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Sports Training

Effect of the inclusion of static stretching in general warming up on muscle strength in Brazilian army military personnel

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Abstract - Aim: Several health professionals prescribe static stretching exercises (SS) as essential for those that practice physical exercises, for injury prevention and performance improvement, although there is still no consensus. There are few studies on the effects of SS use on warming up. Thus study aimed to compare the effects of the inclusion of SS in general warming up procedures on muscle strength in Brazilian army personnel. **Methods:** Thirty-two young military men were selected. They were subjected to anthropometric evaluation and performed knee extension and flexion in an isokinetic digital dynamometer, at a speed of 60°/s. Then, they were divided into two randomized and counter-balanced groups, Traditional Group (TG) and Experimental Group (EG). The TG performed the lower limbs warm-up protocol provided for military physical training (MPT) and immediately after, performed the isokinetic muscle strength test. The EG performed the same protocol, performing the SS in the hamstrings and quadriceps, before warming up. **Results:** An increase was found in the peak isokinetic torque in the knee extension of the EG (Pre: 209.80 ± 21.36 vs Post: 243.98 ± 30.35; p = 0.001) and flexion (Pre: 130.86 ± 18.63 vs Post: 142.41 ± 25.92; p = 0.006). In the TG, significant differences were found in the extension of the knee, but not in flexion (Pre: 209.14 ± 34.27 vs. Post: 239.38 ± 36.17; p = 0.001 and Pre: 129.23 ± 18.43 vs Post: 133.66 ± 13.20; p = 0.297, respectively). **Conclusion:** The inclusion of SS in general warming up did not harm and even improved muscle strength performance in knee extension and flexion in Brazilian Army military personnel.

Keywords: stretching, warm-up, muscular force.

Introduction

Warm-up is used by health professionals to prevent muscle-skeletal pain and injury, and increase performance[1]. Warming up before exercises provides progressive physiological adaptations in tissue and joints; neural and psychological adaptations that prepare the individual for the activity[2]. In this sense, warming up improves muscle viscoelasticity, which enables a more effective muscle stretching[3].

Muscle stretching is one of the most used strategies before the practice of recreational physical exercises, training, and sports competitions[4,5]. This is because, promoting a range of motion (ROM) and increased soft tissue mobility[6], could improve athletic performance and reduce the risk of musculoskeletal injury[7].

Static stretching (SS) is an isometric tension technique applied slowly to a muscle to its greatest extent and maintained in such a position for a period of[8]. This method has been the subject of several studies that investigated its influence on injury prevention[9], rehabilitation[10], range of motion[11], flexibility[12], strength training volume[13], muscle activation[14,] and physical performance[15,16]. Regarding the performance of tasks that predominantly require the muscular system, the SS effects on power[17] dynamic strength[18], isometric strength[19], and isokinetic torque[20] were studied.

Although SS is the most studied stretching technique, there is still no established consensus regarding the advantage of using it before physical exercises, especially in movements that require more of the muscular system, that is, that require greater muscular effort such as sports competitions and military tasks. Some authors have concluded that performing SS does not influence activation levels and muscle strength performance[21,22]. However, most studies indicate a negative acute effect on muscle performance after SS[23,24]. Nevertheless, practicing SS in the preparation for physical exercises is still very common among practicioners[25] because it could contribute to reducing the risk of musculoskeletal injuries[9].

Despite that, the effects of the combination of SS and localized effect exercises as a warming up strategy are poorly studied. Warm-up can be performed with exercises that provide a specific or general preparation[26]. Evidence shows that performing SS before specific localized-effect exercises could cause decreased muscle strength[3]. Although a study on the effects of including SS before exercises with a localized effect on athletic performance was found[27], no studies specifically related to maximal muscle strength tasks have been found. Regardless, there are few studies on the inclusion of SS before the dynamic warm-up protocol, a widely used strategy in practice.

Thus, our study aimed to compare the effects of the inclusion of static stretching in general warming up on muscle strength in Brazilian Army (BA) military personnel.

