Chronic Flexibility Improvement After 12 Week of Stretching Program Utilizing the ACSM Recommendations: Hamstring Flexibility

Authors P. Sainz de Baranda[1], F. Ayala[2]

Affiliation [1]University of Castilla la Mancha, Faculty of Sport and Physical Education, Toledo, Spain
[2]Catholic University of San Antonio of Murcia, Department of Health Sciences and Sports, Murcia, Spain

Key words
- flexibility training
- stretch duration
- static stretching
- hamstring flexibility

Abstract

The ACSM flexibility training recommendations emphasize proper stretching of muscles supporting the major joints, but there is a little evidence to support this recommendation in terms of effectiveness, and which stretching parameters (technique and single stretch duration) are more adequate. A randomized controlled clinical trial design was use to investigate whether the ACSM flexibility training recommendation parameters improve hip flexion range of motion. A total of 173 subjects, 122 men (21.3±2.5 years; 176.33±8.35 cm; 74.42±10.80 kg) and 51 women (20.7±1.6 years; 163.43±6.57 cm; 60.12±7.88 kg), classified as recreationally active young adult university students were randomly assigned to 1 of 7 groups: 1 control group (no stretching) or 1 of 6 stretching groups. All stretching groups performed 12 weeks of flexibility training with a consistent stretch daily dose (180 s) and frequency (3 days per week) parameters and different stretch technique (passive or active) and single stretch duration (15, 30, or 45 s). Hip flexion passive range of motion (PROM) was determined through the bilateral straight-leg raise test before, during (at 4 and 8 weeks), and after the program (12 weeks). All stretching groups performed hip flexion PROM after flexibility training. A significant improvement was identified in mean PROM for each stretching group, but no significant differences were found between stretch technique and single stretch duration ($p > 0.05$). The control group's mean PROM decreased (ΔPROM: −0.08°, 95% confidence interval [CI] = −2.3 to 5.3), whereas all stretching groups increased PROM (ΔPROM: 15.14°, 95% CI = 10.19 to 23.56) in hip flexion after 12 weeks of stretching ($p < 0.05$). The present study suggests that the current ACSM flexibility training recommendations are effective for improving hip flexion ROM in recreationally active young adults.

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Correspondence
Francisco Ayala
Catholic University of San Antonio of Murcia
Department of Health Sciences and Sports
Campus de los Jerónimos s/n. 30107 Guadalupe (Murcia)
Spain
Tel.: +34/968/278 824
Fax: +34/968/278 658
Fayala@pdi.ucam.edu

Introduction

The American College of Sports Medicine (ACSM), in the guidelines for exercise testing and prescription (seventh edition) and in the resource manual for guidelines for exercise testing and prescription (fifth edition), proposes several recommendations for achieving and maintaining flexibility. The recommendations for flexibility exercise in these resources are based on growing evidence of its multiple benefits including improved joint range of motion (ROM) and function [12,14,21,37,39] and enhanced muscular performance [3,27,50].

Optimal musculoskeletal function requires maintenance of an adequate range of motion in all joints. Therefore, preventive exercise programs should include activities that promote flexibility maintenance. The ACSM recommends that exercise programs for elderly people and other populations emphasize proper stretching for all the major joints, especially for areas affected by a reduction in the range of motion, such as the superior and inferior parts of the trunk, the neck and the hips. In this regard, they state that it is particularly important to maintain flexibility in the lower back region and the back of the thighs, because short hamstring muscles are associated with low back pain [8,10,34] and lower extremity injuries [13,45]. Furthermore, with regard to the parameters of training load, several guidelines for flexibility training [1,2] recommend to perform stretching exercises routines with a minimum frequency of 3 days/week, (ideally 5–7 days/week), using static, ballistic, or propioceptive neuromuscular facilitation (PNF) stretch

technique (with static and PNF being the preferred methods). It is recommended that these are performed with three to five repetitions of each stretching exercise (stretch daily dose ranges of 30–150 s) and holding the stretch position for 10–30 s in each exercise with intensity to the point of tightness or mild discomfort.

