THE RELATIONSHIPS OF FUNCTIONAL MOBILITY WITH MUSCLE STRENGTH AND PROPRIOCEPTION AMONG OLDER ADULTS

Qi wang[1], Yanhao Liu[2], Qipeng Song[2], Dewei Mao[2], Xinrui Zhang[3]

[1] Beijing Sport University, Beijing, China
[2] Shandong Sport University, Shandong, China
[3] Universiti Putra Malaysia, Selangor Darul Ehsan, Malaysia

Functional mobility impairment is the most common risk factor for falls among older adults, with three potential factors (muscle strength, tactile sensation, and proprioception) being responsible for their functional mobility. This study aims to compare functional mobility and the three factors, and investigate their relationships among older adults of different ages. One hundred sixty-six participants were categorized into younger (YG), middle (MG), or older (OG) aged groups. The OG has worse functional mobility, muscle strength, tactile sensation, and proprioception than YG and MG. In the YG and MG groups, both proprioception and muscle strength showed correlations with functional mobility. In the MG, only muscle strength demonstrated a correlation with functional mobility. Rehabilitation and exercise are recommended to improve proprioception and prevent falls in older adults.

KEYWORDS: falls, older adults, sensation.

INTRODUCTION: Falls pose a major threat to the health of older adults and are one of the leading causes of injury and accidental death. Statistics show that more than 30 percent of adults aged 60 and older fall at least once a year(Gerards, McCrum, Mansfield, & Meijer, 2017), and that percentage rises to 60 percent among those aged over 80(Gschwind et al., 2013). Functional mobility impairment is one of the most common risk factors contributing to falls(Muir, Berg, Chesworth, Klar, & Speechley, 2010). Changes in the properties of the central nervous system and neuromuscular system with age may negatively affect functional mobility in older adults (Gschwind et al., 2013). The Timed Up and Go test (TUG) is a frequently employed evaluation tool for assessing the functional mobility of older adults, helping in the prediction of fall risk. Muscle strength, tactile sensation, and proprioception emerge as three potential factors influencing the functional mobility of older adults(Song et al., 2021). Muscle strength is then essential to maintain an upright posture and dynamic balance (Gouveia É et al., 2020). Cutaneous mechanoreceptors in the foot soles offer essential feedback to the balance control system, contributing to the maintenance of functional mobility(Shaffer & Harrison, 2007). Proprioception is the internal sense of body position, and is also essential for regulating balance and generating and maintaining a precise movement pattern or gait(Henry & Baudry, 2019). However, the relationship between muscle strength(Gouveia É et al., 2020; Muehlbauer, Gollhofer, & Granacher, 2012), tactile sensation(Menz, Morris, & Lord, 2005; Ünver & Akbaş, 2018), and proprioception(Amin & Herrington, 2014; X. Chen & Qu, 2019) with functional mobility remains controversial. These controversies may be due to the different relationships between functional mobility and underlying factors in various age groups. Therefore, this study aims to compare functional mobility and the three factors, muscle strength, tactile sensation, and proprioception, and investigate their relationships among older adults of different ages.

METHODS: 166 older adults were recruited and divided into younger- (YG, n=56, female=29, 65.45±2.1 years, 1.64±0.08 m, 68.78±10.94 kg, and 24.39±3.18 kg/m^2), medium- (MG, n=57, female=28, 74.86±3.11 years, 1.62±0.07 m, 65.07±9.26 kg, and 24.72±3.23 kg/m^2) or oldest- (OG, n=53, female=36, 85.21±2.74 years, 1.60±0.07 m, 62.81±7.83 kg, and 24.56±2.73 kg/m^2) groups according to age.
The TUG, muscle strength, tactile sensation, and proprioceptive factors were assessed by all participants. The TUG test collected time when participants stood up from a standard armchair, walked a distance of 3 meters, turned around, walked back to the chair, and then sat down again. The strength of ankle plantar/dorsiflexor and hip abductor muscles was recorded by the IsoMed 2000 strength testing system (D. & R. Ferstl GmbH, Hemau, Germany). During the

