 14 lb on the descent. Notably, on one posttest trial he rose without the use of the arms and on two trials he rose using only one hand on the ascent.

Discussion

A limitation of the study was the small sample size and the considerable heterogeneity in the functional ability of the participants which made it appropriate to report the results in a case study format using descriptive statistics. However, an examination of the descriptive data suggests that all the participants showed large percent improvements in gait speed, stability, and the ability to rise out of a chair. It is hypothesized that with severe restrictions in mobility (which can result from aging, disease, or injury) that there is a rapid, substantial loss in neuromuscular control. However, despite this immediate substantial loss in neuromuscular control, the ability to regain much of this control is present in many cases.[5] At the time of this writing there were no published studies that investigated the effects of resistance training on the lower body strength of parapalegics. Nor were there any studies related to the effects of lower body resistance training on the performance of ADLs in persons with incomplete SCI. One of the authors of this study, however, conducted an investigation of the effects of an upper and lower body resistance training program on strength and ambulatory performance.[4] This study revealed that persons with SCI can achieve significant improvements in strength in both the lower body and upper body. Moreover, these improvements in strength could improve the time required to ambulate a short distance with the assistance of a walker.[4] While there are no published studies investigating the effects of resistance training on participants with SCI, there is a small body of related literature investigating the effects of resistance training on the strength and performance of individuals with peripheral neuropathy. For example, Aitkens et al.[5] found that a low to moderate intensity resistance training program improved both upper and lower body strength in those with Charcot-Marie-Tooth (CMS) syndrome, the most common peripheral neuropathy. Similarly, Chetlin et al.[6] found that a 12 wk, home based resistance training program improved strength and ADLs equally in men and women with CMS.

Conclusion

The very large percent changes achieved by each of the participants suggests that BWSs are of value in the conditioning of individuals with incomplete SCI. The results indicate that BWSs can improve both balance and mobility in this population. Future research should include a larger sample size of both ASIA categories. Also, future research might study both strength and performance measures over a longer period of time.

Table 1. Characteristics of the Four Participants with Incomplete Spinal Cord Injury

Participant	Age	Gender	Weight	Level of Injury	ASIA* Score	Years Post Injury
1	46	M	203.8	C5	C	19
2	42	M	196	L2-L5	C	4
3	42	F	137.8	C4-C5	C	20
4	45	M	161	C5-C6	D	2

*American Spinal Injury Association

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