The ACSM has developed these guidelines from the results of different studies related to optimal stretching parameters. Several of these studies have suggested stretching programs to improve hamstring muscle length after analyzing different flexibility training parameters: technique [14,26,37,38], frequency [44], single duration [5,6,20], daily dose [12,41], and length of program [1,11]. According to Nelson and Bandy [36] with regard to mode of stretching, stretching techniques can be classified into two large groups: dynamic or ballistic technique and static technique. Within the static technique, they make a distinction between the active and passive types, distinguishing between the passive types of self-stretch technique and propioceptive neuromuscular facilitation (PNF). Perhaps the more common mode of stretching is the static technique because it has been shown to be very effective at increasing hamstring length [14,29,37–39,42,47] and is probably the easiest type of flexibility training. Moreover, this mode of stretching takes the muscle to its end range and maintains this position for a specified duration [33,46]. With regard to stretching frequency, studies have found that effective stretching programs generally consist of a higher stretching frequency, 5 days per week or more [4,12,21, 39,40,41,43], and/or a higher stretch daily dose [29]. Regarding stretch duration, increases in flexibility have generally been associated with the duration of the application of the tensile force to lengthen muscle and connective tissue. Several authors have shown that an effective single stretch duration ranges from 10 to 60 s [6,9,12,18,20,30,40]. However, there is no clear evidence about the optimal duration for each stretching technique. To our knowledge, no studies have investigated what combination of single stretch duration (15, 30, or 45 s) and static technique (active or passive) is most effective in improving hip flexion range of motion in respect to ACSM flexibility training recommendations for frequency and stretch daily dose. Further, the majority of studies investigating the effects of stretching on muscle length have been programs of 4–8 weeks in length [4,12,20,29,37,39] and perhaps may not have been long enough to assess the real effectiveness of stretching programs. Therefore, the main purposes of this research study were twofold (1) to compare passive-static stretching and active-static stretching and (2) to compare three different single-stretch durations in a randomized, controlled trial by using the same stretching parameters during 4–8 and 12-week training programs in recreationally active young adults.

Materials and Methods

Design

Randomized controlled clinical trial was used to assess two common stretching techniques (active-static and passive-static techniques) and three different single-stretch durations (15, 30 and 45 s) during a 12-wk training program in recreationally active men and women. Randomization was performed independently. Thirty-seven cards for the control group and 35 cards for each stretching protocol were shuffled in a container. After completion of a pre-intervention straight leg raise (SLR) test, each subject picked one card in a blinded manner [32]. The dependent variable was hip flexion range of motion. The independent variables were group (control vs. stretching groups), stretching techniques (active-static vs. passive-static), stretching durations (15 vs. 30 vs. 45 s), sex (men vs. women), test moment (0 vs. 4 vs. 8 vs. 12 week of stretching program) and leg (right vs. left)

Subjects

A total of 250 subjects (young adult university students, 180 men and 70 women) who were recreationally active (engaging in 1–5 h of moderate physical activity 3–4 days per week) started this study. Non-sedentary subjects were utilized for this study based on the perception that active people may demonstrate different muscle activation characteristics than sedentary people [21]. The participants met 5 basic requirements: (1) had no history of impairments to the knee, thigh, hip, or lower back in the 2 years prior to the study, (2) were excluded if found to have short hamstrings ($<65°$) based on a passive straight-leg-raise test described previously [23] (they were excluded in order to maintain a homogeneous design), (3) all subjects were free of DOMS, (4) subjects not already involved in a exercise program for the trunk or lower extremities agreed not to start a program for the duration of the study, and (5) subjects who were already participating in a regular exercise program agreed not to increase the frequency or intensity of their program during the 12-week training period.

