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Review Article

Stretching exercise: prescription and effects on musculoskeletal function in adults and older people

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Abstract: Introduction: Stretching exercises have been included in training and rehabilitation programs to improve the flexibility of adults and older people. However, there is no consensus in the literature about the recommendations for stretching prescription. Objective: The aim of this study was to present an update of recent evidence about the prescription and the musculoskeletal effects of stretching exercises in adults and older. Method: Articles were searched on major databases and related to the period from 2006 to 2017, with the following descriptors: "muscle stretching exercise", "long-term effect", "elderly", *"exercício de alongamento muscular", "efeitos a longo prazo"*, and *"idoso"*. Results: After the analysis, 31 articles were included. The literature reported that the duration of the stretching should be between 10 to 30 seconds, each repetition, for young adults, and from 30 to 60 seconds for the elderly. Regarding acute effects, it was observed that for young adults, stretching durations up to 60 seconds may impair muscle strength performance, what does not seem to occur with elderly people. The main chronic effects found for young and elderly adults were an enhancement in flexibility and range of motion, and for the elderly, it was also observed improvement on torque, balance, gait, mobility, and functionality. The wide methodological variability of the articles analyzed impairs the establishment of a consensus. Conclusion: It is recommended that the stretching exercise must be prescribed considering the evidence for the specific population, i.e., adult or elderly people, as well as the goal to be achieved.

Keywords: *Muscle Stretching Exercises, Exercise Therapy, Musculoskeletal System, Young Adult, Aged.*

Exercícios de alongamento: prescrição e efeitos na função musculoesquelética de adultos e idosos

Resumo: Introdução: Exercícios de alongamento são incluídos em programas de treinamento e reabilitação, no sentido de melhorar a flexibilidade de adultos e idosos. No entanto, ainda não há consenso na literatura acerca das recomendações para prescrição do alongamento. Objetivo: O objetivo deste estudo foi apresentar uma atualização das evidências recentes sobre a prescrição e os efeitos musculoesqueléticos dos exercícios de alongamento no adulto e idoso. Método: Foram realizadas buscas de artigos nas principais bases de dados relacionados ao tema, no período de 2006 a 2017, com descritores *"muscle stretching exercise"; "long-term effect"*; "*elderly*"; "exercício de alongamento muscular", "efeitos a longo prazo", e "idoso". Resultados: Após a análise, 31 artigos foram incluídos. A literatura mostrou que a duração do alongamento deve ser entre 10s e 30s, por repetição, para o adulto jovem, e de 30s a 60s para o idoso. Com relação aos efeitos agudos, observou-se que, para adultos jovens, durações de alongamento a partir de 60s podem comprometer o desempenho de força muscular, fato que parece não ocorrer com idosos. Os principais efeitos crônicos encontrados para o adulto jovem e idoso foram o incremento da flexibilidade e amplitude de movimento, e para o idoso verificou-se também melhora do torque, equilíbrio, marcha, mobilidade

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e funcionalidade. A grande variabilidade metodológica dos artigos analisados dificulta o estabelecimento de um consenso. Conclusão: Recomenda-se que o exercício de alongamento seja prescrito considerando as evidências para a população específica, isto é, adulto ou idoso, bem como de acordo com o objetivo a ser atingido.

Palavras-chave: *Exercícios de Alongamento Muscular, Terapia por Exercício, Sistema Musculoesquelético, Adulto Jovem, Idoso.*

1 Introduction

Muscle stretching exercise is widely used to increase flexibility, both in healthy individuals and in rehabilitation. The muscle is elongated by a traction force, which distracts its origin and insertion, positioning it to a new length and maintaining it in this position for a certain period of time (PEVIANI; GOMES, 2013).

Good levels of flexibility are important to perform activities of daily life (ADL), especially in patients with musculoskeletal disorders (ABATE et al., 2010; WILLIAMSON et al., 2017). This is even more important in aged person since several studies have shown the relationship between the flexibility levels and functional independence (ZOTZ et al., 2014; COSTA et al., 2013; GALLO et al., 2015). The good flexibility of the hip, knee and ankle joints, for example, has a close influence on gait parameters, postural control and balance, and fall's risk (KANG; DINGWELL, 2008a; KANG; DINGWELL, 2008b; BOYER et al., 2012; GRANACHER; MUEHLBAUER; GRUBER, 2012). Thus, it has been recommended to perform stretching exercises to maintain or improve neuromuscular function and activities of daily living (SOUCIE et al., 2011; GARBER et al., 2011; GALLO et al., 2015).

The stretching can be performed as part of a physical training program along with cardiorespiratory and muscular endurance exercises, or as a single program, depending on the goals to be achieved (GARBER et al., 2011). In the current review, the static stretching will be considered, active (self-stretching) or passive (performed by another person), when the soft tissues are stretched, holding it statically in the muscular tension position during a given time (PAGE, 2012); dynamic stretching, which can be active when it involves the maximum range of motion, reached gradually, and repeated several times; or ballistic, which includes rapid movements to the maximum range of motion, but due to the risk of injury, it has not been recommended; and the proprioceptive neuromuscular facilitation technique (PNF), which integrates active muscle contractions during the stretching exercise, to facilitate or inhibit muscle activation and increase the possibility of the muscle to be stretched remaining as relaxed as possible (PAGE, 2012).