Methods

Study design, sample, and ethical issues

This quasi-experimental, cross-sectional study began with 36 military volunteers of the Brazilian Army, who perform physical exercises regularly. Inclusion criteria were being part of the military personnel of the Brazilian Army; not using any anabolic substance; and responding negatively to the questions of the Physical Activity Readiness Questionnaire (PAR-Q) – an instrument that aims to identify possible limitations and restrictions on the practice of physical exercises. Exclusion criteria were the previous history of joint, bone, or muscle injury on lower members and missing any of the scheduled testing. However, 4 volunteers were excluded due to health reasons (muscle injury), and the study was conducted with 32 volunteers.

All volunteers were informed about the risks and benefits before performing any test and signed an informed consent form. The study protocol was approved by the research ethics committee of Universidade Iguaçu (Protocol number: CAAE 77281417.0.0000.8044), followed all the precepts of the research involving human beings contained in Resolution No. 466/12 of the National Health Council of Brazil and the Declaration of Helsinki.

Experimental protocol

Each participant attended 3 visits, first visit for general instructions, anthropometric evaluation, and familiarization with the procedures; the second visit for the isokinetic evaluation to divide the groups (EG or TG) in isokinetic strength level, by the sum of peak torque in knee extension and flexion and obtaining baseline values; the third visit for the experimental protocols.

On the first visit, all participants were initially instructed on the procedures of the experiment, signed the informed consent form, and were subjected to a standardized individual evaluation composed of anamnesis of personal data, completion of the PAR-Q, and anthropometric evaluations for sample characterization. Subsequently, they were instructed not to perform intense activities during the period of the tests, besides becoming familiar with the intensity of stretching and warm-up exercises. Participants were introduced to the flexibility scale and performed one set until the "discomfort" level in the dominant limb. It was explained that they would perform the warm-up exercise as part of their daily military training routine; a trained researcher demonstrated the proper execution. For anthropometric evaluation, we used a digital scale (LÍDER® P200M) with a capacity of up to 200 kg, and a stadiometer (SANNY®, model ES-2060), with a measuring capacity of 115 to 210 cm and tolerance of ± 2 mm.

On the second visit, the first isokinetic evaluations were performed. All participants performed five minutes of systemic warm-up on an exercise bike (TECHNOGYM®, ExcitedMed) with saddle adjusted at the height of the greater trochanter of the femur, in the adjustment of 50 W of power and speed between 20 and 22 km/h, followed by a familiarization protocol in the isokinetic dynamometer Biodex System 4 Pro (BIODEX MEDICAL SYSTEM®), composed of two sets, one set of 180°/s and a set of 120°/s, each composed of 10 submaximal repetitions, with a 60 s interval. Next, an isokinetic evaluation for knee extension and flexion was performed with three sets, where each set was composed of 5 maximum repetitions at 60°/s. Between the sets in each velocity, 60 s intervals were provided. The tests were performed on the dominant limb and the volunteers received verbal encouragement to be motivated to perform maximum strength with each repetition. Then, they were randomly divided and counterbalanced into a traditional group (TG) and an experimental group (EG).

From the third visit, the volunteers performed the experimental warm-up protocols (Figure 1), with a 24-48 h interval between the sessions. The EG members performed 4 sets of the 30 s of static stretching of quadriceps and hamstrings, followed by 90 s of light running, followed by exercises of localized effect for lower limbs, provided for in the moving warm-up in the military physical training of the BA[28]. The TG members performed the same exercises, without static stretching. Immediately after the execution of the protocols, they were subjected to isokinetic evaluation to obtain the concentric peak torque in knee extension and flexion by the Biodex System 4 Pro