In addition, two exclusion criteria related to the proper performing of study design were established: subjects who a) missed more than 2 stretching sessions and b) one testing session were eliminated from the study. Sixty-one subjects missed more than 2 stretching sessions (48 men and 13 women) and sixteen subjects did not complete all testing sessions (10 men and 6 women). Therefore, a total of 173 subjects, 122 men (mean ± SD; age = 21.3 ± 2.5 years; height = 176.33 ± 8.35 cm; weight = 74.42 ± 10.80 kg) and 51 women (mean ± SD; age = 20.7 ± 1.6 years; height = 163.43 ± 6.57 cm; weight = 60.12 ± 7.88 kg) finished this study.

All subjects were informed of the methods to be utilized as well as the purpose and risks of the present study, and informed consent was obtained from all subjects. The protocol of the present study was approved by the research ethics committee of the Catholic University San Antonio (Murcia, Spain) and this study was performed in accordance with the ethical standards of the International Journal of Sports Medicine [25].

Flexibility training

After the initial SLR test, participants were randomly assigned to 1 of 7 groups (only subjects who finished this study have been reported): group 1 was a control group and performed no stretching activities for 12 weeks (20 men and 4 women); groups 2 (13 men and 4 women), 3 (10 men and 4 woman), and 4 (13 men and 6 women) stretched using the passive-static method (**Fig. 1**) [5,6,29,42] with 15, 30, and 45 s of single-stretch duration, respectively; and groups 5 (20 men and 8 women), 6 (25 men and 13 women), and 7 (21 men and 12 women) performed active stretching exercises (**Fig. 2**) [12,14,20,40] with 15, 30, and 45 s of single-stretch duration, respectively.

Women have been found to have greater flexibility than men, but Etnyre and Lee [15] found no significant difference in gain mean flexibility scores between men and women after they had performed a stretching program. According to Etnyre and Lee

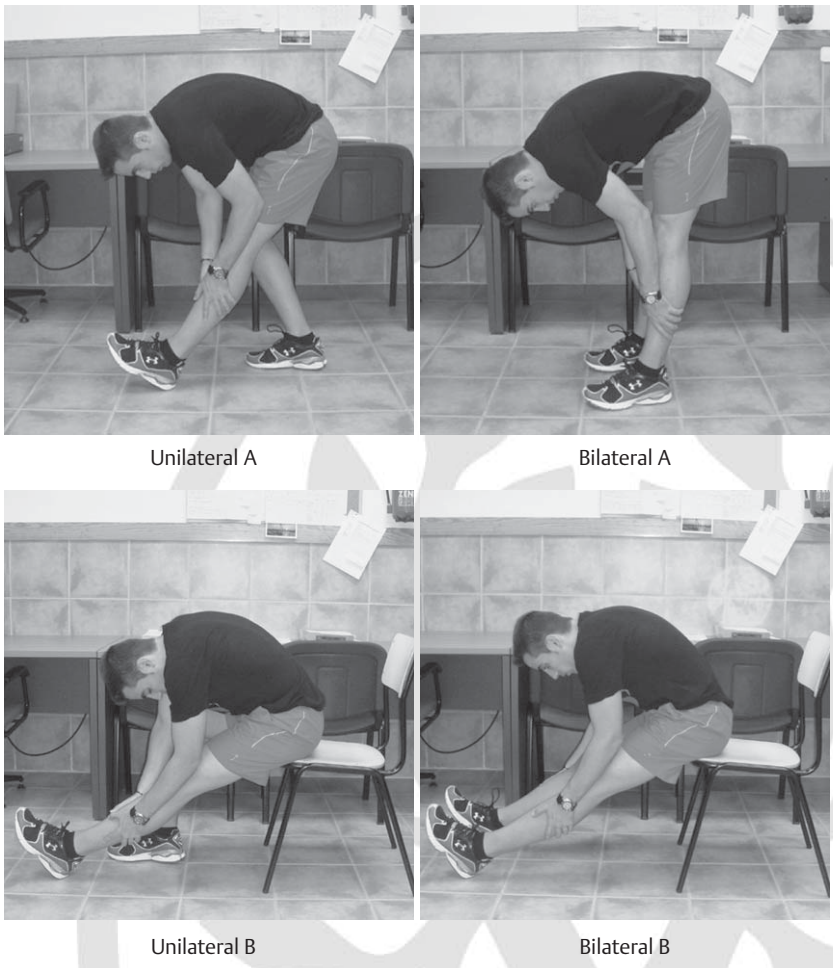

Fig. 1 Passive stretching exercises.

