Resistance Training vs. Static Stretching: Effects on Flexibility and Strength

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Abstract

Morton, SK, Whitehead, JR, Brinkert, RH, and Caine, DJ. Resistance training vs. static stretching: Effects on flexibility and strength. *J Strength Cond Res* 25(12): 3391–3398, 2011—The purpose of this study was to determine how full-range resistance training (RT) affected flexibility and strength compared to static stretching (SS) of the same muscle–joint complexes in untrained adults. Volunteers ($n = 25$) were randomized to an RT or SS training group. A group of inactive volunteers ($n = 12$) served as a convenience control group (CON). After pretesting hamstring extension, hip flexion and extension, shoulder extension flexibility, and peak torque of quadriceps and hamstring muscles, subjects completed 5-week SS or RT treatments in which the aim was to stretch or to strength train the same muscle–joint complexes over similar movements and ranges. Posttests of flexibility and strength were then conducted. There was no difference in hamstring flexibility, hip flexion, and hip extension improvement between RT and SS, but both were superior to CON values. There were no differences between groups on shoulder extension flexibility. The RT group was superior to the CON in knee extension peak torque, but there were no differences between groups on knee flexion peak torque. The results of this preliminary study suggest that carefully constructed full-range RT regimens can improve flexibility as well as the typical SS regimens employed in conditioning programs. Because of the potential practical significance of these results to strength and conditioning programs, further studies using true experimental designs, larger sample sizes, and longer training durations should be conducted with the aim of confirming or disproving these results.

Key Words range of motion, joint mobility, ROM, strength training

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Introduction

Achieving and maintaining adequate range of movement (ROM) in muscle–joint complexes is of importance to athletes and nonathletes alike of all ages. The health and performance implications of inadequate flexibility are well known. However, recent research has questioned the beliefs often promoted by exercise leaders (e.g., that pre-exercise statistic stretching improves power performance and reduces injury risk), and it is likely that there is still much to be learned.

One area that has been sparsely researched is the effects of resistance training (RT) on flexibility. A half-century ago, it was still widely believed that muscle hypertrophy was associated with becoming "muscle bound," and some studies were undertaken to investigate the belief. For example, Massey and Chaudet (12) examined the effect of heavy resistance exercise on flexibility in young men, but because of design issues, their conclusions were ambiguous. Leighton (11) took a different approach and compared the flexibility of a body-building champion and an Olympic weightlifting champion to an untrained man before and after 5 weeks of RT. Most flexibility scores improved, none decreased, and the champions were more flexible than the novice was.

Little further research appears to have ensued for some time after that. Two decades later, Raab et al. (13) noted that the use of arm weights limited ROM during exercise in elderly women, resulting in less improvement in shoulder abduction ROM than through stretching alone. A few years later, Girouard and Hurley (8) concluded that a combination of strength training and flexibility training was inferior to flexibility training alone for older men. In that study, it was stated that the RT was full range, but because most of the exercises were reportedly done on a variable resistance machine, it is possible that the ROM achieved may have been different from the ROM that would have been achieved using free weights. Support for that possibility is suggested by the results of Swank et al. (16) who found that adding weights to stretching exercise increased the passive ROM of stretches thus increasing the effectiveness of flexibility exercises in the healthy elderly.

Around the same time period, Faigenbaum et al. (7) were researching strength training for children, and they reported that flexibility tests improved after 8 weeks of RT—but because stretching was done as part of warm-up and

