CHAPTER 7

The Flexibility Debate

Implications for Health and Function as We Age

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ABSTRACT

Flexibility is the range of motion (ROM) available in a joint or group of joints and can be increased via a flexibility or stretching program. Despite the well-established and long-standing inclusion of stretching programs for fitness routines, there are currently scientific discussions regarding the utility of stretching exercises, which are regularly recommended for overall health and conducted as a part of preexercise protocols to reduce injury and increase performance in athletic-type activities. The implication of this "debate" for the older adult population warrants further discussion, as age-related declines in joint-specific ROM are observed. For the majority of the aging population, ROM status may not be related to fitness activity performance but rather to performance of the activities of daily living. For this reason, the promotion of flexibility in the older adult population is substantial. This chapter reviews the age-related declines of various body parts and how they may relate to function and quality of life as we age. Existing recommendations are based on limited evidence precluding the offering of guidance as to a flexibility intervention related to maintaining or improving functional ROM for older adults.

While ROM decreases with age, older adults do maintain the ability to regain ROM. This chapter summarizes the role of physical activity levels and exercise interventions in the maintenance and training of ROM. The pressing need for high-quality, purposive study of flexibility is warranted in order to establish the magnitude of impact on function.

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INTRODUCTION

Physical fitness standards have been proposed to identify the level of fitness and physical activity needed to remain independent as we age (Rikli & Jones, 2013), and high levels of evidence demonstrate the significant role of exercise training in increasing and maintaining physical fitness across the older adult age range (Paterson & Warburton, 2010). In fact, recently updated international physical activity guidelines are focused on minimum prescriptions of physical fitness components for optimal functional health as well as overall health (Paterson & Warburton, 2010). Whereas the utility of some components of physical fitness (cardiorespiratory fitness and muscle strength and power) are supported by high levels of evidence, one component of physical fitness, flexibility, is not.

The inclusion of flexibility exercise (i.e., stretching) has been a long-standing one in health, fitness, and sport prescriptions. Early recommendations include static stretching as a critical component of warm-up prior to exercise, largely for the purpose of injury prevention. While widespread acceptance of preexercise stretching exists among the general public's consciousness, the past decade has seen a challenge to this long-standing view and the lack of strong evidence (specifically randomized controlled trials [RCTs]) for its support has been identified (Thacker, Gilchrist, Stroup, & Kimsey, 2004). The recommendation for stretching before exercise and as an activity in and of itself is even more pervasive when applied to the older adult population. There is an inordinate amount of emphasis and promotion of the importance of flexibility for older adults, but as in the younger populations, it is unwarranted based on current best evidence (Stathokostas, Little, Vandervoort, & Paterson, 2012). This is not to say that there is no relationship, but rather that one has not yet been demonstrated conclusively. In fact, a lack of evidence recommending stretching routines outside of a rehabilitative context has been identified (Stathokostas et al., 2012).

Simply stated, flexibility is the range of motion (ROM) available in a joint or group of joints; functionally, it can be considered the joint's ability to pass through a given ROM without significant impingement or restriction in performing a given task (American College of Sports Medicine [ASCM], 2014) and can be increased by various methods of stretching (Table 7.1). The ROM of any joint is determined by the distensibility of the joint capsule, muscle viscosity, and the compliance of ligaments and tendons. Two types of connective tissue can affect ROM: fibrous connective tissue (fascia, ligaments, and tendons, consisting primarily of collagen) and elastic connective tissue, many of which undergo changes as a result of immobilization and/or aging. For example, degenerative changes of the intervertebral disc and surrounding structures can lead to alteration of the mechanical properties of the functional spinal unit, with a trend toward spinal stiffening with the increasing degeneration (Galbusera et al., 2014). Flexible,

TABLE 7.1
Various Stretching Techniques

Stretching Technique	Description
Ballistic stretching	Rapid lengthening of the muscle by use of bouncing movements
Dynamic stretching	Gradual progression through movement
Isometric stretching	Static stretching against an immobile force
Passive stretching	Slow sustained muscle lengthening with a partner
Proprioceptive neuromuscular facilitation	Passive muscle lengthening with a partner after an antagonistic muscle contraction
Static stretching	Slow, sustained muscle lengthening held for some duration

pain-free joints are important for well-being, and so the informal observations made of those of advanced age and subjectively reported feelings about "stiffness" by older adults cannot be ignored. However, we need to delineate the primary aging process from the clinical condition of stiffness (the common residual problem of joint immobilization, joint contracture) and investigate whether it is possible to remain "vital and supple" into older age (with/without flexibility training).

