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Isokinetic Strength of Knee Extensors is Associated with Balance in Middle-aged Women

Michal Lehnert[1*], Zdenek Svoboda[2], Frantisek Chmelik[3], Roman Cuberek[4], Erika Zemkova[5] and Iva Machova[6]

[1*, 2, 3, 4, 6]*Faculty of Physical Culture, Palacky University Olomouc, 771 11, Czech Republic*
[5]*Faculty of Physical Education and Sports, Comenius University Bratislava, 814 69, Slovakia*

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ABSTRACT The aim of this paper was to identify the relationship between the strength of the knee extensors and postural stability in middle-aged population. The study involved forty women (age 56.3±4.7 years; weight 77.2±18.3 kg; height 164.3±5.6 cm). Relative concentric extension peak torque (ConEPTR) and average work (ConEAW) were expressed to assess bilateral strength of the knee extensors. Balance was evaluated during a 30s quiet stand with open eyes. Mean velocity of the centre of pressure (COP) in the medial-lateral direction and anterior-posterior direction was measured. Mean velocity of COP in the medio-lateral direction significantly (p<.05) correlated with ConEAW; mean velocity of COP in the anterior-posterior direction significantly (p<.05) correlated with ConEPTR. The findings suggested that the strength of the lower limb muscles in middle-aged women contributed to a better balance and consequently to a decreased fall risk later in life.

INTRODUCTION

Deterioration of the musculoskeletal and neuromuscular function with age can affect both balance and functional mobility. Elderly women have better postural stability than men (Zahalka et al. 2016), but the level of postural stability has a decreasing trend in both groups (Zahalka et al. 2014). This implies that impaired postural stability increases the fall risk (Horak et al. 1989; Fukagawa et al. 1995; Bizovska et al. 2015). An important factor that negatively influences postural stability and increases the fall risk in everyday activities is the age-related decrease in muscle strength (Ochi et al. 2010; Semaltianoy et al. 2011). The decrease in muscle strength with age in men and women has been sufficiently documented in literature (Borges 1989; Perry et al. 2007) and it has been confirmed that the decrease in muscle strength accelerates after the age of 50 (Lindle et al. 1997; Stoll et al. 2000). For people over 50 years of age, the decrease in muscle strength is twelve-fifteen percent per decade (Huges et al. 2001).

For the purposes of daily activities, the strength of the quadriceps is important as it ensures the stability of the knee joint, which is needed for upright posture and gait (Whipple et al. 1987; Kapandji 2002; Beebe et al. 2013). It has been confirmed that the cross-sectional area of the quadriceps is increasingly associated with aging compared with other thigh muscles (Frontera et al. 2000; Ochi et al. 2010) and upper body muscles (Aniansson et al. 1986). The loss of muscle mass occurs in particular due to the reduction in the number of muscle fibres, muscle fibre size, and denervation of motor units (Macaluso and De Vito 2004; Von Haehling et al. 2010).

Although it is generally accepted that reduced lower limb strength has a negative effect on balance, contradictory evidence exists regarding this relationship. A significant relationship between dynamic balance and the strength and power of the lower limb was confirmed by Carter et al. (2002), Melzer et al. (2009), Spink et al. (2011), Ünlüsoy et al. (2011), Forte et al. (2014)

Address for correspondence:
Michal Lehnert,
Faculty of Physical Culture,
Palacky University Olomouc,
771 11, Czech Republic
Phone: +420 585636105
E-mail: michal.lehnert@upol.cz

and Menant et al. (2017). Muscle strength of the knee extensor was identified as the most important determinant of static (10%) and dynamic (26%) balance (Carter et al. 2002). Also, in a study by Forte et al. (2014), the relationship between maximum torque strength and static postural control was confirmed. Zemková et al. (2013) observed that only significant muscle strength reduction was associated with poor balance. Oppositely, in some studies (Ringsberg et al. 1999; Granacher and Gollhofer 2012; Muehlbauer et al. 2012; Muehlbauer et al. 2013; Zemková et al. 2017), a significant relationship between muscle strength and balance was not confirmed, or was observed only in some subgroups (Kligytë et al. 2003). This means that the existence of a direct relationship between muscle strength and balance has not been satisfactorily resolved. According to Forte et al. (2014), it is mainly due to the fact that the assessment of balance is very complex and hindered by various physiological mechanisms of responding to postural deviations or different timing during the execution of balance tasks.