For the proper prescription of stretching exercises, it is important to define the stretching technique, the intensity, the duration of the stimulus, the number of repetitions, the interval between repetitions, the daily and weekly frequency, the period (weeks or months) in which the exercise is performed and the age group, since these parameters influence the effects of the stretching program, being acute or chronic (ZOTZ et al., 2014; FREITAS et al., 2016). The current recommendations of the American College of Sports Medicine (GARBER et al., 2011) for stretching exercises still show evidence level C, that is, they are based on articles that do not present a randomized controlled trial design. Furthermore, in a systematic review with meta-analysis, it was reported difficulty for consensus about the effects of stretching due to the lack of standardization in prescription (ZOTZ et al., 2014).

Considering that due to age differences, young and old adults may require different stretching stimuli, it is important to analyze the exercise prescription parameters for both populations. Also, it is extremely important that health professionals, especially occupational therapists, physiotherapists and physical education professionals know and use the appropriate parameters for the prescription of the stretching exercise, such as intensity, duration, number of repetitions, stretching technique, considering the different age groups (GARBER et al., 2011; O'SULLIVAN; MCAULIFFE; DEBURCA, 2012). Thus, this review aimed to present the most recent evidence on the prescription and musculoskeletal effects of stretching exercises in the young and old adults.

2 Methods

This study is characterized as a narrative review of the literature, with the purpose of describing and discussing the "state of the art" about the prescription

of stretching exercises and their musculoskeletal effects.

Studies published in scientific journals in Portuguese or English between 2006 and 2017 that investigated the prescription and the acute and chronic effects of stretching exercises on the musculoskeletal function of adults and the elderly people were included. The choice of 2006 as the initial year for inclusion of studies in this review was determined from a search performed in the GoPubMed database, using the descriptor "muscle stretching exercise", about the number of articles published on the topic. It was observed that there was an increase in the number of publications from 2006, being 104 articles published in the period between 1976 and 2005, while an increase to 525 articles in the period between 2006 and 2017 (Figure 1).

Studies that did not meet the eligibility criteria, such as books, theses, dissertations, duplicate articles, cohort studies, epidemiological studies, studies in different age groups and experimental animal studies were excluded.

The search for articles was performed in the databases Pubmed, PEDro Database, Scielo, Lilacs, according to the descriptors of the Medical Subject Heading Terms (MeSH) and Health Descriptors (DeCs): [(muscle stretching exercise) and (long-term effect) *and* (elderly) and (adult)] and [(*exercício de alongamento muscular*) and (*efeitos a longo prazo*) and (*idosos*) and (*adultos*)]; from November 2014 to June 2017. Two raters (HSG e JNY) performed the search, selection, extraction, and compilation of data using standardized forms, including author and year of publication; individuals (number of individuals, age and gender); study design; methods of assessments; duration of the study; and outcomes. The outcomes of interest related to the prescription of stretching as type of stretching; duration; number and interval of repetitions; stretched muscle group; daily and weekly frequency; warming up; period of training (number of weeks); kinetic chain that performed stretching and the following outcomes: flexibility; maximum voluntary contraction; hopping height; passive torque (passive stiffness); torque; range of motion; running speed; tolerance to stretching; muscle strength; muscular power; muscular resistance; postural stability; balance; muscular architecture; related to acute and chronic effects on musculoskeletal function in adults and the older people.

3 Results

A total of 678 articles were found, 647 of them were excluded according to the title, abstract, methodology used or language, remaining 31 articles included as shown in Figure 2.

Tables 1 and 2 summarize the studies included in this review, detailing author/year; study design; characteristics of the sample studied; the protocol of stretching exercise and the main outcomes. The information was divided according to the age groups investigated, that is, young (Table 1) and elderly persons (Table 2), to facilitate the understanding and comparison among the studies.

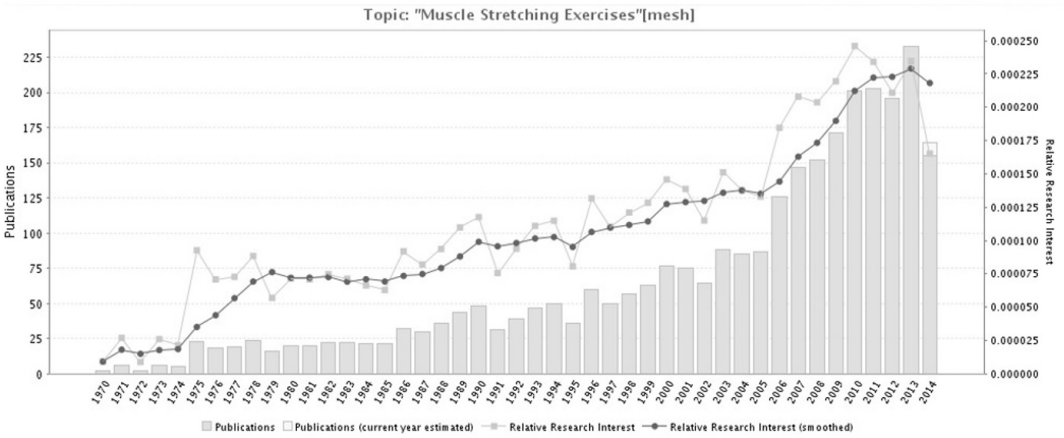

Figure 1. Number of publications with the descriptor MesH "muscle stretching exercise". The ordinate of the graph corresponds to the number of publications and the abscissa per year. Publications; Current year estimated; Relative research interest; Relative research interest smoothed by period analysis.