AGE-RELATED CHANGES IN FLEXIBILITY WITH AGE

Joint flexibility may decrease across the age span (beginning in mid- to late-20s) (Nonaka et al., 2002; Roach & Miles, 1991; Shields et al., 2010), with the rate of decline dependent on the body part measured, the training status of the sample, and population being studied. For example, a loss of as much as 50% has been observed between young and old in spinal extension (Einkauf, Gohdes, Jensen, & Jewell, 1987) and ankle mobility (Vandervoort et al., 1992). Specific to the older age range, the rate of decline in a generally healthy sample has been shown to be 0.5° per year in males and 0.6° per year in females of upper body flexibility (shoulder abduction) and declines in hip flexion of 0.6° per year in males and 0.7° per year in females (Stathokostas, McDonald, Little, & Paterson, 2013). A 1% decline per year in shoulder abduction ROM of older men and women has been reported in a sample reporting high disability (Bassey, Morgan, Dallosso, & Ebrahim, 1989). Rates of 1.5° per year have been reported for lower back flexion (Einkauf et al., 1987).

Potential critical periods of decline in flexibility across the older adult age range have been identified. James and Parker (James & Parker, 1989) reported decreases in active and passive motion in lower limb joints during the period of 70 to 92 years, with the decline becoming more pronounced during the ninth decade. While not significant, Charkravarty and Webley (Chakravarty & Webley, 1993) reported a greater decline in ROM in a group over the age of 75 years versus an age group 65–74 years, adding support for the trend for an accelerated decline in flexibility in the oldest old. Recently, using piecewise linear regression, an accelerated decline was documented to occur at age of 71 years in both upper and lower body flexibility, as shown in Figures 7.1–7.4 (Stathokostas et al., 2013).

FLEXIBILITY, AGE, AND FUNCTIONAL CAPACITY

The observed declines in flexibility with age are purported to affect normal daily function. It is often mentioned that upper body flexibility is known to be important for activities such as getting dressed and reaching for objects and that lower body flexibility is important for maintaining normal walking patterns and activities involving bending and reaching. These associative statements are most often inferred, and there is surprisingly a paucity of evidence that directly links changes in joint specific flexibility with matched functional outcomes. One of the most thoroughly studied joints is the ankle, with decreased strength

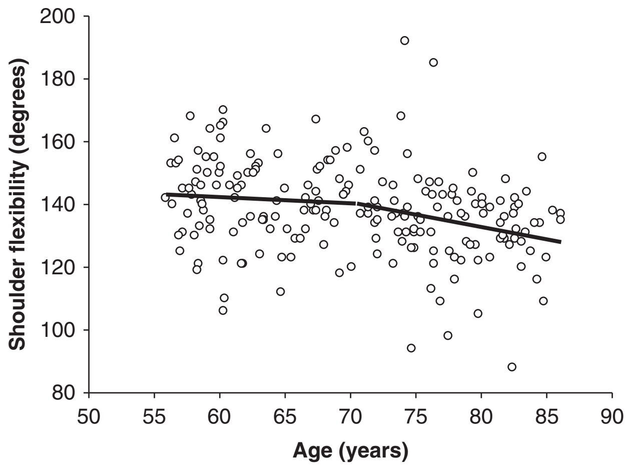

FIGURE 7.1 Age analysis for shoulder flexibility in men. Piecewise linear regression s-segment model shows breaking at age 71 years. Rate of decline prior to age 71 is –0.20° per year and –0.80° per year thereafter (R^2 of fit R^2 = 0.09). Reproduced with permission from Stathokostas et al. (2013).

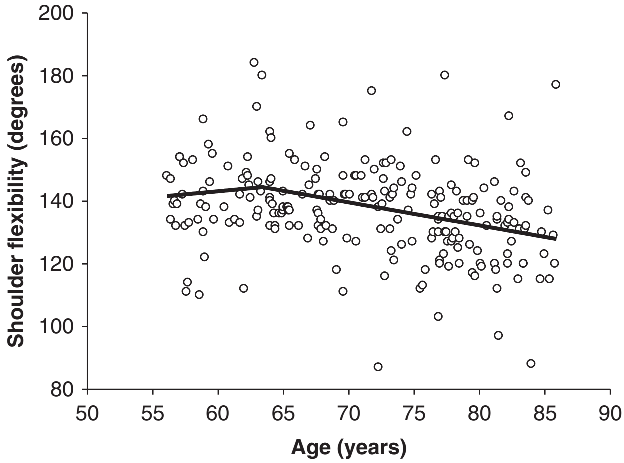

FIGURE 7.2 Age analysis for shoulder flexibility in women. Piecewise linear regression s-segment model shows breaking at age 63 years. Rate of change prior to age 63 is 0.38° per year and –0.74° per year thereafter (R^2 of fit R^2 = 0.09). Reproduced with permission from Stathokostas et al. (2013).

