Journal of Aging and Physical Activity, 2017, 25, 228-233
https://doi.org/10.1123/japa.2015-0316

Human Kinetics
ORIGINAL RESEARCH

Effects of Functional Training and Calf Stretching on Risk of Falls in Older People: A Pilot Study

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This study aimed to determine the effects of a functional training and ankle stretching program in triceps surae torque, passive stiffness index, and in the risk for fall indicators in older adults. Twenty women (73.4 ± 7.3 years) were allocated into an intervention or control group. The 12-week intervention consisted of functional training and calf stretching exercises performed twice a week. Measurements of peak passive and active torque, passive stiffness, maximum dorsiflexion angle, and indexes of risk for falls (Timed Up and Go, functional reach test, QuickScreen-test) were collected. There were no significant differences for all variables, except the maximum dorsiflexion angle, which increased in the intervention group from 33.78 ± 8.57° to 38.89 ± 7.52°. The exercise program was not sufficient to enhance performance on functional tests and decrease the risk for falls in older adults. The significant increase in the maximum dorsiflexion indicates a positive impact of stretching exercises.

Keywords: older adults, risk for falls, passive torque, active torque, functional training, stretching

The literature is full of studies concerning the aging process. Senescence is related to decreased individual homeostatic capacity and declined physiological mechanism functioning (de Bruin, Najafi, Murer, Uebelhart, & Aminian, 2007). As a result, individuals face progressive loss of mobility, which drastically affects their quality of life and functional independence (de Bruin et al., 2007; Narici, Maffulli, & Maganaris, 2008).

Sarcopenia is one of the main factors responsible for the impairment of older adults' functional capacity (Narici et al., 2008; Narici & Maganaris, 2007; Reeves & Narici, 2003), generating slower and less effective responses to external stimuli and affecting gait and balance, thus increasing the risk for falls. Besides muscle changes, tendons are also affected by aging. Reeves et al. (Reeves, 2006) clarify that both the tendon stiffness and elasticity modulus are reduced with aging, affecting the force production and speed of transmission from the muscles to the bone, and therefore the joint movement (Magnusson, Narici, Maganaris, & Kjaer, 2008; Reeves, Maganaris, & Narici, 2003).

In addition to that, aging is accompanied by a reduction of maximum range of motion of lower limbs, especially in older women, which contributes to loss of balance and increased risk for falls (Chodzko-Zajko et al., 2009; Gajdosik, Vander, & Williams, 1999; Schwenk et al., 2013; Wu, Gau, Hsu, Tu, & Tsao, 2012). Studies show that older adults with a history of falls presented reduced ankle range of motion during gait when compared with those with no fall history (Góes et al., 2015; Laroche, Cremin, Greenleaf, & Croce, 2010).

The high incidence of falls among older adults is a major clinical problem and generates high healthcare costs. About 30% people aged 65 and over fall at least once each year (Tinetti, 1994). The three main intrinsic risk factors of falls in older adults are muscle weakness, balance disorders, and gait instability (Chodzko-Zajko et al., 2009; Gschwind et al., 2013; NICE, 2013). In a systematic review, Schwenk et al. (2013) report that balance and ankle flexibility presented small to moderate overall effects over risk for falls, whereas ankle plantar flexion strength and walking performance showed no significant overall effects. Exercise programs can promote functional benefits to older adults, improving physical and coordinative skills, and increasing autonomy and independence in their daily activities (Bean, Vora, & Frontera, 2004; Chodzko-Zajko et al., 2009; de Vreede et al., 2005). Besides the reduction of functional losses, the exercise enables changes in muscles, tendons, and joint movements, which may affect the torque development rate and range of motion and, therefore, avoid slips and stumbles that would result in a fall (de Bruin et al., 2007; Narici & Maganaris, 2006).

It is expected that these factors could be modified with specific training programs, such as a functional training program (FT) and stretching training (ST). The FT includes muscle strengthening and motor skills training such as coordination, balance, agility, gait, and proprioception (Chodzko-Zajko et al., 2009), whereas the stretching training aims to elongate the muscle-tendon unit, minimizing losses in the joint range of motion that can reach 30–40% of the normal range of motion with aging (Chodzko-Zajko et al., 2009; Góes et al., 2015). Although presenting inconclusive results, the FT aims to reduce functional disability (Gill et al., 2002), impacting positively on mobility and functional independence (Pedrinelli, Garcez-Leme, & Nobre, 2009), whereas the ST has proven to be effective in increasing joint amplitude (Weppler & Magnusson, 2010).