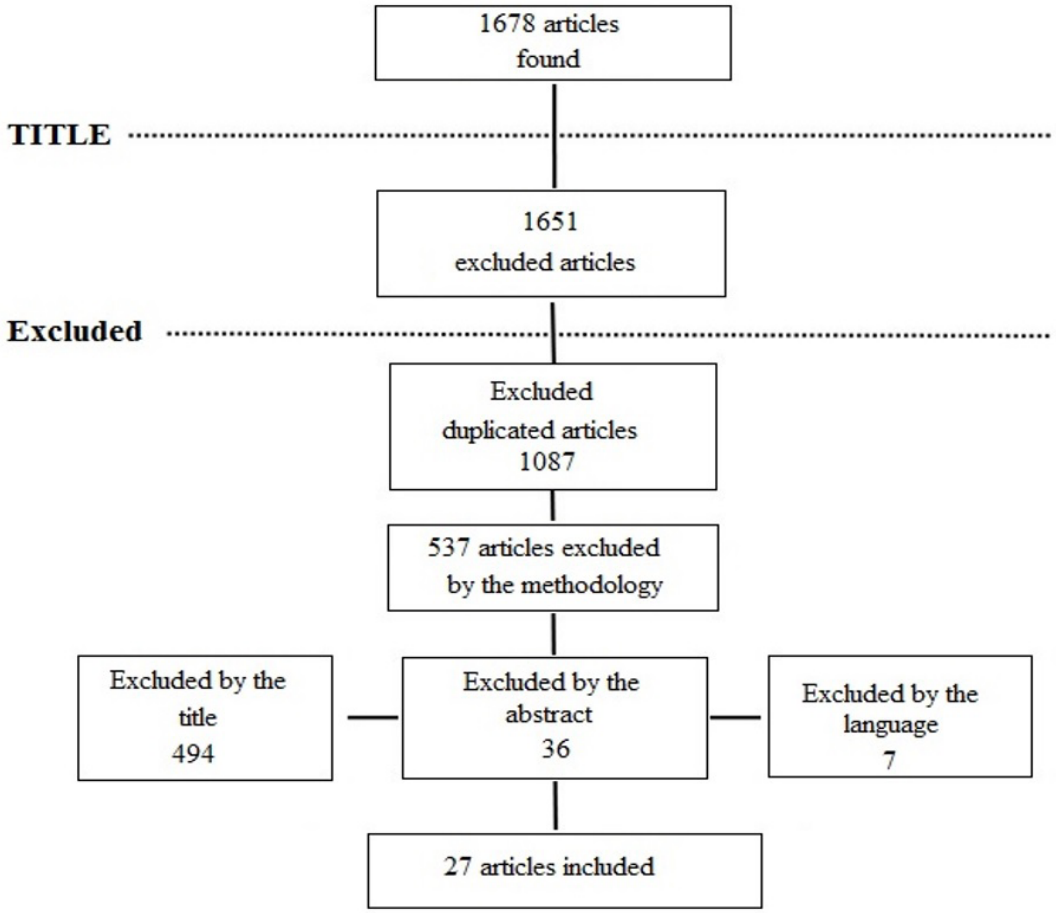

Figure 2. Flowchart for inclusion and exclusion of articles found.

4 Discussion

4.1 Duration of stretching

The recommendations of the American College of Sports Medicine (ACSM) point out that static stretching should be performed with intensity considered as slight discomfort, at the beginning of the pain sensation, and maintained for 10 to 30s, for adult individuals. For older people, the indication of the duration of stretching is longer, between 30 and 60 seconds. However, analyzing the studies cited in this review, it can be observed that the durations adopted for young and old adults were between 10s and 60s (SIATRAS et al., 2008; MCHUGH; NESSE, 2008; ROBBINS; SCHEUERMANN, 2008; VAREJÃO; DANTAS; MATSUDO, 2007; CHRISTIANSEN, 2008; RYAN et al., 2008; LUSTOSA et al., 2010; MIZUNO et al., 2013; GALLO et al., 2013; AYALA et al., 2015; FREITAS et al., 2016).

Sainz de Baranda and Ayala (2010) investigated the effects of stretching exercises, considering the ACSM recommendations for young adults. The participants (university students) performed 12 weeks of active and passive stretching three times a week, performing between 1 and 3 repetitions, with durations ranging from 15, 30 and 45 seconds. The volume (number of repetitions multiplied by the duration of the stimulus) of stretching was 180s per session. No differences were found in either hip flexion ROM or between groups, only when the training groups were compared to the control group.

In an older sample, Gallo et al. (2013) compared the effects of two different durations of active static stretching, the 30s and 60s, performed with 3 repetitions (3x/week, for 16 weeks), on the functionality of community-dwelling older women. ROM improvement, muscle strength, aerobic endurance and general functional fitness

Table 1. Acute and chronic effects of stretching in adults.

ACUTE EFFECTS				
Author, year	**Design**	**Participants**	**Protocol**	**Outcome**
Ogura et al. (2007)	Clinical study, with pre and post- intervention assessments	Young men (n=10)	Active static stretching Active static stretching 1 repetition Two groups, one using 30s and another 60s Hamstrings in OKC	Significant improvement in hamstring flexibility in both groups demonstrated that maximal voluntary contraction was significantly reduced after the 60s condition (-8.76%).
McHugh and Nesse (2008)	Two clinical studies, with pre and post-intervention assessments	Young men (n=18)	Passive static stretching 6 repetitions Duration of 90s 60 intervals between repetitions Hamstrings	8.3% improvement in passive resistance.
			Passive static stretching 6 repetitions Duration of 60s 60s intervals between repetitions Hamstrings	9% improvement in passive resistance.
Robbins and Scheuermann (2008)	Clinical study, with pre and post-intervention assessments	Young men (n=20)	Active static stretching Three groups performing 2, 4 or 6 repetitions, in addition to the control group without intervention Duration of 15s 15s of interval between repetitions 5 minutes warm up on the bike Hamstring and quadriceps in OKC, and triceps sural in CKC	Decrease of vertical jump height in the group which the participants performed 6 repetitions, and compared to the other groups
Ryan et al. (2008)	Clinical study, with pre and post-intervention assessments	Young men (n=7) Young women (n=5)	Passive static stretching Three groups performing 4, 8 or 16 repetitions and control group without intervention Duration of 30s 20s of interval between repetitions Plantar flexors	Decrease of 12% in passive resistance, with reversal effect between 10 and 20min.