[15] results, and following other previous studies [4, 12, 20, 39, 40] the current study decided that gender was not an issue in assigning subjects to the treatment groups.

All stretching groups performed 12 weeks of flexibility training, 3 days per week, never performing these on consecutive days. Subjects performed 4 different stretching exercises in each training session. All stretching groups performed the same stretch daily dose of 180 s.

Stretching groups 2 and 5 performed 3 alternating repetitions of each stretching exercise, and all stretching repetitions were held for 15 s (12 × 15 s). Stretching groups 3 and 6 performed one repetition of unilateral stretching exercises and two bilateral stretching exercises, holding each exercise for 30 s (6 × 30 s). Stretching groups 4 and 7 performed one repetition of each stretching exercise, and all stretching repetitions were held for 45 s (4 × 45 s).

Between each stretching repetition, the subject's hip extensor muscles were returned to a neutral position for a 20 s rest period. The order of application for the stretching exercises was random for each stretching session.

After the initial instructions and demonstration, each subject (stretching protocol) was given a home-exercise sheet that included a schematic representation of the stretching mode and written instructions on flexibility training. To monitor their training program, each person had to complete a personalized calendar of their stretching activity and was contacted every week by one of the investigators to ensure this was undertaken [32].

Equipment test

Flexibility of the hamstring muscles was measured at the beginning of the study, at 4 and 8 weeks after the stretching programs began, and immediately after the stretching programs. Two days of rest were provided before the post-test [37]. Measurements were performed throughout the study by the same examiner at the same time of day for each participant. The examiner was blinded to which group each subject had been assigned to throughout the investigation.

Subjects were examined in their underwear and without shoes. Moreover, no warm-up or stretching exercises were performed by the subjects prior to test measurements [20]. Room temperature was consistently 25 °C.

The hip flexion passive range of motion (PROM) was assessed using the bilateral straight-leg raise test (SLR) [18, 44].

Straight-leg raise test

The subject was in the supine position with his or her legs straight and the ankle of the tested leg in 90 ° of dorsiflexion. A low-back protection support (Lumbosant) was used to maintain the normal lordotic curve [44]. A trained examiner kept the contralateral leg straight to avoid external rotation and fixed the pelvis to prevent posterior pelvic tilt (initial position). The test administrator placed the ISOMED inclinometer (Portland, Oregon) over the distal tibia and the free hand was placed over the opposite knee to keep it straight. The subject's leg was lifted passively by the tester into hip flexion. Both legs were tested. The endpoint for straight-leg raising was determined by 1 or both of