Thus, the current study evaluates the effects of FT and ST programs in triceps surae torque, passive stiffness index, and in the risk for fall indicators in older adults.

Materials and Methods

Sample

This research was accomplished with a convenience sample of 20 healthy older women (73.4 ± 7.3 years, 64.5 ± 10.6 kg, 154 ± 0.6 cm) who volunteered for the study. The examiner interviewed volunteers

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over 60 through anamnesis and the Physical Activity Readiness Questionnaire (PAR-Q), and those with a history of chronic degenerative diseases of the lower limbs or musculoskeletal injuries were excluded from the research. Besides that, the presence of cognitive impairment was evaluated by the Mini-Mental State Examination, following the cut-off points established by Bertolucci, Brucki, Campacci, and Juliano (1994): 13 points for illiterate seniors, 18 points for seniors with up to 8 years of formal education, and 26 points for those with more than 8 years of formal education. All participants presented no suspicion of cognitive impairment. Each volunteer reported the list of drugs in constant use in the last 3 months. The use of four or more drugs, excluding vitamins and dietary supplements, and the use of any psychotropic medication (substances that act on the central nervous system and that are used in the treatment of mental disorders) was considered a positive response to the fall risk and prevented participation in the study.

The participants were randomly allocated into the intervention (IG; $n = 10$) or control group (CG; $n = 10$). The participants were fully informed of the procedures and purpose of this study and they signed an informed consent form. The study was approved by the Ethics Committee of the University Hospital Research Center.

Instrumentation

An isokinetic dynamometer (Biodex System 4, New York, USA) was used to measure plantar flexion passive and active torque. The risk for falls was assessed with the following tools: the Timed Up and Go test (TUG) (Bischoff et al., 2003; Podsiadlo & Richardson, 1991); the Functional Reach Test (FRT) (Duncan, Weiner, Chandler, & Studenski, 1990); and The NeuRA QuickScreen © Clinical Falls Risk Assessment (or QuickScreen for short; Sydney, AU), based on professor Stephen Lord's Physiological Profile Assessment (Tiedemann, Lord, & Sherrington, 2010; Tiedemann, 2006).

Tests Protocols

Before and after the 12-week training, participants were submitted to active and passive peak torque measurement and to the tests: TUG, FRT, and QuickScreen test.

The TUG test evaluates mobility through the measurement of the time used to complete a 3-m gait. Subjects were asked to sit in a chair (height of 50 cm) with the back against the backrest, arms beside the trunk, and the feet parallel. After the verbal command (the word 'go'), they should stand up and walk the 3-m distance at a comfortable and secure pace, turn back, and sit again. The test was conducted twice (the first trial was a familiarization procedure) and the result of the second trial was used for statistical analysis. The test evaluation criteria are as follows: less than 10 s = low risk for falling; 10–20 s = medium risk for falls; up to 20 s = high risk for falls. The TUG has a good reliability (Bischoff et al., 2003) and is recommended by the American Geriatrics Society as a screening test and as a routine for evaluating risk for falls (Barry, Galvin, Keogh, Horgan, & Fahey, 2014).

The FRT analyzes changes in dynamic postural control through the quantification of the maximum anterior displacement of the trunk without loss of balance. The functional reach is the difference between arm's length and maximal forward reach, using a fixed base of support (Duncan et al., 1990). The test consisted of asking standing barefoot subjects to reach with the left hand horizontally forward (90° shoulder flexion and straight arm) while maintaining a fixed and parallel base of support. The participants were instructed to reach forward the maximum they could and to sustain the position during 3 s. The subjects were free to use any movement strategies to accomplish the task but trials were discarded if the participants touched the wall or stepped forward. The highest value achieved in three trials was considered for further analysis. Displacements were correlated with the risk for falls: less than 15 cm = increased risk, 15–25 cm = moderate risk, more than 25 cm = reduced risk (Duncan et al., 1990). The QuickScreen is a multifactorial assessment tool designed for and validated with a large sample of older people. It consists of the following measures: previous falls, medication usage, vision, peripheral sensation, lower limb strength, balance and coordination (near tandem stand test, alternate step test, and sit to stand test). Details of the test methodology can be found in (Tiedemann et al., 2010; Tiedemann, 2006). According to the number of risk factors present in the analysis, the test returns an estimate of the risk for fall of the subject (7, 13, 27, or 49%).