Considering that the acceleration of muscle strength decreases after the age of 50, the issue of an increased fall risk due to deteriorated balance should then be addressed not only in seniors but also in middle-aged respondents. However, the population of over 65 years of age is predominantly examined in studies focusing on the relationship between muscle strength and balance (Carter et al. 2002; Forte et al. 2014).

Objectives

The purpose of the paper was to investigate the relationship between isokinetic strength of the knee extensors and postural stability in middle-aged women (over fifty years of age).

MATERIAL AND METHODS

Participants

The study group consisted of 40 women (age 56.3±4.7 years; weight 77.2±18.3 kg; height 164.3±5.6 cm; body mass index 28.5±6.2 kg/m^2 [M±SD]) who participated in the following study: 'Analysis of health-related benefits of walking: Assessment of walking intervention in sedentary adults'. The reasons for exclusion were orthopaedic disorder of the lower extremities and the trunk, previous surgery of the lower extremity, unilateral or bilateral knee pain, severe osteoporosis, hypertension, and missing data about one of the legs for the above mentioned reasons, and an unsatisfactorily executed movement task during testing because of insufficient familiarization with the task or for other reasons. Leg dominance was verified (preferred kicking leg) before the testing procedure. All women were fully informed about the aim of the study and the procedures employed in the study. A written informed consent of the measurement procedure and the use of the data for further research was obtained. The study was approved by the Ethics Committee of the institution and conformed to the Declaration of Helsinki regarding the use of human subjects.

Data Collection

Bilateral isokinetic strength of the knee extensors was measured using an isokinetic dynamometer IsoMed 2000 (D. and R. Ferstl GmbH, Hemau, Germany). Prior to testing, the participants completed non-specific warm-up exercises, which included cycling on a stationary bicycle ergometer for 6 min at a self-regulated low to moderate intensity, stretching exercises targeting the main muscle groups involved during testing, and 10 half-squats/squats with an increasing range of movement. The warm-up routine was performed under the supervision of the researchers. At the end of the warm-up the participants performed imitated eccentric and concentric actions of the quadriceps against resistance produced by the researchers' hand to become familiar with the upcoming movement task.

The participants were tested in a sitting position with a hip angle of 100°. To fix the pelvis and the thigh of the tested leg, fixing straps were used; the shoulders were fixed by means of shoulder pads in the ventral-dorsal and cranial-caudal direction. The axis of the dynamometer rotation was aligned with the axis of the knee rotation (lateral femoral epicondyle). The arm of the dynamometer lever was fixed to the distal part of the shin, and the lower edge of the shin pad was placed 2.5 cm over the apex of the medial malleolus. Individual seat settings were stored on the computer before measuring the right leg and were automatically activated in the process of measuring the left leg and follow-up testing, respectively. At the beginning of the follow-up testing, individual settings were rechecked and adjusted if necessary. The participants were instructed to hold the handgrips located at the side of the seat during all testing efforts. An angular velocity of 180°·s^{-1} was used for the measurement. A static gravitational correction was applied according to the manufacturer's instructions. The testing range of motion was 80° and was set from 10–90° of knee flexion (with 0° = full voluntary extension).

The testing protocol consisted of two sets (warm-up and testing). In the first warm-up set the women performed five eccentric/concentric reciprocal actions with flexion movements performed first) with a progressive increase in the muscle action until a maximum action was performed. After a 2-min rest the participants performed a set of three maximum repetitions. Regarding some problems with executing the eccentric actions, these results were not used for further analyses in this study. The rest time between the measurement of the right leg and left leg was 3 min; the right leg was measured first. During the testing procedure the participants were provided with concurrent visual feedback in the form of an isokinetic strength curve displayed on the dynamometer monitor. Verbal encouragement was provided. Relative concentric extension peak torque (ConEPTR; Nm) and average work (ConEAW) were used to assess the strength of the knee extensors.