Note OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion; s: seconds.

Table 1. Continued...

ACUTE EFFECTS				
Author, year	**Design**	**Participants**	**Protocol**	**Outcome**
Mizuno et al. (2013)	Clinical study, with pre and post-intervention assessments	Young men (n=11)	Passive static stretching 5 repetitions Duration of 60s No previous warm up 4 assessments, immediately, 5, 10 and 15min after stretching Plantar flexors	Increase in ROM after 15min. Passive stiffness decreased returning after 15min.
Ayala et al. (2015)	Clinical study, with pre and post-intervention assessments	Active adults (n = 49)	Dynamic and Static Stretching 2 repetitions Duration of 30s, being Static stretching Group performing 30s and Dynamic Stretching Group carried out 15 movements every 2s 20s interval Gluteus, psoas, adductors, hamstrings and quadriceps	No changes were observed in the concentric and eccentric isokinetic torque of knee flexion and extension.
Freitas et al. (2016)	Clinical study, with pre and post-intervention assessments	Young men (n=17)	Passive static stretching Two groups, One performed at high-intensity (100% of passive torque) and moderate duration (90s each repetition) One performed at low-intensity (50% of passive torque) with long duration (900s) No previous warm up Knee Flexors	The high-intensity group presented higher ROM and passive torque.

Note OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion; s: seconds.

Table 1. Continued...

CHRONIC EFFECTS				
Author, year	**Design**	**Participants**	**Protocol**	**Outcome**
Kokkonen et al. (2007)	Clinical study, with pre and post-intervention assessments	Young men (n=16) and Young women (n=22)	10 weeks 3 times a week Active static stretching 3 repetitions Duration of 15s 15s interval 15 exercises in OKC and CKC for lower limbs	Significant improvement in flexibility, jump height and distance, running speed, repetition maximal test and knee flexion and extension strength.
Batista et al. (2008)	Clinical study, with pre and post-intervention assessments	Men (n = 11) and adult women (n = 23)	4 weeks twice a week Active static stretching 7 repetitions Duration of 60s 30s interval Knee flexors in the closed kinetic chain	Increased knee extension ROM; Isometric torque; concentric and eccentric knee flexors and extensors
Laroche, Lussier and Roy (2008)	Clinical study, with pre and post-intervention assessments	Adult men (n=29)	4 weeks 3 times a week Active or ballistic static stretching 3 repetitions Duration of 30s 10min warm up 10 stretching exercises in OKC	Improvement of ROM, tolerance to stretching and less pronounced results in strength, capacity and muscle power.
Rancour, Holmes and Cipriani (2009)	Clinical study, with pre and post-intervention assessments	Jovens (n=32)	8 weeks 4 weeks of daily stretching for two groups Twice a day After 4 weeks, the first group continued performing 2-3 times per week and the second group discontinued stretching. Active static stretching 2 repetitions Duration of 30s Hamstrings in CKC	The group that continued to perform stretching maintained hip ROM, when compared to the group that stopped practicing it.

Note OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion; s: seconds.

Table 1. Continued...

CHRONIC EFFECTS				
Author, year	**Design**	**Participants**	**Protocol**	**Outcome**
Ichihashi et al. (2016)	Clinical study, with pre and post-intervention assessments	Young men (n=30)	4 weeks 3 times a week Passive static stretching Two groups of 15 participants Static stretching group and control group 1 repetition 5min Hamstrings	Improvement in muscle stiffness of the semitendinosus, semimembranosus and biceps femoris muscles.

Note OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion; s: seconds.

Table 2. Acute and chronic effects of stretching in the elderly.

ACUTE EFFECTS				
Author, year	**Design**	**Participants**	**Interventions**	**Outcomes**
Cristopoliski et al. (2008)	Clinical study, pre, and post-intervention	Older community-dwelling (n = 5)	Passive static stretching 3 repetitions Duration of 30s 5min warm up 30s interval Flexors and extensors of the hip in OKC	Change in gait pattern immediately after exercise, with a possible reduction in the risk of falls.
Rodacki et al. (2009)	Clinical study, pre, and post-intervention	Older community-dwelling (n = 15)	Static passive stretching 4 repetitions Duration of 60s Flexors and extensors of the hip in OKC	Changes in gait characteristics that left the gait pattern as observed in adults, and suggest that regular stretching can decrease the risk of falls.
Gurjão et al. (2009)	Clinical study, pre, and post-intervention	Older community-dwelling (n = 23)	Static stretching active 3 repetitions Duration of 30s 30s interval Hamstrings, quadriceps, hip adductors, gluteus maximus	Significant reduction in the ability to perform maximal and rapid strength after the stretching exercise.
Gurjão et al. (2010)	Clinical study, pre, and post-intervention	Older community-dwelling (n=10)	Static passive stretching 3 repetitions 30s of duration 30s interval Quadriceps in OKC	Stretching did not affect the ability to produce fast and maximal strength in multi-joint exercises.
Gonçalves et al. (2012)	Clinical study, pre, and post-intervention	Older community-dwelling (n=27)	Static passive stretching 3 repetitions Duration of 30s 30s interval Quadriceps in OKC	No change in ability to produce fast and maximal strength and in single and multi-joint exercises.
Souza, Kirchner and Rodacki (2015)	Clinical study, pre, and post-intervention	Older community-dwelling (n=12)	Passive Static stretching 4 repetitions 60s of duration on each lower limb 60s of rest Uniarticular and biarticular flexors of the hip in OKC	Increase of hip ROM and reduction of the activation time of the anterior tibial and biceps femoris for climbing the ramp and increase of gait speed and step length to ramp down.