For the passive tests, subjects were positioned at the dynamometer (Biodex System 4 Pro—Biodex Medical Systems Inc., New York, USA) with the right knee in full extension, hip flexed, and trunk inclination of 85°. The right foot was firmly fixed to the dynamometer footplate maintaining the lateral malleolus aligned with the center of rotation of the machine. Range of motion (ROM) was then determined by passive mobilization at a velocity of 5°/s from –30° of plantar flexion up to the limit of dorsiflexion in which each individual reported discomfort that was registered as the maximum ROM. The test consisted of three consecutive ankle passive mobilizations in the amplitude previously determined for each subject. Participants were instructed to relax and myoelectric silence was verified with electrodes (Ag-AgCl, Meditrace, Kendall, USA) positioned on the lateral gastrocnemius muscle (EMG System, Brazil, 106 dB CMRR, sampling frequency of 1kHz and an A/D converter). The highest value of passive torque was used in further analysis, including the estimation of a passive stiffness index, calculated as the torque-angle curve derivative for the maximum passive torque.

For the active tests, subjects remained in the same position with the ankle joint at 90°. They performed two maximum voluntary contractions (MVCs) with a duration of 10 s and an interval of 20 s, while receiving visual feedback and verbal encouragement. The highest torque value obtained was considered for further analysis.

Functional and Stretching Training

After the first evaluation (preintervention), subjects in the IG began the training routine whereas those in the CG were instructed to maintain daily activities.

The training consisted of different functional exercises, related to tasks performed daily by participants. These exercises were organized in four different training routines, applied alternately. The 50-min sessions were performed twice a week during 12 weeks. The volunteers executed the exercises according to their individual physical capacity. The effort was monitored by the Borg scale, seeking to maintain scores between 12 (above light) and 13 (somewhat hard).

The sessions were organized in four different 50-min routines, which were alternately applied (Table 1). They consisted of general exercises for warming up and stretching, followed by balance and agility training, when the participants walked around cones and hula hoops, over pillows and labile surfaces, climbed and descended steps, moved changing speed and direction, sat and stood up from a chair or Swiss ball with or without objects in their hands, and engaged in small circuits with different activities, for about 20 min. After that, they engaged in the strength training, which consisted of 2–3 sets of 10–20 repetitions of exercises for lower and upper limbs and the trunk. Table 1 describes training details. The participants used free weights of 0.5 kg or 1 kg in the exercises of lower limbs and of 0.5 kg, 1, kg or 2 kg for the upper limbs. The overload

Table 1 Functional Training

Functional Training Routines			
Routine A	**Routine B**	**Routine C**	**Routine D**
Warm-up (10 min): Stretching of major muscle groups and slow active mobilization of joints.			
Balance and agility training (15 min)	Balance and agility training (15 min)	Balance and agility training (15 min)	Balance and agility training (15 min)
- Walking between sticks (3 min)	- Mixed displacement between cones, over steps and wide-stride gait (7–8 min)	- Tandem gait (3 min)	- Tandem gait (1.5 min)
- Walking over obstacles (3 min)	- Mixed displacement over hula hoops and steps, and walking back with wide stride (7–8 min)	- Walking over obstacles (3 min)	- Lateral displacement (1.5 min)
- Walking back over a line (3 min)		- Lateral and straight displacement between cones (3 min)	- Walking between hula hoops (1.5 min)
- Lateral displacement between cones		- Wide-stride gait (3 min)	-Walking in plantar flexion (1.5 min)
- Wide-stride gait (3 min)		- Ascending and descending the bosu (3 min)	- Lateral displacement (1.5 min)
- Walking straight, sitting and standing up with Swiss ball (3 min)			- Walking over obstacles (1.5 min)
			-Walking in dorsiflexion (1.5 min)
			- Walking back (1.5 min)
			- Walking over proprioceptive discs (3 min)
Strength training (3 sets of 10 reps–20 min)	Strength training (3 sets of 10 reps–25 min)	Strength training circuit (4 stations, 1-min duration, 30-sec rest, 3 reps)	Strength training (3 sets of 10 reps–20 min)
- Biceps curl	- Standing unilateral hip flexion	- First stations: Single leg squat	- Shoulder abduction
- Triceps curl	- Standing unilateral knee flexion	- Second station: Foot with elastic	- Shoulder flexion
- Sit ups	- Standing unilateral hip extension	- Third station: 3-m gait and 3 squats carrying a medicine ball	- Shoulder horizontal abduction
- Hip extension (supine)	- Standing unilateral hip abduction	- Fourth station: Shoulder flexion with barbell	- Shoulder press
- Side-lying hip abduction	- Standing simultaneous plantarflexion		- Biceps curl
- Curl up			
Stretching of major muscle groups and emphasis in triceps surae muscles (5 min)			