Balance was evaluated in the course of a 30s quiet stand with open eyes. The participants performed two attempts. They stood on one force plate (type 9286AA, Kistler Instrumente, Winterthur, Switzerland) in a natural base of support. Raw data was obtained using Bioware software (version 4, Kistler Instrumente, Winterthur, Switzerland) and exported to Matlab software (version R2010b, Mathworks, Inc., Natick, MA, USA), in which filtration was performed using a fourth-order lowpass Butterworth filter and a cut-off frequency of 7Hz. Based on the centre of pressure (COP) movement, the following variables were analysed: v_x – mean velocity of COP in the medial-lateral direction, v_y – mean velocity of COP in the anterior-posterior direction. Before statistical processing the values of the two trials were averaged.

Statistical Analysis

Descriptive statistics, paired sample test, and Pearson correlation coefficient were computed using IBM SPSS Statistics 22. The value of the correlation coefficient was analysed as follows: <.30 low; .31–.69 moderate; .70–1.00 high (Morrow et al. 2005). Statistical significance was considered at a level of $p = 0.05$.

RESULTS

The results of isokinetic measurement are reported in Table 1. No significant differences in ConEPTR (t = 1.56, df = 39, $p = .134$) or ConEAW (t = 1.55, df = 39, $p = .131$) between the dominant leg (DL) and non-dominant leg (NL) were observed. Therefore, PT values of DL and NL were averaged. The results for balance variables are reported in Table 2. The results of the correlation analysis showed that the mean velocity of COP in the medial-lateral direction significantly correlated with ConEAW but not with ConEPTR. On the other hand, the mean velocity of COP in the anterior-posterior direction signifi-

Table 2: Centre of pressure velocity

Variable	*M*	*Min*	*Max*	*SD*
v_x [cm/s]	0.49	0.23	0.80	0.15
v_y [cm/s]	0.89	0.48	1.49	0.25

v_x = mean velocity of COP in medio-lateral direction, v_y = mean velocity of COP in anterior-posterior direction, M = mean, Min = minimum, Max = maximum, SD = standard deviation

Table 1: Isokinetic variables on dominant and nondominant limbs

Variable	*Limb*	*M*	*Min*	*Max*	*SD*	*t*	*p*
ConEPTR [Nm]	Dominant	1.30	0.55	2.11	0.34	-1.56	0.127
	Nondominant	1.34	0.66	1.95	0.29		
	Average	1.32	0.61	1.95	0.30		
ConEAW [J]	Dominant	99.1	22.0	160.0	33.9	-1.55	0.129
	Nondominant	103.5	47.0	155.0	27.8		
	Average	101.3	45.5	152.0	29.7		

ConEAW = relative concentric average work, ConEPTR = relative concentric extension peak torque, M = mean, Min = minimum, Max = maximum, SD = standard deviation, t=testing criteria level cantly correlated with ConEPTR but not with ConEAW (Table 3).

Table 3: Correlation values for isokinetic and balance variables

Variable	*1*	*2*	*3*	*4*
1. ConEPTR [Nm]	-	.35*	-.03	-.52**
2. ConEAW [J]	.35*	-	-.37*	-.03
3. v_x [cm/s]	-.03	-.37*	-	.18
4. v_y [cm/s]	-.52**	-.03	.18	-

ConEAW = relative concentric average work, ConEPTR = relative concentric extension peak torque, v_x = mean velocity of COP in medio-lateral direction, v_y = mean velocity of COP in anterior-posterior direction, (*p<.05; **p<.01)

