EFFECTS OF A SINGLE STEP REQUIREMENT ON BALANCE RECOVERY MANEUVERS IN YOUNG AND OLDER ADULTS

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INTRODUCTION

Step responses are often needed to prevent falls following large balance disturbances [1]. Numerous researchers have studied age effects on step responses using forward lean-and-release balance perturbations (e.g. [2,3]). To simplify testing and data analysis, these studies often require participants to take a single step in response to the balance perturbation. Compared to a step response without this constraint, instructions limiting the number of steps do not impact balance recovery among young adults [4]. However, age reduces the ability to recover balance with a single step [5]; therefore requiring older adults to take single steps may elicit unnatural responses in this population.

The goal of this study was to compare step responses with and without the single step requirement in young (YA) and older adults (OA). We hypothesized that: (1) OA, compared to YA, would use a step response with reduced landing phase ankle joint force; and (2) the single step requirement would cause OA, but not YA, to use larger landing phase ankle joint force in comparison to step responses without the single step constraint.

METHODS

Participants. Twelve healthy YA (mean age 25 ± 3.0 years) and thirteen healthy OA (mean age 71 ± 2.8 years) male participants were recruited and screened for major musculoskeletal, cardiovascular, and neurological disorders. Participants provided informed consent as approved by the institution's human subjects committee.

Tasks. Participants performed ten step responses facilitated by forward lean-and-release balance perturbations. No instructions were given to participants during the first five trials (instruction group #1). During the last five trials, participants were instructed to take a single step with the dominant limb (instruction group #2).

Measurements. Reaction forces and moments were sampled at 1 kHz from force plates (AMTI, Watertown, MA, USA) placed under initial left and right foot stance positions; and under the step foot landing position. Foot and shank positions were sampled at 120 Hz with a Vicon motion capture system (Vicon, Los Angeles, CA, USA) tracking reflective markers placed bilaterally on the second metatarsal, calcaneous, lateral malleolus, tibia, and femoral epicondyle. Manual foot and shank anthropometric measures were taken by the investigators with a measuring tape and callipers.

Data Analysis. An inverse dynamics algorithm was used to determine ankle joint dynamics during the landing phase of each response. Model inputs included force plate, motion capture, and anthropometric data. Model outputs included ankle joint force profiles, which were used to calculate maximum landing phase ankle joint forces in the proximal-distal (PD), medial-lateral (ML), and anterior-posterior (AP) directions.

Statistical Analysis. Statistical analysis was performed with SPSS (SPSS, Inc., Chicago, IL, USA). A multivariate analysis of variance (MANOVA) was performed on all outcome variables, with instruction group (GRP) as the within-subject factor and age group (AGE) as the between-subject factor. Follow-up univariate tests were performed on individual variables demonstrating a significant main effect or interaction. Comparisons with p-values <0.05 were considered statistically significant.

RESULTS and DISCUSSION

The MANOVA revealed a significant overall AGE effect on maximal ankle joint landing force ($p<0.05$). Follow-up univariate tests on this result revealed significant AGE effects on maximal ankle force in the proximal (age-related decrease: $p<0.05$) and posterior (age-related decrease: $p<0.01$) directions. The MANOVA failed to reveal a significant AGE x GRP effect ($p = 0.09$); however, individual univariate tests revealed a significant GRP effect on maximal posterior force (larger for single step condition: $p<0.05$). Follow-up paired t-tests within each AGE group revealed that this effect occurs in OA ($p<0.023$) but not YA ($p = 0.438$). Results are summarized in **Figure 1**.

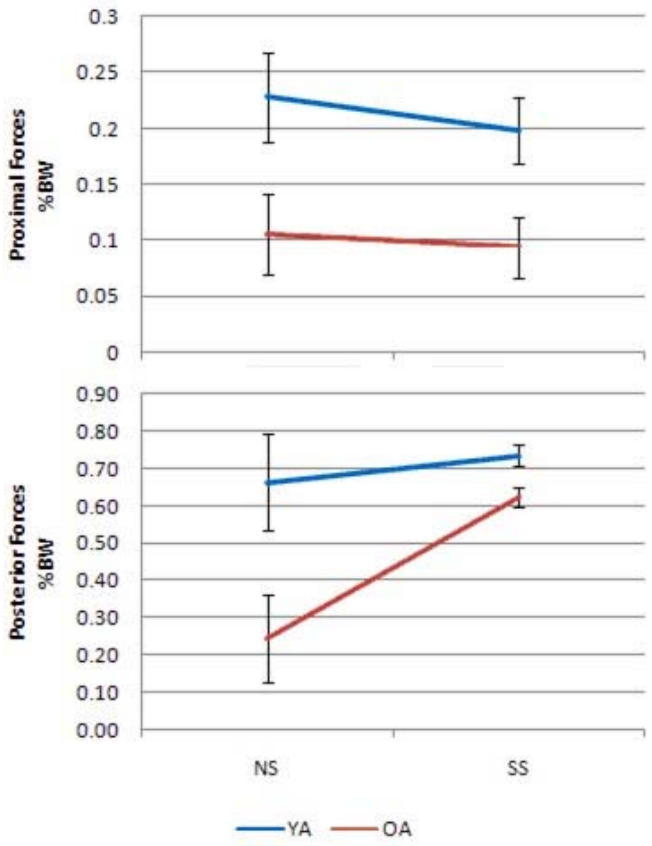

Figure 1: Maximal ankle joint landing forces for Natural Step (NS) and Single Step (SS) conditions.

These results suggest that OA, compared to YA, use smaller ankle joint forces when stepping to arrest a fall. This supports our first hypothesis that an age-related decline would be observed in landing phase ankle forces. This effect occurred in the proximal and posterior directions, suggesting an age-related decrease in the braking forces associated with the stepping maneuver. This effect is likely related to the tendency of OA to take multiple steps, which are smaller in magnitude and often not sufficient to arrest the body's forward momentum [6].

The non-significant AGE x GRP interaction suggests a similar overall GRP effect in each AGE group. This does not support our second hypothesis that OA, but not YA, would generate larger landing forces with a single step requirement. However, we observed a significant GRP effect when considering only maximal posterior ankle force, suggesting larger forces for the single step condition. Follow-up testing revealed that this effect only occurred in OA, suggesting that OA may alter their strategy based on stepping instructions. Although not specifically quantified here, OA may have used larger step lengths to ensure a successful recovery [5], a strategy likely associated with larger biomechanical demands [2]. The absence of this tendency in YA is consistent with studies demonstrating no instructional effects in YA [4].

CONCLUSIONS

This study demonstrates an age-related decrease in ankle joint landing forces used during a balance-restoring step response. Overall, instructions limiting the number of steps did not have an effect on ankle joint forces in YA or OA. However, OA appear to use larger maximal posterior ankle force when asked to take a single step, an effect not observed in YA. This suggests that imposing a single step requirement may elicit unnatural responses among OA during step response balance testing paradigms.

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