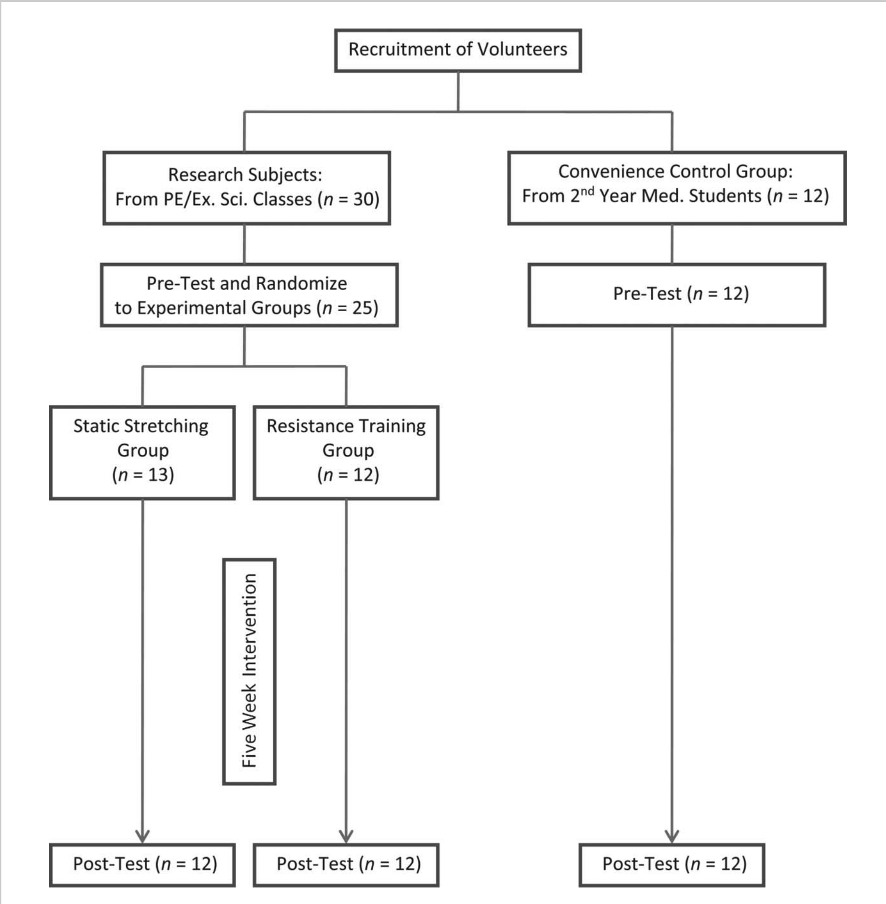

Figure 1. Flowchart showing study sequence of events.

appears to suggest that full-range resistance exercise will influence flexibility–but no supporting citation was given.

This somewhat confusing situation also seems to be complicated by conflation of studies of pre-exercise stretching with research on stretching as part of routine physical conditioning. Shrier (15) elaborated upon that point and cautioned that these uses of stretching should be seen as separate interventions. He also added another caution: "…the real merit of regular stretching will only be known when it is compared to other interventions (e.g., regular strengthening and endurance programs). (p. 1832). Thus, the purpose of this study was to test such a comparison–which in this case was a comparison of the effects 5 weeks of static stretching (SS) compared to full-range strength training (RT) of the same muscle–joint complexes on flexibility and strength. Given the dearth of experimental literature on the topic, we hypothesized that SS would increase flexibility compared to control, but those gains would not be superior to RT. Secondly, we hypothesized that RT would increase strength better than SS and control would.

cool-down, they concluded that "This observation supports the contention that strength training will not result in a loss of flexibility as long as stretching exercises are incorporated into the training regimen." (p. 345). The "contention" in that case was referenced to an early statement from the American Academy of Pediatrics (AAP). The current AAP (1) position stand recommends that strength programs for children "…should address all major muscle groups and exercise through the full range of motion." (p. 1471). This statement

Methods

Experimental Approach to the Problem

This study measured the chronic changes in flexibility and strength between 3 separate groups: an RT group, an SS group, and a control group (CON). The CON was

Table 1. Descriptive statistics of study variables (mean ± *SD*).*

	All subjects (*n* = 36)	RT (*n* = 12)	SS (*n* = 12)	Control (*n* = 12)
Age (y)	21.92 ± 3.64	22.00 ± 5.53	21.25 ± 2.26	22.5 ± 2.36
Height (in)	69.39 ± 3.54	71.17 ± 3.74	69.25 ± 3.47	67.75 ± 2.73
Weight (lb)	174.42 ± 34.01	185.7 ± 42.78	170.1 ±32.48	167.50 ± 24.2

*RT = resistance training; SS = static stretching.

