# CORRELATION BETWEEN MUSCLE STRENGTH AND BALANCE CONTROL WHEN NEGOTIATING OBSTACLES

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## INTRODUCTION

Falls and fall-related injuries are among the most serious and common medical problems experienced by the elderly. Hip fractures account for a large share of the disability, death, and medical costs associated with falls [1]. Falling to the side was found to be one of the important risk factors for hip fracture [2]. A better understanding of the increasing incidence of sideways falls with aging is of great importance in preventing hip fracture in the elderly. Imbalance and tripping over obstacles during gait were reported as two of the most common causes of falls in the elderly [3,4]. Greater motion of body segments during obstacle crossing results in greater excursion of the whole body's center of mass (COM) and perturbs balance maintenance. This requires adequate muscle strength of the lower extremities to support the whole body and maintain appropriate posture. However, the decline in muscle strength that accompanies aging has been recognized and may result in inadequate control of the COM and, subsequently, falls. Thus, to enhance our development of strategies aimed at reducing falls in the elderly, the purpose of this study was to understand the association between declining muscle strength due to aging or pathology and the control of the COM during balance-challenging ambulatory tasks, such as negotiating obstacles.

## METHODS

Fifteen subjects were recruited for this study. The subject population included six healthy young adults (mean age, 30 years), six healthy elderly adults (mean age, 70 years ), and three elderly patients (mean age, 75 years) with imbalance problems. Isometric muscle strength of both lower limbs were measured with a Cybex II isokinetic dynamometer. Isometric abduction strength of the hip joint was measured in a standing position. Isometric extension strength of the knee joint was measured in a seated position at 60 degrees of knee flexion. Isometric plantarflexion strength of the ankle joint was measured in a seated position at 20 degrees of knee flexion and neutral ankle position. Three trials were performed on each muscle group, and the peak value was recorded. Next, a set of 27 reflective markers was placed on bony landmarks before the gait trials were begun. Subjects were then instructed to perform unobstructed level walking and to step over obstacles of heights corresponding to 2.5%, 5%, 10%, and 15% of the subject height, all at a comfortable self-selected speed while barefoot. Unobstructed level walking was performed first. The obstacle height was randomly selected for each trial. Three successful trials were collected for each obstacle height. The obstacle consisted of two adjustable upright standards and a padded crossbar. The subjects wore a safety harness with chest and seat components which was attached to a trolley system secured to the ceiling to protect the subjects from any accidental falls. A six-camera ExpertVison system was used to collect 3-D marker trajectory. Ground reaction forces of the trailing and leading feet were collected from two force plates. A 13-link biomechanical model of the human body, consisting of six links for the lower extremities, four links for the upper extremities, one for the pelvis, one for the trunk, and one for the head, was used to compute the kinematics of the whole body's COM from the weighted sum of the COM of every segment of the body. The effect of obstacle height on the displacement of the whole body's COM in three orthogonal directions and on maximum anterior-posterior and medial-lateral distances between the COM and corresponding (i.e., in time) center of pressure (COP) during the crossing stride were studied. Pearson correlation and regression analyses were used to assess the strength of association between the isometric muscle strength and movement of the COM.

## RESULTS

Healthy young adults demonstrated greater isometric strength in all three muscle groups than the healthy elderly adults (Fig. 1). The difference was greatest for the hip abductors. Furthermore, a significant strength decrease in all three muscle groups was found in elderly patients when compared to the healthy elderly adults. Anterior-posterior (A-P) displacements of the COM were greatest in healthy young adults and medial-lateral (M-L) displacements were greatest in elderly patients when stepping over obstacles of all four heights (Fig. 2). The greatest A-P distances between the COM and COP of the stance foot were found in the healthy young adults. A significant correlation was found between the isometric strength of the knee extensors and the A-P displacement of the COM and between the isometric strength of the hip abductors and the M-L displacement of the COM (Table 1). These associations were more significant as the obstacle height increased. There was a significant correlation between the isometric strength of the ankle plantarflexor and the maximum A-P distances between the COM and COP of the stance foot (Table 1).

## DISCUSSION

Strong relationships between lower extremity strength and balance control were identified in this study. These associations become more significant when negotiating higher obstacles. The decline in hip abductor strength due to aging or pathology significantly increased the M-L displacement of the COM. This may be a contributing factor to the occurrence of sideways falls in the elderly, which have been shown to be the most likely to cause a hip fracture [1,2]. Appropriate strength training of the hip abductors may be beneficial for the elderly and patients with balance problems in order to reduce their risk of hip fracture.

## REFERENCES

(1) Hayes WC et al. *Bone* 18:77S-86S. (2) Greenspan SL et al. *Am J. Med* 104:539-45, 1998. (3) Nevitt M et al. *Falls, Balance and Gait Disorders in the Elderly*, 1992. (4) Tinetti ME et al. *N Engl J Med* 302: 1055-1059, 1989.

## ACKNOWLEDGEMENTS

This study was supported by NIH (AG05770 & HD07447) and Mayo Foundation. Dr. Robert Brey is from the Department of Otorhinolaryngology, Mayo Clinic. The assistance of Brian Kotajarvi, Chris Hughes, Ann Walker, and Diana Hansen in data collection and reduction is greatly appreciated.

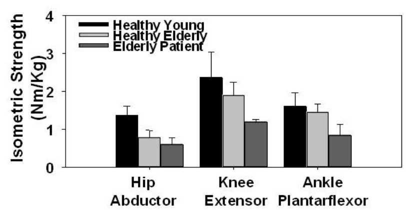


**Figure 1. Isometric strength**

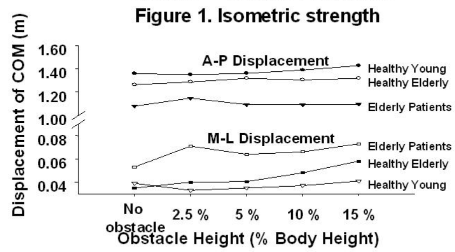


**Figure 2. Displacement of Body Center-of-Mass**

**Table 1. Pearson Correlation Coefficients between Isometric Muscle Strengths and Gait Measurements**

| Obstacle Height | 0% | 2.5% | 5% | 10% | 15% |
|---|---|---|---|---|---|
| Knee extensor strength vs. A-P disp. Of the COM | 0.49 | 0.61 * | 0.64 * | 0.69* * | 0.72 ** |
| Hip abductor strength vs. M-L disp. Of the COM | -0.46 | -0.58 * | -0.59 * | -0.65 ** | -0.70 ** |
| Ankle Plantarflexor strength vs. A-P dist. Between the COM and COP | 0.50 | 0.62 * | 0.57 * | 0.67 * | 0.53 * |

*: p<0.05; **: p<0.01.