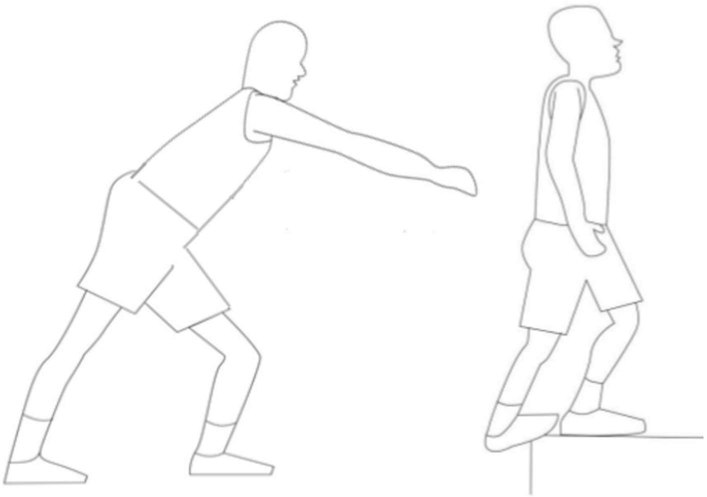

Figure 1 Exercises of stretching training.

was determined by the perceived effort of each subject and it was increased whenever it was considered a light effort.

At the end of each session, the subjects performed light stretching of the major muscle groups (one set of active static stretching). Specifically for the plantar flexors, the volunteers performed three sets of 30 s, with an equal interval duration of two stretching exercises (Figure 1). They were encouraged to move the joint until the point of tolerable discomfort and to maintain the position during the subsequent 30 s.

Statistical Analysis

Data normal distribution was assessed by the Kolmogorov-Smirnov test. A two-way analysis of variance for repeated measures was applied to investigate the effects of the training program over the variables comparing groups (CG / IG) and moment (before and after training). The analysis was conducted with the software Statistica 7.0 (Statsoft, Inc., Tulsa, OK) and the significance level for all tests was set at $p < .05$.

Results

All variables showed a normal distribution and the mean and standard deviation values are presented in Table 2. The results of risk for fall provided by TUG, FRT, and QuickScreen tests showed no significant differences after training. Values of peak active torque showed a tendency to increase after training, however no significant differences were detected.

Maximum passive torque and passive stiffness index showed no significant differences. The intervention group presented significantly higher values of maximum dorsiflexion angle after training. The maximum effect size for the study was 0.384 (eta squared).

Discussion

The results showed that a 12-week intervention based on FT and stretching exercises was not able to promote significant changes in the risk for fall scores, probably due to the use of activities that were not heavy enough to promote this kind of adaptation. In addition to that, the results also showed that the intervention could not generate adaptations in muscle strength, nor in muscle-tendon unit compliance. However, the training induced an increase in the flexibility levels, indicated by a significant increase in the maximum dorsiflexion angle, which was not followed by a concomitant increase in peak passive torque.

The TUG and FRT tests scores are based on accomplishment of tasks or movements that indicate mobility, balance control, and potential risk for falling. Bischoff et al. (2003) consider that when the TUG test is performed within 10 s, the individual can be considered independent and without risk for falls. All the participants of the current study were allocated in this profile before the intervention, with a time average of 7.98 s to accomplish the test. Therefore, any changes in these values induced by the FT were expected to be small. The same was observed in a study by Hernandez et al. (2010), who evaluated the risk for falls in older patients with Alzheimer's dementia before and after a 6-month systematic program of physical activity. Although seniors who comprised the study sample were affected by Alzheimer's dementia and the training was different from the current study, participants performed the test in less than 10 s, indicating the absence of falls risk, both before and after the intervention. Regarding the FRT, it is worth mentioning that the result of this test was shown to be related to the active force of plantar flexion (Daubney & Culham, 1999), which is in agreement with the fact that this variable also remained unaffected by the training.