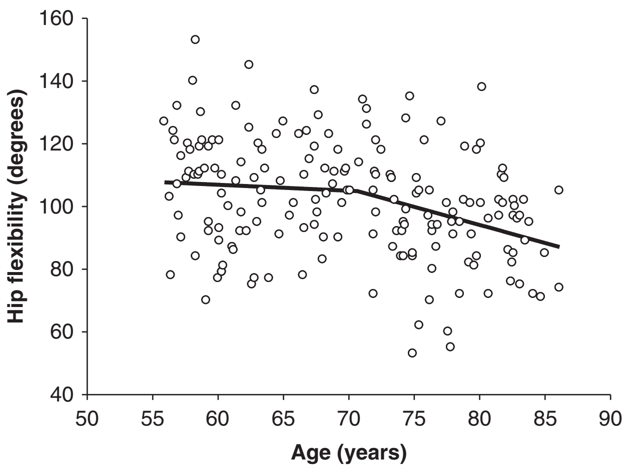

FIGURE 7.3 Age analysis for hip flexion in men. Piecewise linear regression s-segment model shows breaking at age 71 years. The rate of decline prior to 71 years is –0.19° per year and –1.16° per year thereafter (R^2 of fit R^2 = 0.11). Reproduced with permission from Stathokostas et al. (2013).

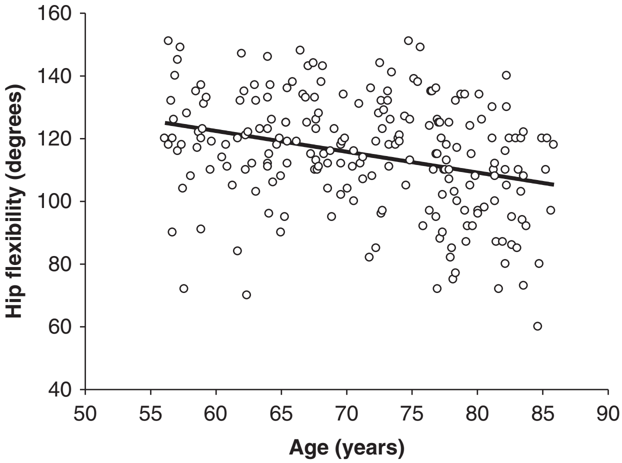

FIGURE 7.4 Age analysis for hip flexion in women. Piecewise linear regression s-segment model shows breaking at age 86 years. The rate of decline prior to 86 years is –0.66° per year and –2.67° per year thereafter (R^2 of fit R^2 = 0.08). Reproduced with permission from Stathokostas et al. (2013).

and flexibility of the muscles around the ankle joint identified as risk factors for falls with age, as shown in Figure 7.5 (Vandervoort, 1999). Tainaka, Takizawa, Katamoto, and Aoki (2009) showed that ankle dorsiflexion ROM was a significant physical fitness factor in predicting 6-year incidence of disability. Shoulder flexibility was also identified as one determinant of independence when comparing a group of independently living older adults versus those in rest or nursing homes. Conversely, there was no association between hip flexion changes with age and self-reported difficulty with stair climbing (Stathokostas et al., 2013). Finally, we compared our results to reference values, indicating that shoulder abduction ROM of 120° and hip flexion values of 30°–50° (for most hip-related functional activities) were considered to be lower end thresholds associated with functional loss (Badley, Wagstaff, & Wood, 1984). Using the "reference" that a value of <120° was related to functional loss, among our community-dwelling, disability-free sample, the probability of the age-related decline in shoulder flexibility falling to below the reference values was very low; less than approximately 10 subjects beyond age 75 years fell below this "functional threshold," and the average for the 85-year-old was close to 130°. For hip flexibility, we were not aware of any similar data to establish a functional threshold. These studies might suggest that the roles of flexibility and function with aging are population dependent and may not be as influential in younger or healthy subgroups of older adults. For example, in a large sample of older adults reporting reduced mobility,

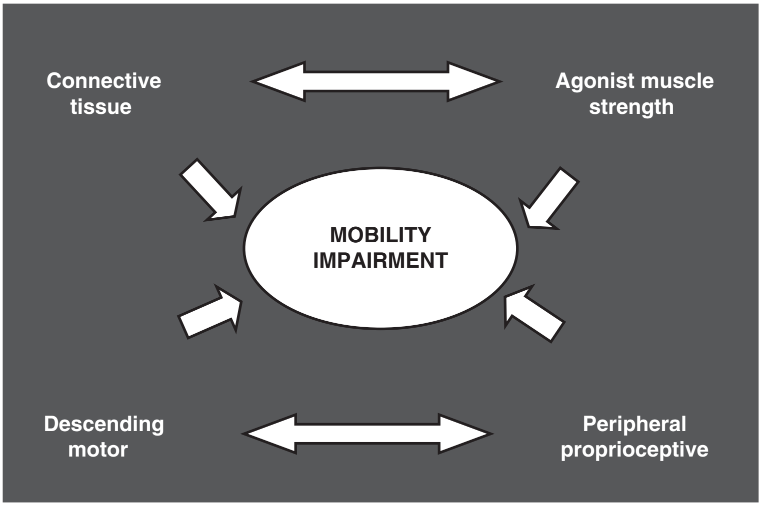

FIGURE 7.5 Key factors in joint mobility. Adapted with permission from Vandervoort (1999).