ankle muscle strength test, ankle motion ranged from 5° of dorsiflexion to 30° of plantarflexion. During the hip muscle strength test, the range of motion of the hip joint is from 0° to 30° of abduction. Participants were asked to perform a maximal isokinetic plyometric test at an angular velocity of 10°/s, with at least a 2-minute rest period between two consecutive tests. Three tests were conducted in each direction. The tactile sensation at the great toe, 1st and 5th metatarsal heads, arch, and heel was measured with a set of Semmes-Weinstein monofilaments (North Coast Medical, Inc., Morgan Hill, CA, USA). The six sizes of monofilaments used here were 2.83, 3.61, 4.31, 4.56, 5.07, and 6.65. Pressure was applied until the monofilament formed a C-shaped bend (90° bend). These touches were performed for 1 second and repeated twice. The minimum monofilament gauge determined the sensitivity threshold. The proprioception of ankle plantarflexion/dorsiflexion and knee adduction/abduction was tested using the proprioceptive testing device (Toshimi, Jinan, Shandong, China). The participants sat in a height-adjustable chair with both feet positioned on the testing pedal, hips and knees flexed at a 90° angle, and ankles in a neutral position. As soon as the passive motion was perceived, the participants immediately pressed a hand-held switch to stop the pedal. The proprioception threshold was defined as the angle of pedal rotation when the passive motion was perceived. Three trials were recorded in each direction. All analyses were performed in SPSS 26.0. The normality of the data distribution was checked using the Shapiro-Wilk. One-way ANOVA (normality) or Kruskal-Wallis H tests (non-normality) were used to compare differences between the three groups. If there were significant differences between groups, post hoc analyses were performed using Bonferroni. Pearson (normality) or Spearman (nonnormality) correlations were used to determine the relationship between TUG and muscle strength, tactile sensation, and proprioception in each group. The height of the participants was also adjusted as a covariate.

RESULTS: The descriptive characteristics are shown in Table 1. A lower TUG score was observed in the YG (p<0.001) and MG (p<0.001) compared to the OG. Compared to the YG, the MG had less muscle strength in ankle plantarflexor (p=0.010) and hip abductor (p=0.002), had worse tactile sensation in the great toe (p=0.035) and heel (p=0.047), had higher proprioception threshold of knee flexion (p=0.030) and extension (p=0.030), and ankle plantarflexion (p=0.010) and dorsiflexion (p=0.039); the OG had less muscle strength in ankle plantarflexor (p<0.001) and dorsiflexor (p<0.001), and hip abductor (p<0.001), had worse tactile sensation in the great toe (p=0.005), and higher proprioception threshold of knee flexion (p<0.001) and extension (p<0.001), ankle plantarflexion (p<0.001) and dorsiflexion (p<0.001). Compared to the MG, the OG had less muscle strength in the ankle plantarflexor (p<0.001) and dorsiflexor (p=0.001), and hip abductor (p=0.010), and higher proprioception threshold of knee flexion (p=0.021) and extension (p<0.001), ankle dorsiflexion (p=0.001).

Table 1: Descriptive characteristics of dates. a. Between-group differences of younger- and medium-group; b. Between-group differences of younger- and oldest-group; c. Between-group differences of medium- and oldest- group.

Variables		YG	MG	OG	*p*
TUG		10.22 ± 1.08^{b}	11.27 ± 1.89^{c}	14.25 ± 3.29	**<.001**
Strength (N*m/kg)	Ankle plantarflexor	0.46 ± 0.17^{ab}	0.35 ± 0.13^{c}	0.23 ± 0.13	**<.001**
	Ankle dorsiflexor	0.25 ± 0.06^{b}	0.22 ± 0.07^{c}	0.17 ± 0.07	**<.001**
	Hip abductor	0.51 ± 0.16^{ab}	0.41 ± 0.16^{c}	0.32 ± 0.15	**<.001**
Tactile sensation (gauge)	Great toe	4.18 ± 0.53^{ab}	4.35 ± 0.56	4.55 ± 0.81	**.015**
	1st Metatarsal	4.26 ± 0.61	4.24 ± 0.59	4.32 ± 0.48	.112
	5th Metatarsal	4.36 ± 0.46	4.34 ± 0.48	4.43 ± 0.48	.386
	Arch	4.41 ± 0.40	4.47 ± 0.64	4.47 ± 0.51	.492
	Heel	4.51 ± 0.50^{a}	4.65 ± 0.57	4.73 ± 0.66	**.025**
Proprioception (°)	Knee flexion	2.25 ± 1.41^{ab}	2.91 ± 1.95^{c}	3.86 ± 2.35	**<.001**
	Knee extension	2.46 ± 1.39^{ab}	3.33 ± 2.60^{c}	4.05 ± 2.62	**<.001**
	Ankle plantarflexion	1.99 ± 1.05^{ab}	3.21 ± 2.59	5.88 ± 4.38	**<.001**
	Ankle dorsiflexion	2.29 ± 1.76^{ab}	3.42 ± 3.18^{c}	5.86 ± 4.00	**<.001**