Regarding maximum active torque, the training had no impact on the plantar flexors' maximum voluntary activation. It is known that, due to reduced muscle mass, decline in strength is one of the outcomes of aging (Narici & Maffulli, 2010). Morse et al. (2004) found that the peak plantar flexion torque was significantly reduced (~ 39%) on active older women compared with active young people.

Table 2 Mean Values and Standard Deviation of the Variables

	Intervention Group		Control Group	
Variables	**Pre**	**Post**	**Pre**	**Post**
QuickScreen test (%)	16.00 ± 7.95	18.60 ± 7.22	18.80 ± 12.41	16.20 ± 12.89
Timed Up & Go results (s)	7.98 ± 1.71	8.54 ± 2.15	7.96 ± 2.93	8.66 ± 4.34
Functional Reach Test (cm)	16.80 ± 7.71	17.90 ± 8.96	20.90 ± 7.83	19.80 ± 5.05
Peak active torque (N·m)	43.33 ± 15.00	49.27 ± 12.98	60.61 ± 21.12	58.00 ± 19.38
Peak passive torque (N·m)	19.15 ± 18.51	23.60 ± 9.92	21.28 ± 11.04	28.56 ± 12.41
Maximum dorsiflexion angle (°)	33.78 ± 8.57	38.89 ± 7.52*	34.67 ± 12.00	35.11 ± 12.13
Passive stiffness (N·m/°)	0.95 ± 0.66	1.07 ± 0.44	1.28 ± 0.30	1.54 ± 0.38

* Significant differences between pre- and posttest.

The authors declare that part of this difference can be attributed to the reduction of muscle volume, coupled with a reduced muscle activation ability (Narici, Reeves, Morse, & Maganaris, 2004). However, the aged muscles are highly adaptable when subjected to overload. Several authors have demonstrated significant increases (ranging from 12–20%) in plantar flexion active torque of older adults after training (de Boer, Morse, Thom, De Haan, & Narici, 2007; Ferri et al., 2003; Morse et al., 2005). However, those studies employed strength training with intensities higher than the one applied in the functional training of the current study. Fiatarone et al. (1990) in a classical study reported that interventions at higher intensities promote greater muscle strength gains even in older individuals. In their study, the authors submitted a group of adults aged older than 90 years to 8 weeks of high-intensity resistive training (80% of 1RM), with weekly load adjustment, and found an increase of 174% in knee extensors maximum strength of these individuals. On the other hand, low and moderate intensities tend to produce little or no increase in strength in older people, as reported by Aniansson and Gustafsson (1981) in another classic study. The authors submitted a group of seniors to a low/moderate intensity strength training for 12 weeks and found increases of 9–22% of knee extensor strength. The same happened in this study, as the FT, conducted with low/moderate intensity and volume (levels 12 levels and 13 of the Borg scale) was not able to promote change in plantar flexor torque levels. Functional trainings prescribed to older individuals are commonly of low intensity to emphasize security and minimize injury risk. However, the present results have shown that this type of training has no effect on strength and on the risk for falls and, therefore, it should be modified to achieve such goals.

It is discussed in the literature that with aging the maximum range of motion of the lower limbs is reduced, contributing to the loss of balance and increasing the risk for falls (Wu et al., 2012). Gajdosik et al. (1999) compared the dorsiflexion range of motion of young, middle-aged, and older women, and found a progressive decrease in maximum dorsiflexion with advancing age. A smaller range of ankle motion during gait was also found in older adults with a history of falls compared with those with no fall history (Góes et al., 2015). It is a consensus that the physical exercises contribute to improved range of motion. Wu et al. (2012) found that older participants of low-impact activities (dance) had higher dorsiflexion levels compared with sedentary older participants. It seems that a specific ST is efficient for the goal of increased amplitude even with older subjects, and the current study corroborates with this fact, with a mean increase of 5.1°, similar to Gajdosik et al. (2005). However, such an increase was not accompanied by a concomitant increase in passive torque, which would indicate an increased stretch tolerance. We speculate that the high interindividual variability of torque values contributed to the results found and that a neural adaptation of increased stretch tolerance would be more plausible than a structural adaptation such as sarcomerogenesis or increases in noncontractile proteins, as suggested by Gajdosik et al. (2005). The authors found that older participants engaged in an 8-week stretching program had a significant increase in the maximum range of dorsiflexion, passive resistive forces throughout the full stretch range of motion, and also enhanced performances in functional activities. Methodological differences, such as force estimates instead of torque measurements and the instrumentation used, could justify these differences.