for activities that involve a high level of physical ability and endurance, such as walking several blocks or getting up from the floor, trunk extensor muscle endurance and knee flexion ROM were important (Bean et al., 2013).

FLEXIBILITY, AGING, AND QUALITY OF LIFE

It has been reported that older adults find personal benefits of physical activity (posed collectively as strength, balance, and flexibility; Franco et al., 2015). In addition, physical function has been shown to be positively associated with perceived quality of life (QOL) in older persons as assessed by the Short Physical Performance Battery (Fusco et al., 2012). However, the direct and independent relationship of flexibility with QOL, well-being, and successful aging has been not been adequately studied. The limited studies in this area indicate that upper and lower body flexibility were not associated with self-rated health and life satisfaction in a sample of independently living, generally healthy older adults (Stathokostas et al., 2013), whereas life satisfaction and social engagement was associated with shoulder ROM in a large sample of older men and women living with a specific arthritis-related disability in that joint (Bassey et al.,1989). Similarly, a study of nonagenarians where almost half the sample reported an orthopedic condition or chronic condition, observed a significant association between upper body flexibility and health-related QOL (Fabre et al., 2007). However, in contrast, proprioception and flexibility (sit and reach) were not correlated with the Short Form-12 (SF-12) in a sample of nursing home residents (Ozcan, Donat, Gelecek, Ozdirenc, & Karadibak, 2005). Low-active older adults increased QOL in a combined strengthening and flexibility intervention (Awick et al., 2015). Spinal ROM in middle- and older-aged adults was associated with QOL (Imagama et al., 2011). While further research is required to understand the role of flexibility in QOL and successful aging, an association is likely related to the presence of a disability or a range of joint motion below some critical threshold.

FLEXIBILITY, PHYSICAL ACTIVITY LEVELS, AND AGING

Although the loss in flexibility with age has been attributable, in part, to decreased activity (i.e., the difference in rate of change in flexibility across joints has been attributed to the degree of use of those joints), the literature describing the influence of physical activity on flexibility and the aging process is limited. The approach of investigating whether “flexibility training” is warranted in older adults by observing whether overall physical activity levels are sufficient to maintain ROM with age is intriguing. It has been established that efforts greater than those provided by activities of daily living or light activities are needed for cardiorespiratory and muscular fitness and functional gains (Paterson & Warburton, 2010). No relationship between self-reported overall physical activity levels and upper or lower body flexibility has been reported (Stathokostas et al., 2013). Similarly, no relationship was observed when physical activity was classified into high and low physical activity categories (Walker, Sue, & Miles-Elkousy, 1984) or when comparing sedentary versus active older adults (Miotto, Chodzko-Zajko, Reich, & Supler, 1999). Bassey et al. (1989) studied the association between shoulder abduction and self-reported customary use of the shoulder and found an association; however, it should be noted that the effect was not significant in women in multiple regression (replaced by effort score), and the effect of customary use was greater in those with a disability. This finding may suggest that a more closely matched flexibility and activity-specific measurement is more reflective of the role of physical activity in the change in flexibility with age.

Further insight is gained when identifying studies of structured, purposeful, repetitive physical activity, that is, exercise. In a small sample of 30 older women, Rikli and Bush (1986) found a significant difference for trunk and shoulder flexibility in active versus nonactive women, where active meant vigorous activity for at least 30 minutes, 3 days per week. This study reported a significant age-by-activity interaction for shoulder flexibility but not for trunk flexion. Voorrips (Voorrips, Lemmink, van Heuvelen, Bult, & van Staveren, 1993), in a sample of 50 women with a mean age of 72 years, reported significantly greater flexion at the hip and spine in women who self-reported high activity levels (several hours per week in aerobic-type exercises). A 5-year longitudinal study by Lan (Lan, Chen, & Lai, 2008) demonstrated that baseline and follow-up thoracolumbar flexibility values were higher in older adults participating in a Chinese conditioning program of repeated motions and postures with ROM warm-up versus a sedentary control group. Further, while both groups showed an age-related decline over the 5 years, the control group had a larger decline in flexibility, supporting a positive role of "physical activity" in attenuating the decline in flexibility with age.