Note GT30: training group 30s; GT60: training group 60s; PNF: proprioceptive neuromuscular facilitation; OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion.

Table 2. Continued...

CHRONIC EFFECTS				
Author, year	**Design**	**Participants**	**Interventions**	**Outcomes**
Varejão, Dantas and Matsudo (2007)	Clinical study, pre, and post-intervention	Older community-dwelling (n=69)	Passive static stretching 24 weeks 3 times a week 2 repetitions 10s of duration Stretching for cervical rotation, horizontal shoulder flexion, horizontal shoulder extension, shoulder abduction, shoulder flexion, lumbar spine flexion, hip flexion, hip extension, and knee flexion.	Improvement in ROM of shoulder flexion, shoulder abduction and hip extension.
Christiansen (2008)	Clinical study, pre, and post-intervention	Older community-dwelling (n=37)	Active static stretching 8 weeks 7 times a week Twice a day 3 repetitions 45s of duration 45s interval Hip extensors and ankle dorsiflexors in CKC	Improvement of ROM of hip extension and ankle dorsiflexion and an increase of walking speed.
Batista et al. (2009)	Clinical study, pre, and post-intervention	Older community-dwelling (n=12)	Active static stretching 4 weeks Twice a week 7 repetitions 60s of duration 30s of rest 5 minutes warm-up 4 weeks of detraining Knee flexors in CKC	Increase in ROM, but with a decrease after detraining; Increase isometric; concentric and eccentric torque of flexors and knee extensors; increase the mobility that was maintained with detraining.

Note GT30: training group 30s; GT60: training group 60s; PNF: proprioceptive neuromuscular facilitation; OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion.

Table 2. Continued...

CHRONIC EFFECTS				
Author, year	**Design**	**Participants**	**Interventions**	**Outcomes**
Stanziano et al. (2009)	Clinical study, pre, and post-intervention	Institutionalized elderly (n=17)	PNF for shoulder, trunk, hip, ankle muscles in CKC 8 weeks 2 times per week 10 repetitions Duration of 4-5s	Increase flexibility of upper and lower limbs; trunk rotation; knee extension; strength resistance of upper and lower limb; lower limb power strength; agility and performance for walking test.
Lustosa et al. (2010)	Clinical study, pre, and post-intervention	Older community-dwelling (n=12)	Passive static stretching 10 weeks 3 times a week 4 repetitions 20s of duration Warm up of 10 minutes Hip flexors, knee extensors, knee flexors, and plantar flexors	Stretching did not interfere with the gain of strength of knee extensors.
Watt et al. (2011a)	Clinical study, pre, and post-intervention	Community-dwelling older men (n=25) and Community-dwelling older women (n=57)	Active static stretching 10 weeks Twice a day Daily 4 repetitions 60s of duration 60s interval Hip flexors in CKC	Improvement of ROM of hip extension and step width.
Watt et al. (2011b)	Clinical study, pre, and post-intervention	Frail older (n=74)	Active static stretching 10 weeks 2 times a day Daily 4 repetitions 60s of duration Hip flexors in CKC	Improvement in gait speed and the peak of dynamic hip extension.

Note GT30: training group 30s; GT60: training group 60s; PNF: proprioceptive neuromuscular facilitation; OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion.

Table 2. Continued...

CHRONIC EFFECTS				
Author, year	**Design**	**Participants**	**Interventions**	**Outcomes**
Gallo et al. (2013)	Clinical study, pre, and post-intervention	Older community-dwelling (n=43)	Active static stretching 16 weeks 3 times a week 3 repetitions Two groups: GT30 (30s); GT60 (60s) 30s interval Stretching of extensors of the shoulder, elbow, hip, and knee; flexors of shoulder, ankle, trunk and hip in OKC and CKC	Improvement in flexibility, muscular strength, aerobic endurance, and general functional fitness index.
Gallo et al. (2015)	Clinical study, pre, and post-intervention	Older community-dwelling (n=43)	Active static stretching 8 weeks 3 times a week 3 repetitions 30s of duration 30s interval Extenders of the shoulder, Improved flexibility, muscular strength, aerobic endurance and general functional fitness index.nd ankle in OKC and CKC	Improvements in the flexibility and score of the General Functional fitness Index.

Note GT30: training group 30s; GT60: training group 60s; PNF: proprioceptive neuromuscular facilitation; OKC: open kinetic chain; CKC: closed kinetic chain; ROM: range of motion.

index were found for the groups that trained when compared to the control group, but there was no difference between groups 30s and 60s. Although not included in this review due to the date of publication, these results differ from those found in a classic study by Feland et al. (2001), (5x/week, 10 weeks), that showed higher increases in the ROM of institutionalized elderly people when the duration of the stimulus was the 60s, compared to the other durations used (15s and 30s), but without significant difference between the groups that trained with 15 or 30s. It is important to note that, besides the studies have investigated samples with different characteristics (community-dwelling and institutionalized), other factors should also be considered, such as the number of repetitions that directly influence the total stretching volume, and the stretching technique (active and passive static). The methodological differences between the studies hindered to compare the results directly and emphasize, even more, the need to prescribe the exercise in an individualized way, considering the characteristics of the patients.