The passive dorsiflexion torque has been used to calculate the passive stiffness, which also remained the same after the training. It is known that the greater the stiffness presented by the structures surrounding the joint (primarily muscle and tendon), the faster the joint reaches a sufficient resistance to prevent an unnecessary joint displacement (Morse, Degens, Seynnes, Maganaris, & Jones, 2008). However, the training applied was not able to promote changes in joint stiffness, ratifying the fact that the risk for falls remained unchanged after the intervention.

The small sample size was a limitation of the current study (demonstrated by the low effect size) and may justify the lack of findings regarding the risk for falls. However, the results indicate a tendency that risks for falls will not change due to a training that is usually prescribed to older adults.

Conclusion

A FT and ST program was not sufficient to promote adaptations in triceps surae torque and ankle passive stiffness index, nor to enhance performance on functional tests, which would indicate a decrease in the risks for falls scores of older volunteers. Furthermore, the significant increase in the maximum range of dorsiflexion indicates a positive impact of specific stretching exercises of triceps surae conducted in the end of each training session.

Further studies with different training protocols are necessary to clarify the effects of functional training programs in torque and in other parameters and structures affected by aging.

References

Aniansson, A., & Gustafsson, E. (1981). Physical training in elderly man with special reference to quadriceps muscle strength and morphology. *Clinical Physiology (Oxford, England), 1*(1), 87–98. doi:10.1111/j.1475-097X.1981.tb00876.x

Barry, E., Galvin, R., Keogh, C., Horgan, F., & Fahey, T. (2014). Is the Timed Up and Go test a useful predictor of risk of falls in community dwelling older adults : a systematic review and meta- analysis. *BMC Geriatrics, 14*(1), 14. PubMed doi:10.1186/1471-2318-14-14

Bean, J.F., Vora, A., & Frontera, W.R. (2004). Benefits of exercise for community-dwelling older adults. *Archives of Physical Medicine and Rehabilitation, 85*(SUPPL. 3), 31–S42. PubMed doi:10.1016/j.apmr.2004.03.010

Bertolucci, P.H., Brucki, S.M., Campacci, S.R., & Juliano, Y. (1994). O Mini-Exame do Estado Mental em uma população geral. Impacto da escolaridade. *Arquivos de Neuro-Psiquiatria, 52*(1), 1–7. PubMed doi:10.1590/S0004-282X1994000100001

Bischoff, H.A., Stahelin, H.B., Monsch, A.U., Iversen, M.D., Weyh, A., von Dechend, M., . . . Theiler, R. (2003). Identifying a cut-off point for normal mobility : a comparison of the timed " up and go " test in community-dwelling and institutionalised elderly women. *Age and Ageing, 32*(3), 315–320. PubMed doi:10.1093/ageing/32.3.315

de Boer, M.D., Morse, C.I., Thom, J.M., De Haan, A., & Narici, M.V. (2007). Changes in Antagonist Muscles' Coactivation in Response to Strength Training in Older Women. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 62*(9), 1022–1027. PubMed

Chodzko-Zajko, W.J., Proctor, D.N., Singh, M.A.F., Minson, C.T., Nigg, C.R., Salem, G.J., & Skinner, J.S. (2009). Exercise and Physical activity for older adults. *Medicine and Science in Sports and Exercise, 41,* 1510–1530. PubMed doi:10.1249/MSS.0b013e3181a0c95c

Daubney, M.E., & Culham, E.G. (1999). Lower-extremity muscle force and balance performance in adults aged 65 years and older. *Physical Therapy, 79,* 1177–1185. PubMed

de Bruin, E.D., Najafi, B., Murer, K., Uebelhart, D., & Aminian, K. (2007). Quantification of everyday motor function in a geriatric population. *Journal of Rehabilitation Research and Development, 44,* 417–426. PubMed doi:10.1682/JRRD.2006.01.0003

de Vreede, P.L., Samson, M.M., van Meeteren, N.L., Duursma, S.A., & Verhar, H.J. (2005). Functional-task exercise versus resistance strength exercise to improve daily function in older women: a randomized, controlled trial. *Journal of the American Geriatrics Society, 53,* 2–10. PubMed doi:10.1111/j.1532-5415.2005.53003.x