FLEXIBILITY TRAINING AND AGING

While it would appear that overall daily physical activity does not positively influence flexibility in older adults, there may be a role for more structured physical activity. As indicated in the studies in the preceding text, flexibility appears to change with engagement in a general exercise or fitness program. Recently, flexibility has been shown to increase in older adults after interventions involving Pilates (Bullo et al., 2015) and resistance training (Carneiro et al., 2015). However, these studies do not focus solely on the role or individual contribution of flexibility training.

Flexibility training encompasses a planned, deliberate, and regular program of exercises that can progressively increase the useable ROM of a joint or set of joints over a period of time, thereby allowing older adults to optimize their flexibility. In an attempt to establish evidence-based guidelines for the prescription of flexibility exercises, we have previously detailed the literature related to interventions specifically designed for flexibility improvement and observation of resultant functional outcomes (26 studies; Stathokostas et al., 2012). Based on the available literature, the review was not able to provide a consensus on flexibility-training prescription for healthy older adults due to the lack of studies solely involving flexibility training and due to the lack of consistency in the flexibility protocols employed. Furthermore, this review found variation in the value of flexibility training for functional outcomes that may be related to the maintenance of independence in daily activities of older adults. The more influential and high-quality studies of community-dwelling older adults in this review (Table 7.2) showed very comparable effects to the overall outcomes of the 26 studies, namely, variation regarding the value of flexibility training for functional outcomes that may be related to the maintenance of independence in daily activities of older adults. In a subgroup of the very old (≥80 years), frail, and assisted-living populations, there were significant improvements seen in functional reach, sit-to-stand, and 30 meter walk times, but no changes in the physical performance test, and mixed results were observed for flexibility, strength, balance, and timed up-and-go tests. This subgroup was very similar to the rest of the populations in terms of interventions received, although this group had less consistency in the flexibility-related outcome measures. Frequency and duration differences between studies showed no noticeable differences. When different muscle groups were targeted, the flexibility outcomes were expectantly fairly body part specific. Regarding the different flexibility-training methods, active assisted stretching had positive and sometimes significant improvements in several outcome measures as compared to the inactive control group but these were less significant than the improvements seen with the proprioceptive neuromuscular facilitation (PNF) techniques. Weighted flexibility exercises were similar to nonweighted exercises in one study but significantly better than nonweighted exercises in another. One study showed agonist contract–relax PNF to be much more effective than contract–relax PNF and static stretching for both ROM and electromyography activity. The overall results point to PNF stretching being more effective than non-PNF techniques for improving flexibility outcomes but not necessarily functional outcome measures. More recently, a practical protocol of flexibility training for spinal ROMs was proposed and resulted in significant increases in sacral/hip and thoracic ROMs (Battaglia et al., 2014); however, no functional outcomes were related to those changes. Due to the low level of evidence and grade available to formulate a prescription for flexibility training, the current Canadian Physical Activity Guidelines for Older Adults do not include a comment on flexibility (Canadian Society for Exercise Physiology, 2011). However, guidance for the improvement in ROM when needed can be found in the ASCM Position Stand for Exercise and Physical Activity for Older Adults (2009), which also identifies the need for further work in this area.

While flexibility training interventions has been shown to increase flexibility and joint ROM in older adults, future studies should consider the relationship that increased flexibility and joint ROM have with functional outcomes to determine if the increased flexibility is beneficial and worthwhile in terms of maintaining or increasing functional capacity for healthy older adults.

THE ROLE OF FLEXIBILITY IN WARM-UP PRIOR TO AN EXERCISE SESSION

While the lack of evidence precludes informing a concise prescription for flexibility in older adults, much can still be gleaned from resources aimed at young and middle-aged adults. The main goal of a warm-up, as indicated by its name, is to engage in submaximal aerobic activity for the purpose of raising body (and thus muscle) temperature by 1–2°C (Young & Behm, 2002). The rise in muscle temperature results in increased muscle compliance, increased nerve conduction

TABLE 7.2
Flexibility Training Studies Examining the Relationship Between Flexibility and Functional Abilities in Older Adults