For the PNF, it is recommended to sustain isometric muscle contraction for 3s to 6s, with intensity between 20%-75% of maximal voluntary contraction (MVC), followed by 10s to 30s of static stretching (GARBER et al., 2011). In a study with institutionalized elderly people, 10 repetitions of PNF with isometric contractions of 4-5s (2x/week, 8 weeks) were adopted, and improvements of ROM, upper and lower limb strength resistance, strength power of lower limbs and mobility were found (STANZIANO et al., 2009).

4.2 Number of repetitions

The number of repetitions presented a greater variation among the analyzed studies, from 2 to 7 repetitions (Tables 1 and 2) while the ACSM recommends the accomplishment of 2 to 4 repetitions, since the volume of stretching per exercise and group muscle reaches 60s (GARBER et al., 2011).

In young adult males, it seems that performing 6 repetitions of active static stretching lasting 15s may promote a more pronounced reduction in vertical jump height, when compared to performing 2 or 4 repetitions, which did not present significant differences between them or when compared to the control group (ROBBINS; SCHEUERMANN, 2008).

4.3 Rest interval between stretching repetitions

Shin and Mirka (2009), in a study with 10 healthy individuals compared the effects of rest intervals between stretching repetitions on the viscoelastic responses of skeletal muscle. The stretching exercise was performed for lumbar flexion for 10 minutes, with or without 30s of rest, and it was observed that 30s of resting were important to modify the viscoelastic responses. This may reduce the risk of injury due to the acute decrease in muscle force after stretching exercise. In general, it is common to use rest intervals of 10s (CIPRIANI et al., 2012), 15s (ROBBINS; SCHEUERMANN, 2008) and 30s (GURJÃO et al., 2010; GALLO et al., 2013, 2015) between each stretching repetition. However, not all the studies included in the current revision described about the resting time in the methodology.

4.4 Daily frequency

Cipriani et al. (2012) compared 53 adult individuals divided into five groups (G), the participants performed 4 weeks of static hamstrings stretching with two repetitions of 30s each, 10s rest interval between repetitions in closed kinetic chain (CKC). The daily and weekly frequencies were different between groups: The G1 performed exercise twice a day, 7 times a week; The G2 performed once a day, seven times a week; The G3 performed twice a day, 3-4 times per week; the G4 performed once a day, 3-4 times a week; the G5 was the control group, which the individuals did not exercise. All groups improved hip flexion ROM when compared to the control group. However, G4 that performed the smallest amount of stretching, obtained the lowest gains.

With the exception of a few studies that have prescribed exercise twice a day (CHRISTIANSEN, 2008; WATT et al., 2011a; CIPRIANI et al., 2012), most of the reviewed literature in this article has adopted once a day frequency.

4.5 Weekly frequency

It has been described that the most pronounced gains in ROM were obtained when the stretching exercises were practiced daily. Performing stretching exercises two to three times a week improves ROM and once a week is sufficient only for ROM maintenance (GARBER et al., 2011).

Marques et al. (2009) implemented a study comparing three groups that did static stretching for the 30s, twice a day for four weeks where G1 performed stretching once a week, G2 performed three times a week, and G3 performed five times a week. When the flexibility gain was analyzed, G2 presented greater gain than G1, but there was no significant difference between G2 and G3. However, G2 still presented greater gains in flexibility when compared to the other groups. Thus, the authors suggested that stretching exercise performed three times a week is sufficient to improve flexibility when compared to five times a week stretching.

4.6 Stretching and warming up

The stretching exercise is more effective when muscle temperature is elevated in a slightly to moderate way, through aerobic exercises, muscle endurance or by external methods, such as warming up with hot water baths or bags, dynamic stretching with large ROM, specific dynamics activities of the sport that will be practiced, warming up specially the muscle group that will be worked (GARBER et al., 2011).

Ferreira et al. (2008) observed that adult and older people take the same time to warm-up skeletal muscle, however, the older ones take more time for cooling down.

Woods et al. (2007) point out that the warm-up intensity should be between 40-60% of the Heart Rate Reserve (HRres), which can be calculated by the following equation: Heart Rate Reserve (HRres) equals Maximum Heart Rate (HRmax) subtracted from the Rest Heart Rate (RHR).

Samson et al. (2012) compared 19 athletes distributed into four groups that performed different types of aerobic warm-up for 5 minutes, and specific exercises according to the practiced sport, before performing three repetitions, of 30s of static or dynamic stretching, G1 performed aerobic warm-up and static stretching, G2 did aerobic warm-up and dynamic stretching, G3 performed aerobic warm-up, specific activity practiced warm-up and static stretching, G4 did aerobic warm-up, specific activity practiced warm-up and dynamic stretching, and evaluated kicking movement time, jump height, sit and reach test and 20-meter run. The authors observed better performance for the groups that performed specific warm-up before both dynamic and static stretching.

Tsolakis and Bogdanis (2012) studied the effects of a 5 minutes of light jogging associated to two stretching protocols of 15s or 45s in the performance of 20 high level jump athletes, who performed quadriceps, hamstrings and triceps sural stretching exercises and observed that the group that performed the 45s stretching protocol had 5.5% worse jump time but that was reversed after 8 minutes, while the 15s group showed no change in performance.