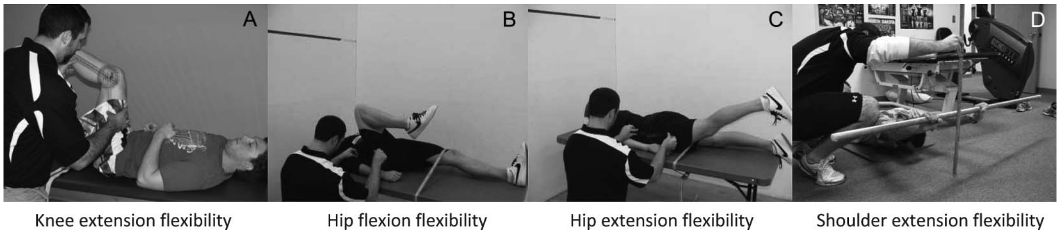

Figure 2. Flexibility tests.

a convenience control of inactive volunteers. The RT and SS groups were randomly assigned (balanced by sex) after pretesting. The groups were pretested for flexibility and strength. Then, the groups concurrently began their respective 5-week interventions. Posttesting session was done 1 week after the intervention end date (Figure 1).

Subjects

Forty-two subjects initially volunteered for this study (men = 30, women = 12). All were students at a medium-sized Midwestern university. Research subjects were recruited from Exercise Science academic classes, and a group of physically inactive second year medical students volunteered

Table 2. Resistance training and static stretching protocol.*†‡

Day	Resistance exercise	Sets	Static stretch	Sets	Held for (s)
1	Back squat	4	Piriformis stretch	1	30
	Pull-ups	4	Standing quadriceps stretch	1	30
	Bench press	4	Groin (adductors) stretch	1	30
	BB good mornings	4	Knees to chest	3	30
	DB shoulder press	4	Standing hamstring stretch	1	30
	DB walking lunge	4	Standing crosslegged hamstring stretch right	1	30
	Split curl to press	4	Standing crosslegged hamstring stretch left	1	30
	DB pullover to extension	4	One-arm pectoralis stretch right	1	30
			One-arm pectoralis stretch left	1	30
			One-arm deltoid stretch right	1	30
			One-arm deltoid stretch left	1	30
			Triceps stretch right	3	20
			Triceps stretch left	3	20
2	Front squat	4	Same stretches as day 1		
	Neutral grip chin-ups	4			
	DB incline bench press	4			
	RDL	4			
	Bradford press	4			
	Split squat	4			
	Bent over row	4			
	Rock stars	4			
3	BW walking lunge	4	Same stretches as day 1		
	Push-ups	4			
	BW good mornings	4			
	Chin-ups	4			

*BB = barbell; DB = dumbell; BW = body weight; RDL = Romanian dead lift; Rock stars = standing weighted alternating landmine press; Bradford press = standing alternating front to back overhead press; RT = resistance training.
†The repetitions in the RT protocol changed slightly from week 1 to week 5.
‡Rest between sets was about 2 minutes.