Duncan, P.W., Weiner, D.K., Chandler, J., & Studenski, S. (1990). Functional reach: a new clinical measure of balance. *Journal of Gerontology, 45*(6), M192–M197. PubMed doi:10.1093/geronj/45.6.M192

Ferri, A., Scaglioni, G., Pousson, M., Capodaglio, P., Van Hoecke, J., & Narici, M.V. (2003). Strength and power changes of the human plantar flexors and knee extensors in response to resistance training in old age. *Acta Physiologica Scandinavica, 177,* 69–78. PubMed doi:10.1046/j.1365-201X.2003.01050.x

Fiatarone, M.A., Marks, E.C., Ryan, N.D., Meredith, C.N., Lipsitz, L.A., & Evans, W.J. (1990). High-Intensity Strength Training in Nonagenarians. Effects on Skeletal Muscle. *Journal of the American Medical Association, 263*(22), 3029–3034. PubMed doi:10.1001/jama.1990.03440220053029

Gajdosik, R.L., Vander, D.W., & Williams, A.K. (1999). Concentric isokinetic torque characteristics of the calf muscles of active women aged 20 to 84 years. *The Journal of Orthopaedic and Sports Physical Therapy, 29*(3), 181–190. PubMed doi:10.2519/jospt.1999.29.3.181

Gajdosik, R.L., Vander Linden, D.W., McNair, P.J., Williams, A.K., & Riggin, T.J. (2005). Effects of an eight-week stretching program on the passive-elastic properties and function of the calf muscles of older women. *Clinical Biomechanics (Bristol, Avon), 20*(9), 973–983. PubMed doi:10.1016/j.clinbiomech.2005.05.011

Gill, T.M., Baker, D.I., Gottschalk, M., Peduzzi, P.N., Allore, H., & Byers, A. (2002). A program to prevent functional decline in physically frail, elderly persons who live at home. *The New England Journal of Medicine, 347*(14), 1068–1074. PubMed doi:10.1056/NEJMoa020423

Góes, S.M., Leite, N., Stefanello, J.M.F., Homann, D., Lynn, S.K., & Rodacki, A.L.F. (2015). Ankle dorsiflexion may play an important role in falls in women with fibromyalgia. *Clinical Biomechanics (Bristol, Avon), 30*(6), 593–598. PubMed doi:10.1016/j.clinbiomech.2015.03.026

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 Geriatrics, 13,* 105. PubMed doi:10.1186/1471-2318-13-105

Hernandez, S.S.S., Coelho, F.G.M., Gobbi, S., & Stella, F. (2010). Effects of physical activity on cognitive functions, balance and risk of falls in elderly patients with Alzheimer's dementia. *Brazilian Journal of Physiotherapy, 14*(1), 68–74. PubMed doi:10.1590/S1413-35552010000100011

LaRoche, D.P., Cremin, K.A., Greenleaf, B., & Croce, R.V. (2010). Rapid torque development in older female fallers and nonfallers : A comparison across lower-extremity muscles. *Journal of Electromyography and Kinesiology, 20*(3), 482–488. PubMed doi:10.1016/j.jelekin.2009.08.004

Magnusson, S.P., Narici, M.V., Maganaris, C.N., & Kjaer, M. (2008). Human tendon behaviour and adaptation, in vivo. *The Journal of Physiology, 586*(1), 71–81. PubMed doi:10.1113/jphysiol.2007.139105

Morse, C.I., Degens, H., Seynnes, O.R., Maganaris, C.N., & Jones, D.A. (2008). The acute effect of stretching on the passive stiffness of the human gastrocnemius muscle tendon unit. *The Journal of Physiology, 586*(1), 97–106. PubMed doi:10.1113/jphysiol.2007.140434

Morse, C.I., Thom, J.M., Davis, M.G., Fox, K.R., Birch, K.M., & Narici, M.V. (2004). Reduced plantarflexor specific torque in the elderly is associated with a lower activation capacity. *European Journal of Applied Physiology and Physiology, 92,* 219–226. PubMed doi:10.1007/s00421-004-1056-y