4.7 Acute and chronic effects of stretching exercises

The acute effects of muscle stretching exercises are considered to be the results obtained immediately or after a short time, that is, when the exercise promotes an increase in viscoelastic component extensibility of the musculotendinous unit, increasing ROM and stretching tolerance (SAINZ DE BARANDA; AYALA, 2010; KOKKONEN et al., 2007). Thus, acute can be considered the effects collected after seconds (s), minutes (min) and hours (h) or till one week (RYAN et al., 2008; WEPPLER; MAGNUSSON, 2010).

On the other hand, chronic effects represent the long-term stretching effects that provide increase in the ROM due to neuromuscular adaptations and may last for weeks (SAINZ DE BARANDA; AYALA, 2010; KOKKONEN et al., 2007; WEPPLER; MAGNUSSON, 2010; SECCHI et al., 2008).

4.8 Acute effects of stretching on musculoskeletal function in adults

Some authors have studied the acute effects of stretching on passive torque, the long-term effects and detraining (RYAN et al., 2008; MCHUGH; NESSE, 2008; MCHUGH; COSGRAVE, 2010). McHugh e Nesse (2008) observed a decrease of 8.3% in passive torque after performing six repetitions with 90s duration of static stretching, and a reduction of 9% in passive torque after six repetitions of 60s of static stretching. Ryan et al. (2008) used four repetitions, of 30s of passive stretching for plantar flexor muscles and found a 12% decrease in passive torque, however, the effect was reversed after 10min.

Simic, Sarabon and Markovic (2013), in a systematic review, found that the acute effect of stretching can induce a decrease in strength, power, and explosive muscular strength. However, these effects tend to be smaller when shorter stretching duration are used, i.e., less than 45s.

In fact, recent reviews of literature (BEHM; CHAOUACHI, 2011; KAY; BLAZEVICH, 2012) showed that total stretching volumes (number of repetitions multiplied by the duration of repetitions) between 60s and 120s of static stretching are enough to promote transient reduction in muscle strength and power in the various parameters of the muscular force. Moreover, the acute reduction of muscle strength after static stretching routines may depend on the dose-response relationship (from 60s volume) and on the muscle group evaluated, among other variables (KAY; BLAZEVICH, 2012).

The dose-response relationship between the volume of stretching adopted and the muscular responses has been investigated by several studies (RYAN et al., 2008; OGURA et al., 2007; SIATRAS et al., 2008). Ogura et al. (2007) compared the effect of two different stretching volumes (30s and 60s) in young adults and observed a decrease in MVC after the condition of 60s (-8.76%). Ryan et al. (2008) analyzed larger volumes of static stretching (120s, 240s, and 480s) and found linear and decreases in MVC values and peak of force development rate after 240s and 480s volumes. Siatras et al. (2008) compared groups that stretched for 10s, 20s, 30s and 60s and observed that, from the duration of 30s of stretching, there is a reduction in quadriceps peak torque. Robbins and Scheuermann (2008) evaluated the influence of stretching on jump quality, comparing two, four and six repetitions of 15s of stretching, and found that six repetitions of 15s stretching (volume of 90s) impaired jump quality.

Regarding stretching duration effects, Mizuno et al. (2013), using a protocol of 5 repetitions of 1min, assessing at 5min, 10min, and 15min after the stretching protocol, it was found an increase of ROM even after 15min and the passive stiffness decreases, returning after 15min interval.

4.9 Chronic effects of stretching on musculoskeletal function in adults

Laroche, Lussier and Roy (2008) evaluated young individuals who performed four weeks of static or ballistic stretching training three times a week, performing 10 stretching exercises, lasting 30s each repetition. The authors did not find a difference between the stretching and control groups for ROM values, stretching tolerance, strength and muscular power, suggesting that four weeks are not enough to promote the improvement of these outcomes.

Kokkonen et al. (2007) found significant improvement in flexibility, jumping height, jumping distance, running speed, maximal repetition test (MRT) and knee flexion and extension strength in subjects who underwent lower limbs stretching three times a week, during 10 weeks, three repetitions of 30s each.

Rancour, Holmes and Cipriani (2009) evaluated the effects of intermittent training (two to three times a week for four weeks) on flexibility maintenance after daily practice of two 30s repetitions of static stretching for four weeks in two groups and found that the group that continued to perform stretching, hip ROM maintained, when compared to the group that stopped practicing it.

Batista et al. (2008) evaluated 34 volunteers who performed knee flexor active stretching, seven repetitions of 60s, and 30s of rest between repetitions in CKC, twice a week for four weeks. It was observed an increase of knee extension ROM and flexor and extensor knee torque.

Table 1 summarizes other studies that investigated the acute and chronic effects of stretching in young adults.

4.10 Acute effects of stretching on musculoskeletal function in the older people

In a study with middle-aged men and women (50 years old), Handrakis et al. (2010) did not find any alteration in the performance, evaluated by the distance jump test, after the use of three repetitions of stretching with duration of 30s (total volume of 90s). Gurjão et al. (2010) and Gonçalves et al. (2012) also used three 30s repetitions of static stretching in older women and did not find significant acute changes in muscle strength, MVC, and peak force development rate. Gurjão et al. (2009) observed a significant reduction of 6.5% in MVC and 14.1% in the rate of peak force development, after three 30s repetitions of static stretching of an older sample.

It is believed that the different results found for young and old adults for muscle strength performance after performing acute stretching exercises are related to the morphophysiological changes of the musculotendinous system. It is known that stretching exercises increase complacency of the musculotendinous unit, which can increase the time for muscle contraction, impairing the production of strength (OGURA et al., 2007). Middle-aged

adults have increased muscle stiffness and decreased viscoelastic properties that in part might be less affected by acute static stretching than younger adults (HANDRAKIS et al., 2010; BEHM et al., 2006).