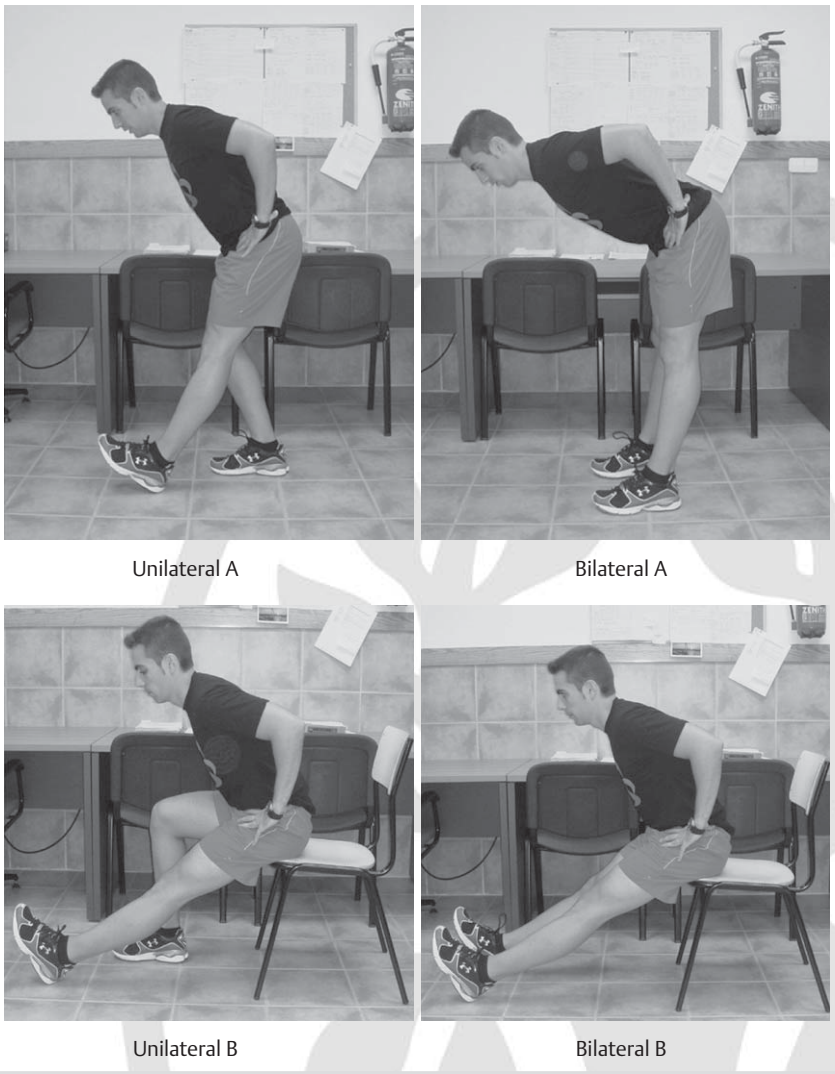

Fig. 2 Active stretching exercises.

2 criteria: (a) the examiner's perception of firm resistance, and/or (b) palpable onset of pelvic rotation. The score criterion of hip flexion PROM was the maximum angle read from the inclinometer at the point of maximum hip flexion.

Statistical procedures and analysis

Before data collection, the reliability coefficient was evaluated on 12 healthy subjects using a test-retest design. Range of motion was measured twice with a week interval. An interclass correlation coefficient was calculated from the results of subsequent measurements. Results of pre-and post-measurements showed a high reliability coefficient ($r = 0.95$) consistent with previous studies [6, 44].

Means and standard deviations for all groups and measurements were calculated for hip flexion passive range of motion (PROM) as were the mean differences between pre-test and post-test scores (gain scores) for the dependent variable PROM (in degrees). To verify the normality of the PROM scores, the Kolmogorov-Smirnov test was used. Two-way analysis of covariance (7 × 4), stretching program (active technique with a stretch duration of 15 s vs. active technique with a stretch duration of 30 s vs. active technique with a stretch duration of 45 s vs. passive technique with a stretch duration of 15 s vs. passive technique with a stretch duration of 30 s vs. passive technique with a stretch duration of 45 s) and measurement moment (pre-test vs. 4 week-test vs. 8 week-test vs. post-test), with repeated measures in the last factor were used to analyze whether hip flexion PROM scores varied by group [48]. The baseline measurement was used as covariate. When significant intergroup differences were noted, post-hoc Bonferroni tests were carried out. All data were analyzed using SPSS 15.0 for Windows, and statistical significance was accepted at the 95 % level ($p < 0.05$).

A post-hoc power analysis was conducted using the software package, G*Power 3.1.2 [16, 17]. The sample size of 173 was used for the statistical power analyses (ANCOVA). The alpha level used for this analysis was $p < 0.05$. The post-hoc analyses revealed the statistical power for this study was 0.81. It could be concluded that the given sample size was large enough to detect significant effects [4, 35]

Results

The mean and standard deviation values for hip flexion PROM in each group by the length of the flexibility programs are reported in **Table 1**. The results show no significant differences in the joint ROM between right and left sides for the seven groups. Thus, only the results of the right side will be presented.