Table 3. Knee, hip, and shoulder flexibility pre–post changes.*

	Group	Pretest	*SD*	Posttest	*SD*	Change	*SD*
KEA (hamstring flexibility)	RT ($n = 12$)	35.63	13.39	68.50	10.78	32.88†	18.50
Pre–post changes (degrees from 90)	SS ($n = 12$)	31.29	7.89	63.54	12.76	32.25‡	13.21
	Con ($n = 12$)	44.17	17.59	58.00	17.90	13.83	11.14
	Total ($n = 36$)	37.00	14.30	63.35	14.55	26.32	16.78
Hip flexion pre–post changes (degrees from zero)	RT ($n = 12$)	73.17	9.78	62.59	6.17	10.58†	7.26
	SS ($n = 12$)	64.63	12.52	59.25	12.60	5.38‡	7.18
	Con ($n = 12$)	62.92	8.99	63.50	5.83	0.58	7.86
	Total ($n = 36$)	66.90	11.16	61.78	8.79	5.13	8.58
Hip extension pre–post changes (degrees from zero)	RT ($n = 12$)	15.00	5.89	24.88	6.60	9.88‡	4.29
	SS ($n = 12$)	17.92	4.91	22.59	7.26	4.67‡	6.89
	Con ($n = 12$)	21.75	6.55	23.25	4.42	1.50	8.10
	Total ($n = 36$)	18.22	6.58	23.57	6.15	5.35	7.32
Shoulder extension	RT ($n = 12$)	9.17	3.96	11.96	4.00	2.79	2.16
Pre–post flexibility changes (in.)	SS ($n = 12$)	11.83	4.64	13.58	4.54	1.75	2.04
	Con ($n = 12$)	10.92	3.32	12.08	2.51	1.17	1.59
	Total ($n = 36$)	10.64	4.05	12.54	3.75	1.90	2.0

*KEA = knee extension assessment.
†Different from control $p < 0.01$.
‡Different from control $p < 0.05$.

to serve as a convenience CON. All participants were given a verbal description about the nature of this study and gave their informed consent in line with the current university Institutional Review Board regulations (Table 1).

Procedures

All flexibility and strength tests were administered by the same tester pre and post. The strength testing took place in an athletic training room, and the flexibility testing was done in an exercise physiology laboratory. The pre and posttesting procedures were identical and were carried out after subjects had warmed up on a stationary bicycle with minimal resistance.

Knee Extension Flexibility. The first measurement taken (Figure 2A) was the knee extension assessment (KEA) test using the protocol described by Davis et al. (5). The subject was instructed to lie on his or her back with the hips and knees fully extended. A universal goniometer was used to measure degrees of extension. The axis was placed over the lateral epicondyle of the femur. The stationary arm was placed parallel to the longitudinal axis of the femur pointing toward the greater trochanter. The moveable arm was placed parallel to the longitudinal axis of the fibula, pointing toward the lateral malleolus. The leg to be tested was then passively raised by the examiner to 90° of hip flexion as recorded by another universal goniometer. The axis of this goniometer was placed on the greater trochanter of the femur, the stationary arm was placed parallel to the midaxillary line of the trunk, while the moveable arm was placed parallel to the longitudinal axis of the femur, pointing toward the lateral

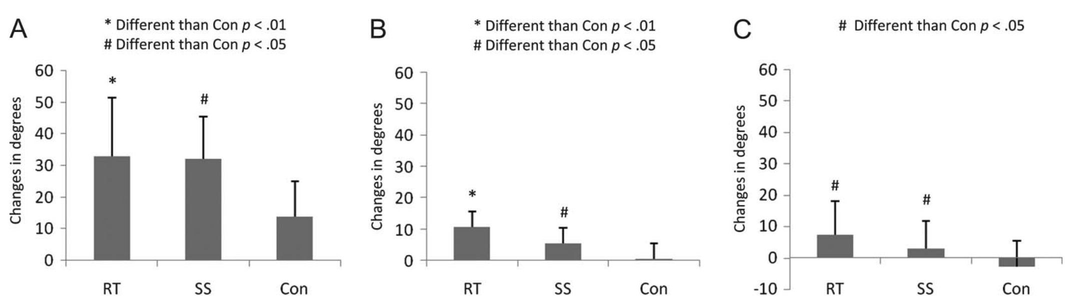

Figure 3. Knee and hip pre–post flexibility changes.