DISCUSSION

The study showed low to moderate correlations between the variables of the isokinetic strength of the knee extensors and body balance. More specifically, a significant correlation was observed between the strength of the knee extensors and balance, although not in all of the observed parameters. The highest correlation was found between PT and anterior-posterior postural sways. These findings are in agreement with the results of a study by Fukagawa et al. (1995), who observed that the lower value of PT deteriorated stability in the posterior direction. The relationship between strength and postural stability has previously been studied primarily in the elderly population (above 65 years of age). Therefore, the results can be directly compared only with those previous studies (Whipple et al. 1987; Carter et al. 2002; Beebe et al. 2013) in which a significant relationship was prevalently confirmed. For example, Beebe et al. (2013) observed that individuals with higher PT demonstrated better stability results and the researchers recommended isokinetic training as an intervention to prevent falls. Another study (Carter et al. 2002) evaluated the moderator effect of static postural control on the association of power and strength using dynamic balance tests. The reseaerchers found significant relationships between dynamic balance and PT and power, as well as postural control. The reseaerchers concluded that good static postural control facilitated the use of lower limb strength to enhance the quality of complex and functional balance tasks.

In this paper, it was also observed that medio-lateral stability significantly correlated with average work of the knee extension. The researchers consider this finding important as it was confirmed that mediolateral sway is significantly associated with recurrent falls (Stel et al. 2003). Baloh et al. (1998) even reported that mediolateral displacement was a more sensitive indicator of instability than anteroposterior displacement. Taking this into account, the finding that balance in the mediolateral direction significantly correlates with ConEAW also seems to be of a great importance from the perspective of fall prevention and risk of injury.

This study confirmed the importance of muscle strength of the knee extensors to maintain balance. It supports the results of studies which confirmed that muscle strength and quadriceps power were the predictors of falls in elderly individuals (Whipple et al. 1987; Semaltianoy et al. 2011; Skelton et al. 1994). Other fall risk factors could be the difference between the strength and power of the knee and ankle muscles, including knee extensors (Skelton et al. 1994; Baloh et al. 1998; Perry et al. 2007; Portegijs 2008) and other strength-related asymmetries in the case of lower extremities and the core (Mitchell et al. 2016). Moreover, it has been proven that strength asymmetry increases with age (Perry et al. 2007; Carabello et al. 2010). It has also been suggested that strength asymmetry of the knee extensors in middle-aged women could be influenced by their participation in vigorous physical activity (Lehnert et al. 2014), which was for example, confirmed in the case of circuit training (Carabello et al. 2010). Nevertheless, the decrease in muscle strength with age accelerates already after the age of 50 (Lindle et al. 1997; Stoll et al. 2000), and therefore, maintaining sufficient strength already in the middle age is important in the prevention of falls in the following stages of development. Considering this knowledge and also the fact that strength training and in particular maximum strength training can be higly efficient even in the elderly population (Cvecka et al. 2015; Wang et al. 2017), the researchers recommend participation in supervised strength training at this age.

It needs to be considered that balance was not tested in unstable conditions in this study and that only a limited number of parameters were used. In case of the strength, for example, the rate of force development was not measured and the measurement did not include ankle muscle strength or hip abductor strength, which is closely associated with thigh muscle functional movements.

CONCLUSION

In the current study, the medio-lateral and the antero-posterior postural stability in middle-aged women was associated with the strength of the knee extensors. This finding indicates that the strength of lower limb muscles in women over fifty contributes to a better balance, and consequently may decrease the fall risk later in life. Consistently with many previous papers, this association has not been confirmed, and futher studies are needed to investigate the association between strength and power of lower limb muscles and balance in different population groups.

RECOMMENDATIONS

Taking the findings of the study into account, the reserachers suggest that middle-aged women should participate in well-designed resistance training programmes.

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REFERENCES

Aniansson A, Hedberg M, Henning GB, Grimby G 1986. Muscle morphology, enzymatic activity, and muscle strength in elderly men: A follow-up study. *Muscle Nerve*, 9: 585-591.

Baloh RW, Ying SH, Jacobson KM 1998. A prospective study of posturography in normal older people. *J Am Geriatr Soc*, 46: 438-443.

Beebe JA, Hines RW, McDaniel LT, Shelden BL 2013. An isokinetic training program for reducing falls in a community-dwelling older adult: A case report. *J Geriatr Phys Ther*, 36: 146-153.

Bizovska L, Svoboda Z, Janura M 2015. The possibilities for dynamic stability assessment during gait: A review of the literature. *J Phys Edu Sport*, 15: 490-497.