Publication Study Type	Objective	Methods	Outcomes	Comments and Conclusions
Bird et al., 2009 Randomized crossover trial Focus: major muscle groups	To determine the effect of community-based resistance-training (RT) vs. flexibility-training (FT) programs on balance and related measures	*n* = 32 Age: mean 67 yr Males = 18, females = 14 *Pre-post:* 16 wks, 4-wk washout, 16 wks (crossover) *Intervention* Both groups had 3 sessions wk^{-1} for 16 wks, then 4-wk washout, then switch to other group for 16 wks RT: 2–3 sets of 10–12 repetitions FT: 40–45 min with 16–20 stretches; two stretches for each of hamstrings, quadriceps, back, and chest *Assessments* Balance, force plate Timed up and go (UG) 10 times sit to stand Step test Lower limb strength (right and left knee—flexion and extension) with an isokinetic dynamometer	Lower limb strength increased significantly in the RT group, but not in the flexibility group and there was a significant difference between the two groups. Significant improvements were seen in both groups for timed UG, 10 times sit to stand, and step test. Significant improvements in medial–lateral sway *range* were seen in the flexibility group only. Significant decreases in sway *velocity* were seen in both conditions.	Significant improvements in balance performance were achieved with both RT and standing FT programs in healthy untrained older adults. Flexibility program did incorporate some degree of balance training in the nature of the flexibility tasks.

(*Continued*)

TABLE 7.2

Flexibility Training Studies Examining the Relationship Between Flexibility and Functional Abilities in Older Adults (Continued)

Publication Study Type	Objective	Methods	Outcomes	Comments and Conclusions
Brown et al., 2000 Randomized controlled trial (RCT) Focus: major muscle groups	To examine effects of low-intensity exercise on factors associated with frailty (gait, flexibility, strength, balance, sensation, response time, coordination) vs. flexibility control group	*n* = 87 Age: 83 ± 4 yr *Pre-post:* 3 mo *Intervention* EXER: 22 low-intensity strength and flexibility exercise for upper and lower body 3x/wks for total of 36 sessions (~3 mo) HOME: 9 upper and lower body flexibility exercises Conducted at home (self-report), option to participate on site $1 \cdot wk^{-1}$ *Assessments* Strength: physical performance test, isokinetic dynamometer (knee flexors/ extensors, ankle flexors/extensors), handheld dynamometer (upper extremities)	*Strength* Significant increases in knee flexor and extensor strength (9% change vs. −1% in control), and shoulder abductors. *Range of motion (ROM)* Flexibility increased in all measurements and in both groups. *Balance* Significant improvements in EXER group for obstacle course, full tandem of Romberg, Berg balance test, and one-limb standing time. No significant changes in control group.	These results suggest that the more comprehensive the exercise intervention, the greater the likely scope of improvement in frailty.

		ROM: goniometry (shoulders, hips, knees, ankles, trunk) Balance: static (Romberg test), dynamic (balance bean, obstacle course, and gait speed), and weight shift (Berg balance test) Gait: pressure-sensitive foot switches Coordination: Purdue peg board Speed of response: red light to green light, stepping on brake and gas pedals Sensation: Semmes-Weinstein monofilaments	*Gait* Significant change in preferred walking cadence in EXER group. *Coordination* Difference between groups was "*almost* significant." *Response time* Unchanged in both groups. Sensation: No apparent differences.	
King et al., 2000 RCT Focus: major muscle groups	To evaluate the effects of two different community-based physical activity regimens—on 1-yr physical performance outcomes, perceived functioning, and well-being in a sample of community-dwelling, sedentary women and men	*n* = 103 Age: 70 ± 4 yr Males = 36, females = 67 *Pre-post:* 12 mo, 6 mo interim assessment 2 exercise classes/wk and home exercise at least $2 \cdot wk^{-1}$ Classes 1 hr, home exercise built up to 40-min sessions	(values reported separately for men and women for each group) *Functional capacity/endurance* Submax HR: Fit & Firm had significantly greater improvement vs. Stretch & Flex. *Strength and flexibility* Lift-and-reach task: Fit & Firm had significantly greater upper body strength than Stretch & Flex. Sit to stand: No significant results.	Community-based physical activity regimens focusing on moderate-intensity endurance and strengthening exercises or flexibility exercises can be delivered through a combination of formats that result in improvements in important functional and quality-of-life outcomes.

(*Continued*)

TABLE 7.2

Flexibility Training Studies Examining the Relationship Between Flexibility and Functional Abilities in Older Adults (Continued)

Publication Study Type	Objective	Methods	Outcomes	Comments and Conclusions
		Experimental group (Fit & Firm) Progressive moderate-intensity endurance and strengthening exercises 5–10 min warm-up, 40–45 min aerobic and strength-training circuit, 5–10 min cooldown; target heart rate 60%–75% HRR Control group (Stretch & Flex) Stretching and flexibility exercises 5–10 min warm-up, 40 min stretching section, 5–10 min relaxation exercises; stretching for neck, shoulders, back, chest, waist, hamstrings, calves, and hands *Assessments* Functional capacity/endurance: Graded treadmill exercise test (GXT) Strength and flexibility: Upper body strength (lift-and-reach task), lower body strength (sit to stand), and flexibility (sit and reach [SR] with Accuflex 1 Sit and Reach box) Self-rated physical performance: a self-efficacy questionnaire	SR: Men assigned to Stretch & Flex had significantly greater increases than men in Fit & Firm. No statistical difference in women, but trend for greater improvement for women in Fit & Firm vs. Stretch & Flex. Women in Fit & Firm had significantly greater increases in flexibility at 12 mo than men. *Self-rated physical performance* Significantly greater increases in walking distance and self-efficacy for heavy lifting in Fit & Firm than in Stretch & Flex. *Perceived functioning and well-being* Only pain scale had significantly greater effects for Stretch & Flex (also statistically significant within group) than Fit & Firm.	