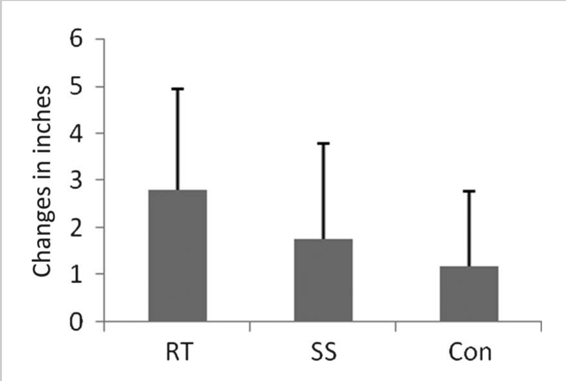

Figure 4. Shoulder extension pre–post flexibility changes.

epicondyle. The subject's knee was then passively straightened to a point where the subject reported a strong but tolerable stretch in their hamstrings. The contralateral lower extremity was fixed to the table in full knee extension using a nylon strap over the distal thigh. The angle of the knee (KEA) was then measured using the universal goniometer placed on the knee (5).

Hip Flexion Flexibility. The second measurement was the Hip flexion test (Figure 2B) using protocol described by Clarkson (3). The subject was instructed to lie on his or her back with the hips and knees fully extended. The trunk is stabilized with body positioning and the tester stabilizes the pelvis. A universal goniometer was placed on the greater trochanter of the femur. The stationary arm was placed parallel to the midaxillary line of the trunk. The moveable arm was placed parallel to the longitudinal axis of the femur, pointing toward the lateral epicondyle. The hip is then flexed to the limit of motion while flexing the knee (3).

Hip Extension Flexibility. The third measurement was the Hip extension test (Figure 2C) using protocol described by Clarkson (3). The subject was instructed to lie on his or her stomach, both hips and knees are in the neutral position and feet are over the end of the table. The pelvis is stabilized using a nylon strap. A universal goniometer is placed on the greater trochanter of the femur. The stationary arm is placed parallel to the midaxillary line of the trunk. The moveable arm is placed parallel to the longitudinal axis of the femur, pointing toward the lateral epicondyle. The knee is maintained in extension while the hip is extended to the limit of motion (3).

Shoulder Flexibility. The fourth measurement was the Arm Lift Test (Figure 2D) using the protocol described by Corbin and Lindsay (4). The distance was measured with a measuring tape, between the subject's arm pits and then recorded for posttesting. The subject was instructed to lie face down while gripping a 1-in. diameter wooden dowel using the arm-pit measurement for spacing. Then, the subject was instructed to raise his or her arms as high as possible above the mat, with arms held straight and the chin kept in contact with the mat. The measurement was taken from the mat to the bottom of the dowel using a yard stick (4).

Hamstring and Quadricep Strength Assessment. Using a Biodex B-2000 Dynamometer, peak torque for knee extension and flexion was recorded from a 5-repetition test set at a speed of $180°\cdot s^{-1}$. Both pre-and posttests were conducted by the same athletic trainer who was experienced in conducting strength tests using the equipment.

Resistance Training. The RT group followed a 5-week program designed and supervised by a Certified Strength and Conditioning Specialist (CSCS) (Table 2). The program was designed to be balanced and practical for a subject unaccustomed to weight training. Using weights that were carefully selected using established formulas (3), subjects were instructed in all RT movements with specific emphasis on the full ROM aspects of each lift. The CSCS professional was on hand for all weight training sessions. The sessions lasted from 45 minutes to an hour. A 5-minute warm-up on unloaded stationary

Table 4. Knee extension and flexion peak torque pre–post changes ($180°\cdot s^{-1}$)

