LOWER LIMB STRENGTH CAPACITY AND MOMENT DEMANDS DURING THE LANDING PHASE OF RECOVERY FOLLOWING A FORWARD FALL: COMPARISON BETWEEN SINGLE AND MULTIPLE STEPPERS

1Christopher P Carty, 1Neil Cronin, 1,2Glen Lichtwark, 1Peter Mills and 1Rod Barrett
1Griffith Health Institute, Griffith University, Queensland, Australia & School of Physiotherapy and Exercise Science, Griffith University, Queensland, Australia, 2School of Human Movement Studies, University of Queensland, Queensland, Australia

SUMMARY
The purpose of this study was to investigate the differences in moment demands on the stepping lower limb during the landing phase of recovery from a forward fall between older adults that could recover with a single step and those who could not, and to assess whether strength differences were a factor limiting the ability to recover. Eighty-five, older adults were released from a range of forward lean magnitudes. Data were collected using a 3D motion analysis system and two force platforms. Isometric strength across a range of joint angles were assessed at the ankle, knee and hip joints using an isokinetic dynamometer. Peak hip extension torque during the landing phase was significantly lower in multiple compared to single steppers. Task specific measures of strength showed that multiple steppers were weaker at all joints compared to single steppers. Findings suggested that the lower limb joint angles adopted during the landing phase of balance recovery were not optimal for force generation. Proportional calculations of isometric strength at task specific angles relative to the moment demands during balance recovery revealed that strength may be limiting factor in the ability to recovery from a forward fall with a single step.

INTRODUCTION
Falls are a leading cause of morbidity and mortality in older adults [1]. The ability to recover from a forward fall relies on rapid translation of the stepping foot to a position anterior to the whole body centre-of-mass and the subsequent generation of sufficient recovery limb joint moments [2]. It is known that lower limb strength is an independent predictor of a future fall in older adults [3], however there is conflicting evidence regarding the relative importance of lower limb strength in the ability to recover from a forward fall in older adults. The purpose of this study was to investigate the differences in moment demands on the stepping lower limb during the landing phase of recovery from a forward fall between older adults that could recover balance with a single step and those who could not, and to assess whether strength differences were a factor limiting the ability to recover with a single step.

METHODS
Eighty-five healthy, older adults (47 men, 38 women; mean ± SD: age, 70±3 years; height, 1.67±0.1 m; mass, 76.2±12.6 kg) that were randomly selected from the electoral roll participated in the study. The balance recovery task involved the release of participants from a range of initial static forward lean magnitudes that corresponded to 15, 20 or 25% of body weight (BW) on a force transducer placed in series with the horizontal restraint cable. Participants were instructed to recover their balance by taking a single step. Three trials were performed in a random order at each lean magnitude. Trajectories of 57 reflective markers attached to the head, trunk, pelvis, and upper and lower limbs were recorded at 200 Hz using a 10-camera 3D motion analysis system (Vicon Motion Systems, USA). Ground reaction force data were acquired simultaneously at 1kHz using two piezoelectric force platforms (Kistler Instruments, USA). Kinematic analysis of 3D marker trajectories and inverse dynamic calculations were performed using OpenSim [4].

The landing phase of recovery was defined from the time the stepping foot contacted the ground until the time of maximal knee joint flexion in the stepping lower limb following foot contact. Participants were classified as either single steppers, multiple steppers or those that used a mixed stepping strategy (a mixture of single and multiple steps across the three trials). Participants that utilised a mixed stepping strategy were excluded from the analysis.

Isometric strength of the ankle, knee and hip flexors and extensors in the stepping lower limb were assessed at five angles throughout the available range of motion using an isokinetic dynamometer (Biodex System 4, Biodex Medical Systems, USA). For each trial participants were instructed flex or extend the joint of interest “as hard as they could” for three seconds, with verbal encouragement provided to maximize effort. Isometric torque measurements at each joint were adjusted to account for the weight of the dynamometer attachment and lower limb segments distal to the joint being tested. Peak isometric strength torque (i.e., the peak value on the strength curve) and relative isometric torque (i.e., the torque at corresponding to the angle whereby maximal torque during the landing phase of balance recovery was required) values were then extracted from each strength curve.

Data were analysed using Matlab (v2007a, The MathWorks, Inc., USA) and SPSS (v13, SPSS, Inc., USA). Analysis of variance were used to assess differences in lower limb torque production during the landing phase of balance recovery between single and multiple steppers. A repeated measures general linear model was used to assess strength differences between peak and relative measures of isometric strength.
(within subject factor) and to assess strength differences between single and multiple steppers (between subject factor). Data were presented as the mean ± one standard error of the mean (SEM). Significance was accepted at $p < 0.05$.

RESULTS AND DISCUSSION
Representative data from the balance recovery task and strength testing session are presented in figure 1.

Figure 1: (Upper panels) Joint kinetic and kinematic measurements of the stepping lower limb from toe off onwards. The vertical dotted line represents foot contact. (Lower panels) Strength curves for the ankle, knee and hip.

The 20%BW lean magnitude resulted an approximate split of single ($n = 35$) and multiple steppers ($n = 30$) and therefore comparison were made at this magnitude. The remaining participants that utilised a mixed strategy were excluded. Peak hip extension torque during the landing phase of balance recovery was significantly lower in multiple compared to single steppers (Figure 2). There was also a tendency for ankle and knee extension torques to be lower in multiple compared to single steppers (not significant).

Figure 2: Peak ankle, knee and hip joint extension torque measured during the landing phase of balance recovery.

Relative isometric extension strength was significantly lower than peak isometric extension strength at all joints (Figure 3) suggesting that the joint angles adopted by participants during the landing phase of balance recovery were not optimal for force production at any given joint.

Multiple steppers were significantly weaker than single steppers in isometric measurements of ankle, knee and hip extension strength (Figure 3). When relative measurements of ankle, knee and hip extension strength were assessed relative to the peak torques measured during the landing phase of balance recovery there was no main effect of group membership (single or multiple stepper) at any joint. This finding suggests that participants utilised a proportional amount of their available strength during balance recovery and that an increase in relative strength may increase the likelihood of being able to recover with a single step.

Figure 3: Peak and relative measures of isometric strength at the ankle, knee and hip for single and multiple steppers.

CONCLUSIONS
Findings suggest that the angles adopted at the ankle, knee and hip joints during the landing phase of balance recovery are not optimal for force generation. Proportional calculations of isometric strength at task specific angles relative to the moment demands during the landing phase of balance recovery revealed that strength may be limiting factor in the ability to recovery from a forward fall with a single step.

ACKNOWLEDGEMENTS
This work was supported by the National Health and Medical Research Council (Grant number: 536508).

REFERENCES