The age-specific correlations are shown in Table 2. Among the YG, the muscle strength of the ankle plantarflexor (95%CI: −0.581- -0.076) and hip abductor (95%CI: −0.547- 0.007) was correlated with TUG. The proprioception of knee flexion (95%CI: 0.141-0.493) and extension (95%CI: 0.094-0.552), and ankle dorsiflexion (*r*=-0.001-0.502) was correlated with TUG. Among the MG, the muscle strength of hip abductor (95%CI: -0.640- -0.153) and the proprioception of knee flexion (95%CI: -0.033-0.410) were correlated with TUG. Among the OG, the muscle strength of ankle plantarflexor (95%CI: -0.673- -0.236) and dorsiflexor (95%CI: -0.671- -0.131), and hip abduction (95%CI: -0.669- -168) was correlated with TUG.

Table 2 Age-specific correlations

Variables		TUG					
		Younger group		Medium group		Oldest group	
		r	*p*	*r*	*p*	*r*	*p*
Strength (N*m/kg)	Ankle plantarflexor	**-.347**	**.010**	-.159	.242	**-.459**	**.001**
	Ankle dorsiflexor	-.174	.204	-.220	.103	**-.387**	**.005**
	Hip abductor	**-.307**	**.023**	**-.400**	**.002**	**-.436**	**.001**
Tactile sensation (gauge)	Great toe	.129	.349	.245	.068	.009	.948
	1st Metatarsal	-.085	.537	-.127	.352	-.020	.887
	5th Metatarsal	.003	.984	.242	.072	-.222	.127
	Arch	.085	.539	.262	.051	-.059	.683
	Heel	-.055	.690	.094	.490	-.022	.877
Proprioception (°)	Knee flexion	**.340**	**.011**	**.320**	**.015**	.115	.422
	Knee extension	**.330**	**.014**	.119	.384	.066	.646
	Ankle plantarflexion	.253	.062	.154	.257	.107	.457
	Ankle dorsiflexion	**.291**	**.031**	.149	.272	.132	.357

Bold: $p < .05$

DISCUSSION: We detected that among the elderly population, functional mobility, muscle strength, tactile sensation, and proprioception continue to decline with age. The functional mobility was correlated with proprioception and muscle strength in the YG and MG, but it was only correlated with strength in the OG.

The OG group had lower TUG scores compared to the other two groups. Functional mobility is crucial for the prevention of falls in older adults. Muscle strength was weaker in the OG group compared to the other two groups and was associated with functional mobility in all three age groups. This suggests that despite the decline in muscle strength with age, muscle strength continues to play a crucial role in maintaining functional mobility among older adults.

The tactile sensation was worse in OG compared to MG and YG, and there was no correlation between tactile sensation and functional mobility among the three age groups. Aging could influence the mechanical properties of the skin, along with changes in skin receptor density, morphology, and physiology, potentially resulting in diminished tactile sensation among older adults (Peters, McKeown, Carpenter, & Inglis, 2016). The absence of a correlation between tactile sensation and functional mobility in this study might be attributed to the compensation of other sensory information, such as proprioceptive, visual, and vestibular sensory inputs when maintaining balance(E. W. Chen, Fu, Chan, & Tsang, 2012; Ferlinc, Fabiani, Velnar, & Gradisnik, 2019).

OG exhibited a higher proprioception threshold in comparison to the other two groups. Additionally, while proprioception was correlated to functional mobility in the YG and MG, such a correlation was not observed in the Older Group. This suggests a decline in proprioception with age. The decline in proprioception could be associated with age-related changes in the musculus and its neural pathways, potentially resulting in deficits in the processing and input of proprioceptive signals. Despite this, the lack of a correlation between proprioception and functional mobility in the OG suggests that proprioception among the OG may not offer sufficient information regarding functional mobility. This implies a deterioration of proprioception (to a certain extent) among older adults over 80 years, with a diminished ability to provide meaningful information on functional mobility in this age group. Moreover, the decline in proprioception may have a more significant impact on functional mobility among older adults older than 80, potentially explaining the increased risk of falling in the OG.