Borges O 1989. Isometric and isokinetic knee extension and flexion torque in men and women aged 20-70. *Scan J Rehabil Med*, 21: 45-53.

Carabello RJ, Reid KF, Clark DJ, Philips EM, Fielding RA 2010. Lower extremity strength and power asymmetry assessment in healthy and mobility-limited populations: Reliability and association with physical functioning. *Aging Clin Exp Res*, 22: 324-329.

Carter ND, Khan KM, Mallinson A, Janssen PA, Heinonen A, Petit MA, McKay HA 2002. Knee extension strength is a significant determinant of static and dynamic balance as well as quality of life in older community-dwelling women with osteoporosis. *Gerontology*, 48: 360-368.

Cvecka J, Tirpakova V, Sedliak M, Kern H, Mayr W, Hamar D 2015. Physical activity in elderly. *Eur J Transl Myol*, 25: 249-252.

Forte R, Boreham CA, De Vito G, Ditroilo M, Pesce C 2014. Measures of static postural control moderate the association of strength and power with functional dynamic balance. *Aging Clin Exp Res*, 26: 645-653.

Frontera WR, Hughes VA, Fielding RA, Fiatarone MA, Evans WJ, Roubeno VR 2000. Ageing of skeletal muscle: A 12-yr longitudinal study. *J Appl Physiol*, 88: 1321-1326.

Fukagawa NK, Wolfson L, Judge J, Whipple R, King M 1995. Strength is a major factor in balance, gait, and the occurrence of falls. *J Gerontol A Biol Sci Med Sci*, 50A(Special Issue): 64-67.

Granacher U, Gollhofer A 2012. Is there an association between variables of postural control and strength in prepubertal children? *J Strength Cond Res*, 26: 210-216.

Horak FB, Shupert CL, Mirka A 1989. Components of postural dyscontrol in the elderly: A review. *Neurobiol Aging*, 10: 727-738.

Huges VA, Frontera WR, Wood M, Evans WJ, Dallal GE, Roubenoff R, Fiatarone Singh MA 2001. Longitudinal muscle strength changes in older adults: Influence of muscle strength, physical activity, and health. *J Gerontol A Biol Sci Med Sci*, 56: 209-217.

Kapandji IA 2002. *The Physiology of the Joints: Volume Two, Lower Limb*. 5th Edition. Edinburgh: Churchill Livingstone.

Kligytë I, Lundy-Ekman L, Medeiros JM 2003. Relationship between lower extremity muscle strength and dynamic balance in people post-stroke. *Medicina*, 39: 122-128.

Lehnert M, Chmelík F, Cuberek R, Svobodová V 2014. Strength asymmetry of the knee extensors and physical activity in middle-aged women. *Acta Gymnica*, 44: 141-147.

Lindle RS, Metter EJ, Lynch NA, Fleg, JL, Fozard, JL, Tobin J, Roy TA, Hurley BF 1997. Age and gender comparisons of muscle strength in 654 women and men aged 20-93 yr. *J Appl Physiol*, 83: 1581-1587.

Macaluso A, De Vito G 2004. Muscle strength power and adaptations to resistance training in older people. *European J Appl Physiol*, 91: 450-472.

Melzer I, Benjuya N, Kaplanski J, Alexander N 2009. Association between ankle muscle strength and limit of stability in older adults. *Age Ageing*, 38: 119-23.

Menant JC, Weber F, Lo J, Sturnieks DL, Close JC, Sachdev PS, Brodaty H, Lord SR 2017. Strength measures are better than muscle mass measures in predicting health-related outcomes in older people:

Time to abandon the term sarcopenia? *Osteoporos Int,* 28: 59-70.

Mitchell UH, Johnson AW, Vehrs PR, Feland JB, Hilton SC 2016. Performance on the functional movement screen in older active adults. *J Sport Health Sci,* 5: 119-125.

Morrow JR, Jackson AW, Disch JG, Mood DP 2005. *Measurement and Evaluation in Human Performance*. Champaign, IL: Human Kinetics.

Muehlbauer T, Besemer C, Wehrle, Gollhofer A, Granacher U 2012. Relationship between strength, power and balance performance in seniors. *Gerontology,* 58: 504-512.