		Perceived functioning and well-being: scales from the Medical Outcomes Study (MOS) including physical functioning, bodily pain, emotional well-being, energy/fatigue, sleep problems, sense of mastery, and self-esteem		
Klein, Stone, Phillips, Gangi, & Hartman, 2002 Prospective two-stage intervention Focus: major muscle groups	To examine the impact of proprioceptive neuromuscular facilitation (PNF) on physical function in an assisted-living population by assessing ROM and isometric strength	*n* = 14 Age: 87 ± 6.5 yr Male = 2, female = 12 Baseline (T1), pre-training (T2, 5 wks), post-training (T3, 10 wks) Pre-training 1·wk^{-1} visit with trainer to increase rapport and interest in participation *Training program* 40–60 min, 2·wk^{-1} Warm-up, cool down, and flexibility (single set 15–20 min, later 2–3 sets) Flexibility: 8 exercises using passive contract–relax PNF technique (6 s isometric contraction, then passive stretch held for 20 s, then 20 s rest). Hamstrings, gluteals, shins, calves, and back	*n* = 11 Statistically significant differences in 6 of 18 variables: Sit to stand decreased significantly from 9.33 to 7.91 s (p = 0.42). No change in balance, get up and go, single-leg stand. Ankle flexion ROM decreased (improved) from 26.25° to 20.27º (p = 0.009). Shoulder-flexion ROM increased from 163.8 º to 177.6º (p=0.016). No change in hip flexion, hip extension, ankle extension, functional reach, SR.	PNF flexibility training can improve ROM, isometric strength, and selected physical function tasks in assisted-living older adults. Because the training period was short, 10 wks, the results suggest that continued training might have a greater impact on physical function and the ability to perform routine daily activities.

(*Continued*)

TABLE 7.2

Flexibility Training Studies Examining the Relationship Between Flexibility and Functional Abilities in Older Adults (Continued)

Publication Study Type	Objective	Methods	Outcomes	Comments and Conclusions
		Assessments Isometric strength (dynamometer), flexibility (bubble inclinometer for shoulders, hips, and ankles; SR for spine; functional reach for shoulder) Mobility: get-up-and-go test, sit to stand	Significant increases in strength for hip extension and ankle flexion/extension. No change in hip flexion, shoulder extension, shoulder flexion strength.	
Stanziano, Roos, Perry, Lai, & Signoril, 2009 RCT Focus: major muscle groups	To examine impact of an active assisted (AA) flexibility program on ROM and functional performance variables in older persons living in a residential retirement community (RRC)	*n* = 17 Age: 88 ± 5.4 yr Experimental group *n* = 8 90 ± 4.5 yr 1 male, 7 female Control group *n* = 9 88 ± 6.2 yr 3 male, 6 female *Pre-post:* 8 wks; $2 \cdot wk^{-1}$	*n* = 13 Flexibility Significant increases in ROM made by experimental group for all measures but left-side BS and right-side SR. Control group showed no change in any flexibility measure but a significant loss in ROM for right-side knee extension.	Eight wks of AA stretching may be an effective intervention for improving ROM, mobility, and functional power for older persons living in an RRC. Data provide clear link between flexibility and functional performance in older persons and support the inclusion of flexibility training in interventions designed to increase independence in older persons.

	Experimental group 10 stretches: back scratch (BS; shoulder flexion/abduction), standing thigh (hip hyperextension), side lunge (hip abduction), overhead back (shoulder hyperflexion), overhead side (lateral trunk flexion), cross chest (horizontal shoulder adduction), seated trunk twist (trunk rotation), seated hamstring (trunk/hip flexion), and seated calf (dorsiflexion) 10 repetitions, 4–5 s each Control group Arts and crafts class with limited physical exertion *Assessment* Conducted 1 wk pretraining and posttraining period Flexibility: BS test; modified chair SR test; Supine knee extension (KE) test; modified total body rotation (BR) test	Functionality Experimental group significantly improved CS and MRPT, while control had significant declines. Experimental group significantly improved in AC and the GJST, while control had no change. Experimental group reduced time taken to complete the UG and GS.