CONCLUSION: Senior older adults aged over 80 and above exhibit poorer functional mobility, decreased muscle strength, and diminished tactile sensation and proprioception compared to their younger counterparts. In the 60–69 and 70–79 age groups, both proprioception and muscle strength showed correlations with functional mobility. However, among older adults aged over 80, only muscle strength, and not proprioception, demonstrated a correlation with functional mobility. Preventing the decline of proprioception with age may be the key to reducing falls among senior older adults.

REFERENCES

Amin, D. J., & Herrington, L. C. (2014). The relationship between ankle joint physiological characteristics and balance control during unilateral stance. *Gait Posture, 39*(2), 718-722. doi:10.1016/j.gaitpost.2013.10.004

Chen, E. W., Fu, A. S., Chan, K. M., & Tsang, W. W. (2012). Balance control in very old adults with and without visual impairment. *Eur J Appl Physiol, 112*(5), 1631-1636. doi:10.1007/s00421-011-2139-1

Chen, X., & Qu, X. (2019). Age-Related Differences in the Relationships Between Lower-Limb Joint Proprioception and Postural Balance. *Hum Factors, 61*(5), 702-711. doi:10.1177/0018720818795064

Ferlinc, A., Fabiani, E., Velnar, T., & Gradisnik, L. (2019). The Importance and Role of Proprioception in the Elderly: a Short Review. *Mater Sociomed, 31*(3), 219-221. doi:10.5455/msm.2019.31.219-221

Gerards, M. H. G., McCrum, C., Mansfield, A., & Meijer, K. (2017). Perturbation-based balance training for falls reduction among older adults: Current evidence and implications for clinical practice. *Geriatr Gerontol Int, 17*(12), 2294-2303. doi:10.1111/ggi.13082

Gouveia É, R., Ihle, A., Gouveia, B. R., Kliegel, M., Marques, A., & Freitas, D. L. (2020). Muscle Mass and Muscle Strength Relationships to Balance: The Role of Age and Physical Activity. *J Aging Phys Act, 28*(2), 262-268. doi:10.1123/japa.2018-0113

Gschwind, Y. J., Kressig, R. W., Lacroix, A., Muehlbauer, T., Pfenninger, B., & Granacher, U. (2013). A best practice fall prevention exercise program to improve balance, strength / power, and psychosocial health in older adults: study protocol for a randomized controlled trial. *BMC Geriatr, 13*, 105. doi:10.1186/1471-2318-13-105

Henry, M., & Baudry, S. (2019). Age-related changes in leg proprioception: implications for postural control. *J Neurophysiol, 122*(2), 525-538. doi:10.1152/jn.00067.2019

Menz, H. B., Morris, M. E., & Lord, S. R. (2005). Foot and ankle characteristics associated with impaired balance and functional ability in older people. *J Gerontol A Biol Sci Med Sci, 60*(12), 1546-1552. doi:10.1093/gerona/60.12.1546

Muehlbauer, T., Gollhofer, A., & Granacher, U. (2012). Relationship between measures of balance and strength in middle-aged adults. *J Strength Cond Res, 26*(9), 2401-2407. doi:10.1519/JSC.0b013e31823f8c41

Muir, S. W., Berg, K., Chesworth, B., Klar, N., & Speechley, M. (2010). Balance impairment as a risk factor for falls in community-dwelling older adults who are high functioning: a prospective study. *Phys Ther, 90*(3), 338-347. doi:10.2522/ptj.20090163

Peters, R. M., McKeown, M. D., Carpenter, M. G., & Inglis, J. T. (2016). Losing touch: age-related changes in plantar skin sensitivity, lower limb cutaneous reflex strength, and postural stability in older adults. *J Neurophysiol, 116*(4), 1848-1858. doi:10.1152/jn.00339.2016

Shaffer, S. W., & Harrison, A. L. (2007). Aging of the somatosensory system: a translational perspective. *Phys Ther, 87*(2), 193-207. doi:10.2522/ptj.20060083

Song, Q., Zhang, X., Mao, M., Sun, W., Zhang, C., Chen, Y., & Li, L. (2021). Relationship of proprioception, cutaneous sensitivity, and muscle strength with the balance control among older adults. *J Sport Health Sci, 10*(5), 585-593. doi:10.1016/j.jshs.2021.07.005

Ünver, B., & Akbaş, E. (2018). Effects of plantar sensitivity on balance and mobility in community-dwelling older adults: A Turkish study. *Australas J Ageing, 37*(4), 288-292. doi:10.1111/ajag.12558