Muehlbauer T, Gollhofer A, Granacher U 2013. Association of balance, strength, and power measures in young adults. *J Strength Cond Res,* 27: 582-589.

Ochi M, Tabara Y, Kido T, Uetani E, Ochi N, Igase M, Miki T, Kohara K 2010. Quadriceps sarcopenia and visceral obesity are risk factors for postural instability in the middle aged to elderly population. *Geriatr Gerontol Int,* 10: 233-243.

Perry MC, Carville SF, Smith IC, Rutherford OM, Newham DJ 2007. Strength, power output and symmetry of leg muscles: effect of age and history of falling. *Eu J Appl Physiol,* 100: 553-561.

Portegijs E 2008. *Assymetrical Lower-limb Muscle Strength Deficit in Older People*. Jyväskylä: University of Jyväskylä.

Ringsberg K, Gerdhem P, Johansson J, Obrant KJ 1999. Is there a relationship between balance, gait performance and muscular strength in 75-year-old women? *Age Ageing,* 28: 289-293.

Semaltianoy E, Kabitsis CH, Harahousou Y, Lazou V 2011. Investigation of fall prediction factors in elderly population using isokinetic assessment of the knee joint. *Biology Exerc,* 7: 49-62.

Skelton DA, Greig CA, Davies JM, Young A 1994. Strength, power and related functional ability of healthy people aged 65-89 years. *Age Ageing,* 23: 371-377.

Spink MJ, Fotoohabadi MR, Wee E, Hill KD, Lord SR, Menz HB 2011. Foot and ankle strength, range of motion, posture, and deformity are associated with balance and functional ability in older adults. *Arch Phys Med Rehabil,* 92: 68-75.

Stel VS, Smit JH, Pluijm SM, Lips P 2003. Balance and mobility performance as treatable risk factors for recurrent falling in older persons. *J Clin Epidemiol,* 56: 659-668.

Stoll T, Hubert E, Seifert B, Michel BA, Stucki G 2000. Maximal isometric muscle strength: normative values and gender-specific relation to age. *J Clin Rheumatol,* 19: 105-113.

Ünlüsoy D, Aydog E, Tuncay R, Eryüksel R, Ünnlüsoy I, Çakci A 2011. Postural balance in women with osteoporosis and effective factors. *Turk J Osteoporos,* 17: 37-43.

Von Haehling S, Morley JE, Anker SD 2010. An overview of sarcopenia: Facts and numbers on prevalence and clinical impact. *J Cachexia Sarcopenia Muscle,* 1: 129-133.

Wang E, Nyberg SK, Hoff J, Zhao J, Leivseth G, Tørhaug T, Husby OS, Helgerud J, Richardson RS 2017. Impact of maximal strength training on work efficiency and muscle fiber type in the elderly: Implications for physical function and fall prevention. *Exp Gerontology,* 91: 64-71.

Whipple RH, Wolfson LI, Amerman PM 1987. The relationship of knee and ankle weakness to falls in nursing home residents: An isokinetic study. *J Am Geriatr Soc,* 35: 13-20.

Zahalka F, Maly T, Mala L 2016. Static and dynamic postural stability manifestations in the elderly population. In: H Stepankova, R Slamberova (Eds.): *Starnuti 2016*. Prague: Charles University, pp. 216-225.

Zahalka F, Maly T, Mala L 2014. Body postural stability in ageing. In: H Stepankova, R Slamberova (Eds.): *Starnuti 2014.* Prague: Charles University, pp. 168-173.

Zemková E, Jeleò M, Kováèíková Z, Mikloviè P, Svoboda Z, Janura M 2017. Balance performance during perturbed standing is not associated with muscle strength and power in young adults. *J Mot Behav,* 49: 514-523.

Zemková E, Jeleò M, Štefániková G, Hamar D 2013. Balance Performance in Elderly Subjects is Affected by a Significant Reduction in Muscle Strength. In: *13th Asian Federation of Sports Medicine Conference*, 25 - 28 September, Kuala Lumpur, Malaysia.

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