	Group	Pretest	*SD*	Posttest	*SD*	Change	*SD*
Knee extension	RT ($n = 12$)	100.53	21.58	107.61	23.91	7.26†	10.75
Pre–post changes	SS ($n = 12$)	88.38	23.30	91.36	25.21	2.98	8.66
	Con ($n = 12$)	98.66	24.51	95.86	25.38	−2.80	8.31
	Total ($n = 36$)	95.80	23.14	98.28	25.16	2.48	9.95
Knee flexion	RT ($n = 12$)	48.02	11.03	53.03	13.27	5.01	6.31
Pre–post changes	SS ($n = 12$)	44.29	12.17	45.10	11.06	0.81	6.89
	Con ($n = 12$)	48.21	10.89	50.46	13.01	2.24	9.89
	Total ($n = 36$)	46.84	11.21	49.53	12.59	2.69	7.69

*RT = resistance training; SS = static stretching.
†Different from control $p < 0.05$.

bicycles preceded the RT. The subjects were instructed to refrain from any stretching during the 5-week period.

Static Stretching. The SS group followed a 5-week program designed by a CSCS (Table 2). The program was designed to stretch the same ranges of movement that were being trained in the full-range RT program while still being SS. The CSCS professional was on hand for all SS sessions and timed each stretch. The sessions lasted from 25 to 35 minutes. The subjects did not warm up before beginning the SS. The subjects were also instructed to refrain from any extra physical activity, particularly any RT, during the 5-week period.

Statistical Analyses

SPSS for Windows software was used for all statistical analyses. Data were analyzed using a 1-way analysis of variance (ANOVA) using prepost flexibility and strength difference scores as dependent variables. Because there were some concerns about small group differences in pretest scores, the data were also analyzed using analysis of covariance (ANCOVA) with the pretest scores as the covariate in each analysis. Tukey's post hoc tests were used in both analyses. Statistical significance was set at $p \leq 0.05$ for all tests.

Results

The purpose of this study was to compare the effects of SS and RT on flexibility of several joint–muscle complexes. Specifically, the study examined hamstring flexibility (with a KEA), Hip flexion and extension (Hip Flexion, Hip Extension tests), shoulder extension (Arm Lift test), and quadriceps and hamstring strength (using Peak Torque Knee Extension and Flexion on the Biodex B-2000 Isokinetic Dynamometer). The results from the ANOVA and ANCOVA analyses were essentially the same, except that 2 intervention groups (SS on hip flexion and extension) were marginally significantly different from control ($p = 0.049$) in the ANCOVA analyses but not in the ANOVA analyses. For ease of interpretation, the pre–post difference data are presented in the tables and figures.

It was hypothesized that (a) The RT and SS groups would gain flexibility in the hamstrings, hip flexion, hip extension, and shoulder significantly when compared to the CON; (b) the strength levels of the RT group would increase significantly when compared to the SS group and CON; (c) The RT group would gain flexibility in the hamstrings, hip flexion, hip extension, and shoulder at the same rate or higher than the SS.

Knee Extension Flexibility. The KEA was used to assess hamstring flexibility for all participants (using the averages of the scores from the right and left leg of each subject as the dependent variable). Both treatment groups improved flexibility significantly more than the CON did (RT $p < 0.01$, SS $p < 0.05$), but there was no significant difference between the SS and RT conditions (Table 3 and Figure 3A).

Hip Flexion Flexibility. The averages of the scores from the right and left legs of each subject were used as the dependent variable. Both treatment groups improved flexibility significantly more than control (RT $p < 0.01$, SS $p < 0.05$), but there was no significant difference between the SS and RT conditions (Table 3 and Figure 3B).

Hip Extension Flexibility. The averages of the scores from the right and left legs of each subject were used as the dependent variable. Both treatment groups improved flexibility significantly more than control did (RT $p < 0.01$, SS $p < 0.05$), but there was no significant difference between the SS and RT conditions (Table 3 and Figure 3C).

Shoulder Flexibility. There were no significant differences between conditions. The data are given in Table 3 and Figure 4.

