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Strength or power, which is more important to prevent slip-related falls?

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ABSTRACT

Falls are a serious health and medical concern facing older adults worldwide. Both muscle strength and power have been related to falls among older adults. The primary purpose of this study was to identify which one of these two muscular performances is more important in preventing a slip-related fall. Twenty-six healthy young adults participated in this study. Their muscle strength (torque) and power capacities were assessed at the right knee under maximum voluntary isometric (flexion and extension) and isokinetic (concentric extension and flexion at three different contraction speeds: 60 deg/s, 120 deg/s, and 180 deg/s) contractions, respectively. They were then subjected to an identical and unannounced slip during gait on a treadmill under the protection of a safety harness after walking regularly for five times on the treadmill. Accuracy of predicting slip outcome (fall vs. recovery) was examined for each muscle performance measurement using logistic regression. Results showed that overall the joint power capacity measurements predicted the slip outcome among these subjects with higher accuracy than did the joint torque capacity measurements. Such results suggested that muscle power could be more closely related to a fall initiated by a slip during gait. The findings from the present study could provide guidance to identify individuals at increased risk of falling using the joint power capacity measurement and to design effective fall prevention training paradigms aiming at maximizing muscle power among older adults and others with physical disabilities.
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1. Introduction

Falls present a significant medical, societal, and economic challenge in the growing population of elderly (Tinetti, 2003). Slip-related falls account for about 40% of all outdoors falls among seniors, which often lead to grave consequences such as hip fractures (Luukinen et al., 2000; Stevens, Corso, Finkelstein, & Miller, 2006). It is, therefore, of utmost importance to understand the causes contributing to falls, to develop efficient risk assessment tools, and to design effective interventions for reducing falls.

It is well known that the aging process is associated with a progressive decline in overall mechanical muscle function due to the loss of skeletal muscle mass (Goodpaster et al., 2006), decrease in the tendinous stiffness (Reeves, 2006), and the reduction of the specific tension of the skeletal muscle (Yu, Hedstrom, Cristea, Dalen, & Larsson, 2007). A direct reflection of such decline in neuromuscular function is reductions in the strength and power that skeletal muscles can produce. From

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a functional perspective, such deteriorations progressively limit older adult's capability of carrying out daily motor activities and increase their risk of falls (Caserotti, 2010).

Muscles, particularly the lower limb muscles, are actuators to terminate a falling following the loss of balance when one encounters an external perturbation (like slips or trips) during locomotion. It is intuitive that muscle strength has been identified as one of the important predictors for falls in elderly (Horlings, van Engelen, Allum, & Bloem, 2008; Moreland, Richardson, Goldsmith, & Clase, 2004). The importance of lower extremity strength in recovering from an induced slip (Cham & Redfern, 2001; Pai, Yang, Wening, & Pavol, 2006) and trip (Pavol, Owings, Foley, & Grabiner, 2002; Pijnappels & Van der Burg, 2008) has been demonstrated as those with low strength fall due to the inability to support the body during the reactive stepping. In another study, it was reported that falls are related to muscle weakness with an odds ratio as high as 4.4 among older adults (AGS, 2001).

Emerging evidence suggests that muscle power (the product of muscle strength and contraction velocity) may also play an essential role in preventing falls (Evans, 2000). It was found that the loss of muscle power due to normal aging has greater functional impact on mobility than loss of strength among older adults (Bean et al., 2003; Foldvari et al., 2000). Decline with aging in muscle power is more visible than in strength (3–4% vs. 1–2% per year) (Skelton, Greig, Davies, & Young, 1994). It was documented that senior fallers demonstrated less power in the lower limbs than their non-faller counterpart (Orr et al., 2006; Skelton, Kennedy, & Rutherford, 2002), suggesting that lower muscle power may be an early indicator of the risk of falls (Orr et al., 2006). Muscle power requires the integration of muscle strength with the ability to develop contraction velocity (Kraemer & Newton, 2000). Since falls usually occur in a very short duration (approximately 200–500 ms) after a perturbation (Pijnappels, Bobbert, & van Dieen, 2005; Yang, Bhatt, & Pai, 2009), the reactions to the perturbation must be sufficiently quick. Post a slip, the slipping limb needs to generate flexor moment to pull the base of support backward close to the body's center of mass to restore stability (Cham & Redfern, 2001; Yang & Pai, 2010), while the recovery limb must provide sufficient limb support rapidly to impede the falling (Pai et al., 2006). From this perspective, muscle power could be more essential than muscle strength to regain balance during an impending fall initiated by a slip.

However, no study, to our best knowledge, has been carried out to investigate which one between muscle strength and power is more critical to prevent falls, specifically slip-related falls. This is not a trivial issue given the fact that more and more exercise-based muscle strengthening programs are developed to reduce or prevent falls among older adults (Granacher, Muchlbauer, & Gruber, 2012; Horlings et al., 2008; Moreland et al., 2004). Most of these training programs adopted relatively slow movement velocity and high training intensity to improve muscle strength (Fry, 2004). If muscle power is more critical to prevent falls than muscle strength, the preventive effort and the limited fall-prevention resources should be distributed to develop paradigms aiming at enhancing the muscle power in the older population. This shift will make the utilization of the limited health-care resources more efficient.

The primary purpose of this study was, therefore, to determine whether the knee joint strength (torque) or power is more closely related to falls after a slip induced in gait. We hypothesized that the knee joint power is more important to prevent a slip-related fall during gait than the joint torque. The findings from this study would provide valuable guidance to screen those who are subject to high risk of falls and to develop cost-efficient, yet effective, training programs to prevent falls from happening among older adults or individuals with movement dysfunctions.

2. Methods

2.1. Subjects and experimental protocol

Twenty-six young adults (23.8 ± 4.3 years, Table 1) participated in the experiment. To eliminate the potential influence of obesity on the findings of this study, only those with a body mass index less than 30 kg/m^2 were recruited. All participants were free of any clinically significant history of musculoskeletal disorders, neurological disorders, orthopedic conditions, and cardiovascular conditions. All of them gave written informed consent which was approved by the Institutional Review Board. After being evaluated for the muscle strength and power, they were exposed to an identical slip perturbation when walking on a treadmill.

2.2. Evaluation of muscle strength and power

The important role of knee joints in resisting slip-related falls has been analytically (Yang & Pai, 2010) and empirically proven (Cham & Redfern, 2001). The strength (joint torque under isometric condition) and power (joint power under isokinetic

Table 1
The demographics in mean ± SD for both groups (fall vs. recovery).

Groups	Recovery (n = 14)	Fall (n = 12)	p value	Pooled (n = 26)
Age (years)	23.4 ± 4.4	24.3 ± 4.3	0.637	23.8 ± 4.3
Gender (female)	6 (42.9%)	3 (25.0%)	0.340*	9 (34.6%)
Height (cm)	163.4 ± 8.2	163.1 ± 7.3	0.928	163.3 ± 7.6
Mass (kg)	60.7 ± 14.0	65.2 ± 11.7	0.389	62.7 ± 12.9
BMI (kg/m^2)	22.4 ± 3.5	24.4 ± 3.3	0.156	23.3 ± 3.5

* The χ^2 test was used.

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