The two factors (7×4), (experimental groups and measurement moments) with repeated measures in the last factor analysis of covariate (initial measurement) ANCOVA revealed interaction effect among groups ($p<0.0005$). Post-hoc test revealed significant differences between the control group and the stretching groups ($p<0.05$). In addition, no significant differences were found between the different stretching groups (▶ **Table 1**).

The intra-group analysis showed significant differences in hip flexion ROM across all the measured time points for each stretching group ($p<0.0005$). Further analysis revealed that: 15 s-passive stretching group showed significant differences between 4 week-test and 12 week-test ($p<0.001$) and between 8 week-test and 12 week-test ($p<0.001$); 30 s-passive stretching group revealed significant differences between 4 week-test and 12 week-test ($p<0.05$); in 45 s-passive stretching group significant differences were found between 4 week-test and 8 week-test ($p<0.001$) and between 4 week-test and 12 week-test ($p<0.001$); 15 s-active stretching group showed significant differences between 4 week-test and 8 week-test ($p<0.001$) and between 4 week-test and 12 week-test ($p<0.001$); 30 s-active stretching group revealed significant differences between 4 week-test and 8 week-test ($p<0.01$), between 4 week-test and 12 week-test ($p<0.001$), and between 8 week-test and 12 week-test ($p<0.01$); in 45 s-active stretching group significant differences were found between 4 week-test and 8 week-test ($p<0.05$) and between 4 week-test and 12 week-test ($p<0.001$).

Analysis of the different flexibility testing scores among the different groups at each testing moment (inter-group differences) revealed significant interaction effect. Bonferroni test showed significant statistical differences at 4 week measurement test ($p<0.001$), at 8 week measurement test ($p<0.001$) and at 12 week measurement test ($p<0.001$). Specifically, at 4 week-test only statistical significant differences were shown between 15 s-passive stretching group and 15 s-active stretching group ($p<0.05$). At 8 week-test significant differences were only found between control group and 15 s-passive stretching group, 15 s-active stretching group ($p<0.001$), 30 s-active stretching group ($p<0.001$) and 45 s-active stretching group ($p<0.001$). At 12 week-test, statistical significant differences were revealed between control group and all stretching groups ($p<0.001$). No significant differences were found between the different stretching groups.

Therefore, the baseline measurement that was used as covariate exerted a statistical significant influence on hip flexion ROM in all stretching groups ($p<0.0005$).

Discussion

This study investigated different stretching routines with diverse training parameters (stretch technique, sets of stretching, and stretch duration) but with the same daily and weekly training bouts (180 s and 540 s, respectively). The stretch techniques and the daily and weekly flexibility training doses were consistent with ACSM flexibility exercise recommendations. The results showed significant improvement in hip flexion PROM after 12 weeks of flexibility training in all stretching routines, when compared to the control (no stretching) group. The current study identified changes in PROM of 15.14 (95% CI = 10.19 to 23.56) degrees in the SLR test. A number of studies have documented similar changes in ROM after shorter stretching routines with higher stretch bouts per training session and week [20,29] and/

Table 1 The results of the general linear model for repeated measures on the passive hip flexion ROM measurements (mean and 95% confidence interval [CI]).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
	No stretch	(12×15 s)	(6×30 s)	(4×45 s)	(12×15 s)	(6×30 s)	(4×45 s)
		Passive technique	Passive technique	Passive technique	Active technique	Active technique	Active technique
	(n=24)	(n=17)	(n=14)	(n=19)	(n=28)	(n=38)	(n=33)
	Mean	Mean	Mean	Mean	Mean	Mean SD	Mean SD
	(95% CI)	(95% CI)	(95% CI)	(95% CI)	(95% CI)	(95% CI)	(95% CI)
pre-test	86.13	83.24	84.20	85.45	88.54	89.82	87.94
(baseline)	(83.56–89.85)	(80.10–87.32)	(78.45–84.90)	(80.37–87.98)	(82.27–90.51)	(86.37–94.88)	(84.01–91.38)
4-week test	87.75	93.51	95.35	88.90	97.62	94.75	95.75
	(84.87–90.64)	(89.93–97.10)	(90.43–100.26)	(85.20–92.61)	(94.53–100.70)	(92.24–97.26)	(93.09–98.42
8-week test	87.90	97.66	98.35	96.68*	103.07*	98.92*	99.54*
	(84.12–91.69)	(92.95–102.36)	(91.89–104.80)	(91.82–101.55)	(99.01–107.13)	(95.63–102.22)	(96.04–103.04)
12-week	86.05	104.00†‡	102.58†	100.00†	106.45†	102.75†‡	102.55†
post-test	(82.06–90.04)	(99.18–109.11)	(95.77–109.39)	(95.67–105.93)	(102.18–110.74)	(99.28–166.23)	(98.86–106.24)