Quadriceps Strength. The averages of the scores from the right and left legs of each subject were used as the dependent variable. There was a statistically significant difference ($p < 0.05$) between

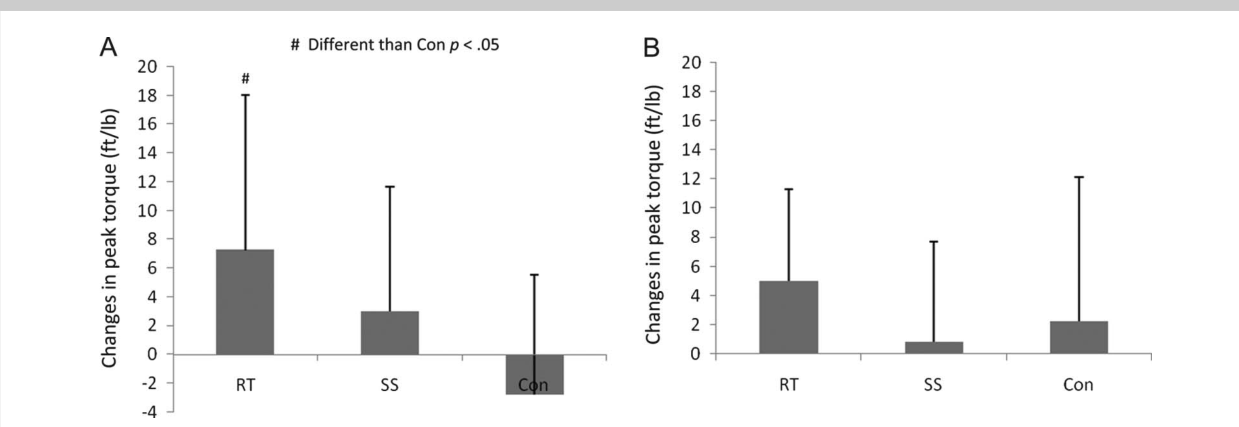

Figure 5. Knee extension and flexion peak torque pre–post changes.

the control and RT groups. However, there was no significant difference between the SS and RT conditions or between the SS and control conditions (Table 4 and Figure 5A).

Hamstring Strength. The averages of the scores from the right and left legs of each subject were used as the dependent variable. There were no significant differences between conditions. The data are given in Table 4 and Figure 5B.

Discussion

It is appropriate to preface this discussion with an acknowledgment that this experiment should be seen as a preliminary study of the topic. It did not have a true experimental design (nonrandomized CON), its sample size was fairly small, and for a training study, the duration was probably too short to produce clear effects. However, the results were consistent, and would seem to have heuristic merit, and potentially important practical significance.

The main hypothesis in this study, intended to reflect an attempt at a reasonable overview of the extant literature, was that SS would increase flexibility compared to control, but those gains would not be superior to RT. Both parts of the hypothesis were supported–because full-range RT produced flexibility improvements of equal magnitude to SS in 3 out of 4 comparisons (with no significant differences between treatments and control in the fourth. Our second hypothesis, that RT would increase strength better than SS and control, was supported in one out of 2 comparisons (with no significant differences between conditions on the other). Thus, these results strongly question the notion that RT reduces flexibility (the old "muscle bound" notion), and they certainly question the implicit (if not explicit) view that those who do RT should stretch what they strengthen (a Google search in June 2010 on "stretch what you strengthen" elicited 1.1 million hits).

Of course, a major limitation of this study is its short duration. Unfortunately, because of calendar and facility constraints, it was only possible to continuously run the interventions for a 5-week period. Thus, given the consensus in the extant research (2,6), it is likely that the RT results represent mostly early stage neural adaptations–and it is possible that different results could have occurred after the hypertrophy changes that would have been likely in longer duration training interventions. Whether the SS results would have been different over a longer intervention period is also a question that likely needs further study–especially because in contrast to RT, research indicates that mechanical adaptations to SS precede neural adaptations (9). Further experimental research using direct RT–SS contrasts over a longer intervention period is obviously required before any definitive conclusions can be made.