4.11 Chronic effects of stretching on musculoskeletal function in the elderly population

In the elderly population, flexibility training has provided an increase in the ROM of several joints (CHRISTIANSEN, 2008; CRISTOPOLISKI et al., 2008; STANZIANO et al., 2009; VAREJÃO; DANTAS; MATSUDO, 2007). However, the difference in the gain magnitude seems to be related to the joint and movement evaluated, for the same joint.

It was found that after 16 stretching sessions with the PNF technique, twice a week, with 10 repetitions of 4 to 5s, flexibility was improved (STANZIANO et al., 2009). Cristopoliski et al. (2009), using four repetitions of 60s (volume of 240s), verified a 23% gain for plantar flexion. On the other hand, the increase observed for hip flexion and extension movements was 26%, close to the Gallon et al. (2011) study of 30%.

Studies have shown that flexibility training may be effective in improving gait parameters (CHRISTIANSEN, 2008; CRISTOPOLISKI et al., 2009; RODACKI et al., 2009). Cristopoliski et al. (2009) evaluated the effects of passive static stretching with four repetitions of 60s (240s volume), three times a week, for four weeks, and found greater step length and gait speed, and reduced double support time. The authors also observed improvement in hip and ankle flexibility. Christiansen (2008) observed that eight weeks of training, twice a day, with three repetitions, lasting 45s (135s stretching volume), were sufficient to increase gait speed by 0.07 m/s and ROM of hip extension, knee flexion, and ankle dorsiflexion.

It was also found an improvement in agility and the ability to walk after flexibility training in institutionalized older people (STANZIANO et al., 2009). Stanziano et al. (2009) observed higher strength of upper and lower limbs (45.7% and 17.1% respectively) and lower limb muscle power (25.6%), after eight weeks of PNF stretching of multiple joints (shoulder, trunk, hip, and ankle). On the other hand, Gallon et al. (2011) did not observe an increase in isokinetic peak of torque after flexibility training.

It is important to emphasize that active individuals have higher levels of flexibility when compared to inactive individuals (SILVA; RABELO, 2006) and institutionalized elderly (KRÓL-ZIELINSKA et al., 2011).

Batista et al. (2009) investigated the effect of active static stretching on hamstring CKC, performed for four weeks, twice a week, and assessed flexibility, torque, and mobility in older adults. They observed an increase in ROM, in isometric, concentric and eccentric knee flexors and extensors torque; and mobility that remained after detraining.

Gallo et al. (2013) investigated the effects of static stretching on SCC and CKC for 16 weeks three times a week in community-dwelling elders who performed three 30s or three 60s repetitions. Both groups improved flexibility, muscle strength, aerobic endurance, and functional fitness index.

Lustosa et al. (2010) performed a study with community older women, three sessions per week, divided into two groups: one group performed exercises with load and previous static stretches of four repetitions of 20s, and another group performed only exercises with load, for hip flexor muscles, knee extensors and flexors, and plantar flexors muscles. Pre warm-up (walking) was performed for 10 minutes in both groups. Previous static stretching did not interfere with the muscle strength gain of knee extensors after a 10-week muscle strengthening program.

Watt et al. (2011a,b) investigated the effects of hip flexor stretching training with healthy elderly individuals in CKC using four 60s repetitions every day, twice a day for 10 weeks and found improvement in hip extension ROM, gait speed and step length.

Studies that reported the acute and chronic effects of stretching in the older people are presented in Table 2.

5 Conclusion

Considering the literature reviewed, it was observed that stretching exercises are commonly prescribed between 2 and 4 repetitions, with duration varying between 10s-30s for young adults and 30s-60s for older adults. It is recommended a minimum stretching volume (duration of each repetition multiplied by the number of repetitions) of 60s for each muscle group, both for adults and older people.

Regarding the acute effects in young adults, it was detected a dose-dependent performance drop, that is, duration of stretching up to 60s can impair muscle performance. On the other hand, for older adults, the acute effects on performance are still inconclusive since the reviewed articles reported a decrease in muscle strength and other studies did not verify any change. Regarding the musculoskeletal effects of chronic stretching exercises, there was an increase in ROM in adults as well as in the elderly individuals. In addition, the improvement of flexibility, torque, balance, gait, mobility, fall's risk and functionality in the elderly individuals must be highlighted, once they represent important parameters of the activities of daily living.

This study shows some limitations as it was not a systematic review, such as the restricted inclusion of randomized or quasi-randomized clinical trials, the absence of quality and risk of bias assessment of studies by appropriate instruments and, consequently, the absence of a meta-analysis. However, the results presented in this review are consistent to point out the need for adequate stretching exercise prescription, considering parameters such as type of stretching, duration of each repetition, number of repetitions, rest time, daily and weekly frequency, and adjusting them according to the patient´s physical and clinical condition and the short-term (acute effects) and medium-long-term (chronic effects) goals.

Multidisciplinary actions among the various health professionals (physiotherapists, occupational therapists, and physical trainer) could favor the benefits of stretching exercise programs not only for health promotion and prevention of adults and older population but also for the rehabilitation of these individuals. It is important to emphasize that the stretching exercise should be prescribed based on evidence, considering population specificity, young or older adults patient's treatment goals, interest, and musculoskeletal condition.

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Henrique and Jéssica were responsible for the design of the text, organization of sources and/or analysis, writing of the text. Luiza was responsible for revising the text. Silvia Regina was responsible for the writing of the text and review. Anna Raquel was responsible for the design of the text, writing of the text and review. All authors approved the final version of the text.

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