Analysis of covariance (ANCOVA) baseline values as covariate:
Main effect time $p<0.001$
Interaction effect $p<0.001$
Post-hoc: *: significant difference between 4-week test and 8-week test ($p<0.05$); †: significant difference between 4-week test and 12-week test ($p<0.05$); ‡: significant difference between 8-week test and 12-week test ($p<0.05$)

or when using subjects with limited hamstring flexibility [9, 14, 37, 39, 49]. For example, Borms et al. [9] obtained gains in knee extension of approximately 12 degrees after a 10-week static stretching routine in sedentary female young adults. Bandy et al. [4] also showed gains in hamstring flexibility of approximately 10 degrees in passive knee extension (PKE) after a static stretching program of 5 days/week over 6 weeks. Whilst Nelson and Bandy [37] obtained changes in ROM of 12.79 degrees in PKE after a 6-week static stretching program in subjects with limited hamstring flexibility.

Perhaps stretching programs with a higher stretching frequency (5 days per week or more) and a shorter length of program (4 to 8 weeks) obtain similar ROM improvement as flexibility programs within ACSM's recommended flexibility parameters. However, flexibility training programs with a higher stretching frequency are decontextualized because people normally perform physical fitness conditioning programs with moderate frequency (for example 2–4 days per week) [52]. Therefore, the current study suggests that the ACSM's recommendation regarding stretch frequency (3 days per week) is most adequate and contextualized in subjects that are beginning or already performing a physical fitness conditioning program because it has been found in this study to be effective in improving ROM.

When improvement progression is analyzed, at 4 weeks of flexibility training, both active and passive groups showed significant improvement in PROM (11.56% and 8.62%, respectively) with a stretch daily dose of 180 s. It is thought that the initial improvement in flexibility is due to an increase in ROM as the result of enhanced stretch tolerance [24, 29, 31]. LaRoche and Connolly [29] had a similar increase in ROM, approximately 9.5% after 4 weeks of static stretching, 3 days/week, with a stretch daily dose of 300 s. On the other hand, David et al. [14] found that active stretching did not significantly increase hamstring flexibility over a control when performing a 4-week stretching program, 3 days per week, with a stretch daily dose of 30 s. Perhaps a possible explanation is that they used only 30 s of total daily stretch duration and their participants had poor initial flexibility scores, whilst in this study, the design included a total daily stretch duration of 180 s and included subjects with moderate, rather than poor, flexibility scores. Therefore, a moderate stretch daily dose (>30–180 s) is perhaps most adequate for improving hip ROM because (1) it is the minimum dose to improve ROM and (2) it is equally effective as a high stretch daily dose and allows for a better use of training time.

Moreover, it is important to note that when the gains in hip flexion PROM were observed in each test session, there were differences found, when improvement occurred. For example, at 8 weeks of stretching, all active stretching groups produced statistically significant improvements in hip flexion PROM from their own pre-test and 4-weeks test, while all passive stretching groups produced statistically significant improvements in flexibility from their own pre-test but not with their 4-weeks test scores. At 12 weeks, all stretching groups increased their hamstring flexibility, but only passive groups obtained large significant differences with their 8-weeks test score. Therefore, it is possible that the different progression observed in the PROM improvement may explain the different results shown in several studies regarding effectiveness of stretching techniques. At 4 weeks of flexibility training, in subjects with poor to moderate flexibility scores, there may be an improvement in stretch tolerance and ROM regardless of stretching techniques [24, 29, 31]. Perhaps more than 4 weeks are needed for the next significant improvement in PROM, and it is possible that the time required for these changes is different for each stretching technique.