Morse, C.I., Thom, J.M., Mian, O.S., Muirhead, A., Birch, K.M., & Narici, M.V. (2005). Muscle strength, volume and activation following 12-month resistance training in 70-year-old males. *European Journal of Applied Physiology and Occupational Physiology, 95,* 197–204. PubMed doi:10.1007/s00421-005-1342-3

Narici, M.V., & Maffulli, N. (2010). Sarcopenia : characteristics, mechanisms and functional significance. *British Medical Bulletin, 95,* 139–159. PubMed doi:10.1093/bmb/ldq008

Narici, M.V., Maffulli, N., & Maganaris, C.N. (2008). Ageing of human muscles and tendons. *Disability and Rehabilitation, 30*(20-22), 1548–1554. PubMed doi:10.1080/09638280701831058

Narici, M.V., & Maganaris, C.N. (2006). Adaptability of elderly human muscles and tendons to increased loading. *Journal of Anatomy, 208,* 433–443. PubMed doi:10.1111/j.1469-7580.2006.00548.x

Narici, M.V., & Maganaris, C.N. (2007). Plasticity of the muscle-tendon complex with disuse and aging. *Exercise and Sport Sciences Reviews, 35*(3), 126–134. PubMed doi:10.1097/jes.0b013e3180a030ec

Narici, M.V., Reeves, N.D., Morse, C.I., & Maganaris, C.N. (2004). Muscular adaptations to resistance exercise in the elderly. *Journal of Musculoskeletal & Neuronal Interactions, 4*(2), 161–164. PubMed

NICE. (2013). Falls in older people : assessing risk and prevention. [Web page]. Available: https://www.nice.org.uk/guidance/cg161/chapter/1-recommendations

Pedrinelli, A., Garcez-Leme, L.E., & Azul Nobre Rdo, S. (2015). The effect of physical training on the locomotor apparatus in elderly people. *Revista Brasileira de Ortopedia, 44*(2), 96–101. PubMed doi:10.1590/S0102-36162009000200002

Podsiadlo, D., & Richardson, S. (1991). The Timed "Up & GO": a test of basic mobility for frail elderly persons. *Journal of the American Geriatrics Society, 39,* 142–148. PubMed doi:10.1111/j.1532-5415.1991.tb01616.x

Reeves, N.D. (2006). Adaptation of the tendon to mechanical usage. *Journal of Musculoskeletal & Neuronal Interactions, 6*(2), 174–180. PubMed

Reeves, N.D., Maganaris, C.N., & Narici, M.V. (2003). Effect of strength training on human patella tendon mechanical properties of older individuals. *The Journal of Physiology, 548*(3), 971–981. PubMed doi:10.1113/jphysiol.2002.035576

Reeves, N.D., & Narici, M.V. (2003). Behavior of human muscle fascicles during shortening and lengthening contractions in vivo. *Journal of Applied Physiology, 95*(3), 1090–1096. PubMed doi:10.1152/japplphysiol.01046.2002

Schwenk, M., Jordan, E.D., Honarvararaghi, B., Mohler, J., Armstrong, D.G., & Najafi, B. (2013). Effectiveness of foot and ankle exercise programs on reducing the risk of falling in older adults: a systematic review and meta-analysis of randomized controlled trials. *Journal of the American Podiatric Medical Association, 103*(6), 534–547.

Tiedemann, A. (2006). *The development of a validated falls risk assessment for use in clinical practice*. Wales, UK: University of New South Wales.

Tiedemann, A., Lord, S.R., & Sherrington, C. (2010). The development and validation of a brief performance-based fall risk assessment tool for use in primary care. *The Journals of Gerontology, Series A, Biological Sciences and Medical Sciences. 65*(8), 896–903. PubMed

Tinetti, M.E. (1994). Prevention of falls and fall injuries in elderly persons: a research agenda. *Preventive Medicine, 23,* 756–762. PubMed doi:10.1006/pmed.1994.1130

Weppler, C.H., & Magnusson, S.P. (2010). Increasing muscle extensibility: a matter of increasing length or modifying sensation? *Physical Therapy, 90*(3), 438–449. PubMed doi:10.2522/ptj.20090012

Wu, H., Gau, J., Hsu, C.H., Tu, J.H., & Tsao, T.H. (2012). Effects of habitual low-impact dance on the balance and torque of the knees of older female individuals. *Advances in Physiology Education, 2*(2), 39–43. doi:10.4236/ape.2012.22007