(*Continued*)

TABLE 7.2

Flexibility Training Studies Examining the Relationship Between Flexibility and Functional Abilities in Older Adults (Continued)

Publication Study Type	Objective	Methods	Outcomes	Comments and Conclusions
		Strength/power: 30-s chair stand (CS); modified ramp power test (MRPT); 30-s arm curl (AC); gallon jug shelf test (GJST) Mobility: 50-foot gait speed test (GS); 8-foot timed UG		
Takeshima et al., 2007 Non-RCT Focus: major muscle groups	To compare the effects of a walking-based aerobic program, a band-based resistance program, a stretching flexibility program, a customized balance program, and a Tai Chi program on functional fitness in a group of community older adults	*n* = 117 73 ± 6 yr 64 male, 49 female *Pre-post:* 12 wks *Intervention* Supervised 2 days· wk^{-1} (RES, BAL, FLEX, T-CHI) 3 days per wk (AER) AER—outdoor walking RES—progressive elastic band exercises for all major muscle groups BAL—eyes open/closed, exercise on floor, on foam mats FLEX—15 static stretches for upper and lower body (15–20 s each) T-CHI—standardized 24 forms	Improvement in cardiorespiratory fitness (12-min walk) was limited to AER (16%) RES, BAL, AND T-CHI resulted in improvements in upper and lower body strength and balance/agility. RES showed greatest upper body strength improvement (31%). BAL showed greatest lower body strength improvement (40%). Balance/agility were similar across RES, BAL, AND T-CHI (10%).	It is recommended that older adults participate in a well-rounded exercise program vs. single mode. RES, BAL, and TAI CHI cross domains not specifically targeted in their design. AER necessitates aerobic-specific activity to improve cardiorespiratory fitness.

	Assessments Functional fitness 30-s AC test 30-s CS time 8-foot timed UG BS test Chair SR Test 12-min walk test	Functional reach, similar improvements for AER (13%), BAL (16%), RES (15%). No significant changes in either FLEX or control (CON) group on any measure.	With FLEX, lack of improvement suggests that further study is needed to explore the effect of flexibility exercise training in older adults.

Note: PNF = proprioceptive neuromuscular facilitation; HR = heart rate; HRR = heart rate reserve.

velocity, and enzyme cycling (Young & Behm, 2002). While traditionally considered a staple of warm-up, available evidence suggests that static stretching may be detrimental to subsequent strength-, power-, speed, and agility-type performance (Peck, Chomko, Gaz, & Farrell, 2014). In addition, there is now a general consensus that stretching in addition to warm-up does not positively affect the incidence of overuse injuries (Thacker, Gilchrist, Stroup, & Kimsey, 2004). There is evidence that preparticipation stretching reduces the incidence of muscle strains, but there is clearly a need for further work (McHugh & Cosgrove, 2010). Thus, due to equivocal evidence thus far, the current ASCM's guidelines for exercise testing and prescription (ACSM, 2014) recommended the removal of static stretching as part of a warm-up routine for strength and power activities.

Older adults may be less concerned with high-performance benefits from increased flexibility and more focused on being safely active and safely performing activities of daily living. Injury and fall prevention are also common motives for recommending flexibility programs to older adults. The 2011 ACSM position stand (Garber et al., 2011) notes that flexibility training may enhance postural stability and balance when combined with resistance training; however, no consistent link has been shown between regular flexibility exercise and a reduction of musculoskeletal injuries or delayed onset of muscle soreness. In contrast, other exercise modalities, such as Tai Chi Chu'an, involving gait, balance, coordination, functional exercises, and muscle strengthening seem to have the greatest impact on balance in older adults (Hackney & Wolf, 2014). As such, the choice of this modality involving gentle stretching into controlled postures (and challenging other fitness variables) may be a more effective option for injury prevention. In summary, a general whole-body warm-up by gradually increasing the physical activity intensity up to that of the target level of the exercise session followed by dynamic stretching is advisable, with static stretching conducted after the exercise session.

CONCLUSIONS

Definite conclusions in the flexibility debate are premature and await further analyses that are able to discern whether the age-related losses in flexibility impact functional outcomes to an important extent. There is also the question about what degree of loss of ROM might relate to disability. In particular, a more direct matching of specific limb ROM and meaningful functional outcome is needed. Additionally, the specific type of physical activity that may influence the age-related loss needs to be further elucidated. While there is a lack of evidence to recommend stretching routines outside of a rehabilitative context, there is no apparent health or functional risk in including flexibility exercises. As such, in light of increases in functional outcomes achieved by other exercise modes (endurance, aerobic exercise, strengthening exercises), a formal program of stretching exercises can be included as an adjunct to the above, but the current literature would indicate that it would not add much to the overall functional benefits of exercise.

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