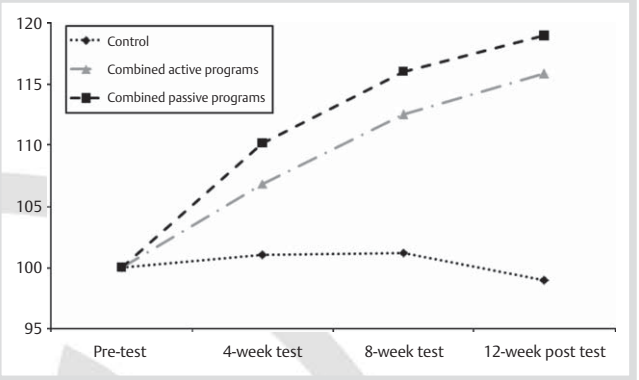

Fig. 3 Combined technique stretching treatment (as a percentage of pre-stretching values) demonstrated significant hip flexion ROM differences between stretching and not stretching treatments ($p < 0.05$) at each testing moment. Moreover no significant differences have been shown between active and passive stretching treatments at each testing moment ($p > 0.05$).

However, although the PROM progression was different between stretching techniques, no significant differences were shown regarding total gains in PROM after 12 weeks of flexibility training: both stretching techniques were equally effective in improving hip flexion ROM (**Fig. 3**). This concurs with Winters et al., [49] who concluded that active and passive stretching techniques were equally effective at improving ROM after 6 weeks of a stretching routine in subjects with limited hip extension.

With regard to sets of stretches and stretch duration, there were no significant differences found in improvements in hip flexion PROM in the post-test. As a result, no relationship was revealed between single stretch duration and improvement in PROM when the total daily dose of the stretch remained the same for each stretch group (180 s). Therefore, the current study suggests that no particular single duration was better with regard to its quantitative effect on chronic gains in ROM.

The results of this study corroborate the conclusions by Robert and Wilson [40], Rubley et al. [41] and Cipriani et al. [12] in that a single short stretch duration was as effective as a single longer stretch duration of up to 120 s with the same daily dose of stretch. In addition, the results of this study corroborate the notion of both Robert and Wilson [40] and Cipriani et al. [12] that the total time stretching in a given day may be more important than the actual duration of a single stretch repetition. The overall duration appears to be a key factor influencing stretching effectiveness. In addition, as with Cipriani et al. [12], perhaps for individuals who tolerate long duration-type stretching, the 30 or 45 s or longer protocol may be best. However, for individuals who do not tolerate the sensation of stretching, a shorter duration (15 s) but more frequent approach may be best suited for them, although these suppositions are purely theoretical.

Conclusions

The current study suggests that the ACSM flexibility training recommendations are effective for improving hip flexion ROM in recreationally active young men and women. A flexibility train-

ing program with a moderate stretching frequency of 3 days per week and daily dose of 180 s is equally effective as flexibility training programs with higher stretching bouts. Moreover, the ACSM flexibility training recommendations are more adequate and contextualized for recreationally active men and women training with a weekly frequency. Furthermore, according to the individual's level of physical conditioning, the degree of flexibility, and the previous experience in flexibility work, an individual could choose between the active or passive technique and between different stretch durations, to maintain the same gains in flexibility. One of the limitations of this study however was the muscle group stretched (the hamstring), and because other muscle groups were not included, the results of this investigation should not be generalized to other muscle groups. In terms of its practical application, it is recommended from the results of this study that the effect of acute stretching prior to intensive physical activities should be considered by strength and conditioning specialists before using these stretching routines as part of a pre-exercises warm up routine.

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