Despite the issues arising from the limited duration of the training intervention in this study, a key question is whether the significant effects that resulted are plausible from a neuroanatomical perspective? In answering that question, it seems appropriate to reemphasize that the few relevant extant studies do seem to suggest that a key point is that RT exercises should be *full range* to maintain, or improve flexibility. Indeed, as Raab et al. noted (13), in some circumstances, the weights used in RT might cause exercisers to limit the ROM used. However, with that caveat kept in mind, we would postulate that our results are plausible simply on the basis that full-range RT is essentially, from a neuroanatomical perspective, a form of proprioceptive neuromuscular facilitation (PNF) stretching (where a precontraction of a muscle is followed by a full ROM passive stretch). The PNF-passive stretching is generally accepted to be more effective than passive stretching alone (9), and moreover, in a recent study investigating optimal contraction intensities for PNF stretching, it was concluded that approximately 65% of maximum isometric contraction in the precontraction produced the largest increases in ROM during the subsequent stretch (14). This level of intensity is similar to the intensity used by the RT group subjects in this study and is fairly typical of the percentage of 1RM used by many athletes and fitness exercisers in their RT sets.

This conceptual comparison of full-range RT to PNF stretching is offered as a common sense rationale for the results of this study. Of course, further research is clearly required to confirm or refute this idea, but as Shrier (15) alluded, research on stretching needs some conceptual organization and clarification. Over the decade or so, research on stretching has challenged old beliefs and provided actual evidence to support new recommendations (e.g., avoid SS during the warm-up for dynamic performance activities). However, confusion or conflation regarding the study or application of stretching as a tool for movement preparation, performance enhancement, injury prevention, or simply as a way to improve flexibility in general conditioning is common. Moreover, terminology has become muddled with the addition of some concepts that are either unclear or simply misused. For example, "dynamic warm-up" and "dynamic stretching" have been used as synonyms in recent research (10) to describe a dynamic callisthenic routine used to warm-up athletes before activity. The range of "dynamic technique used" is wide. While some can be described as callisthenic, others could be seen as a type of ballistic stretch while most probably fall somewhere in the middle. Clearly, there needs to be clarification of both terminology and application specifics in future research on stretching.

In summary, this study attempted to address one such clarification by independently studying the effects of RT and SS on flexibility and strength. Although the experiment was preliminary in nature, and practically oriented (as opposed to having laboratory-type control), its results indicate that full–range RT may improve flexibility as much–at least for the short duration of the interventions used (and had larger sample sizes yielded the same mean scores, it is likely that the RT changes would have been significantly greater than SS). If these results can be replicated, the implications to coaches and exercise leaders are of obvious importance. Thus, future research is clearly needed, and such research should employ stronger designs, longer interventions, and should also investigate the topic comparing different muscle–joint complexes using a variety of RT and stretching protocols.

Practical Applications

Both RT and SS are commonplace in exercise and athletic settings. The results of this study suggest that RT–so long as it is done over the appropriate full ROM–will have positive benefits on flexibility. As such, these results question the notion that RT will reduce flexibility (the "muscle bound" notion), and they also suggest that the commonplace "stretch what you strengthen" lore is questionable. The significance of this will obviously vary across different circumstances–for example, a sprinter and a distance runner have very different ROM requirements as do football players vs. baseball players etc. For those exercisers and athletes who use RT to increase lean muscle mass and improve power and force development, this study has suggested that flexibility can also improve. Because the athletes already participate in RT, there may be less need to incorporate additional stretching exercises than has previously been believed.

However, further research is clearly necessary before this preliminary study can be used to justify major changes in practice, and future studies should aim at both experimental replication (with stronger methodology) and extension (focusing on different joint–muscle complexes and examining other RT and stretching protocols).

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