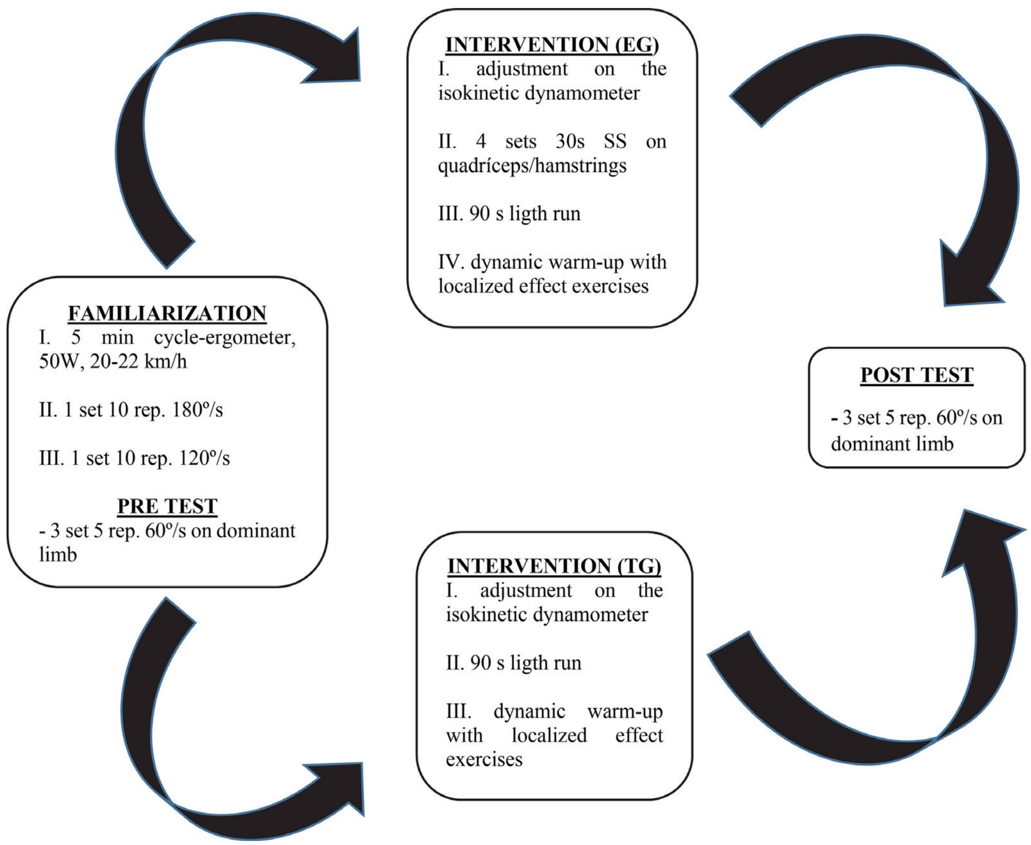

Figure 1 - Experimental protocols.

digital dynamometer (BIODEX MEDICAL SYSTEM®). Before starting the warm-up protocol, each participant was adjusted in the dynamometer, to provide a minimum interval between the end of the warm-up and the beginning of the muscle strength assessment. For data analysis, the highest peak torque value in the 3 sets at 60°/s was considered.

Warm-up protocol (Static stretching and Localized-effect exercises)

Static stretching

Static stretching was performed passively, that is with a help of a researcher, in four sets of 30 s with a 10 s rest interval[29].

For quadriceps stretching, the participants were positioned in lateral decubitus, with the contralateral leg with 90° knee and hip flexion. The pelvis was stabilized to avoid compensation. For complete hip extension ROM, complete knee flexion was not performed in the elongated thigh, because the femoral muscle, which is biarticular, may restrict amplitude – the joint limits of each participant were respected. For the hamstrings, the position changed to a supine position with a complete extension of the contralateral leg[30]. The candidates were asked about the subjective sensation caused by stretching, and then informed that they must not feel pain[31]. The evaluation was made through the Perceived Flexibility Effort Scale (PERFLEX) which has five different sensations. For our study, the sensation of "discomfort" (level 61-80) was used to control stretching intensity[32].

Localized-effect exercises

The participants performed exercises of dynamic localized effects for lower limbs, provided for in the military physical training of the BA[28]. The exercises were, in this sequence, Race with knee elevation, Race with leg extension in front, Race with heel elevation, and Lateral race[28] (Figure 2). Before starting the exercises, the volunteers ran slowly for 90 s, followed by performing the exercises of a localized effect, 20 s in each exercise. After each exercise, the volunteers returned to the slow run for 10 s before moving on to the next one. The activity was conducted by a military physical education professional and lasted around 3 min 50 s.

Isokinetic muscle strength testing

The volunteers were firmly anchored to the dynamometer chair, with belts in the trunk, hip, thigh, and ankle region to avoid undesirable compensation. The mechanical axis of the dynamometer was aligned with the lateral

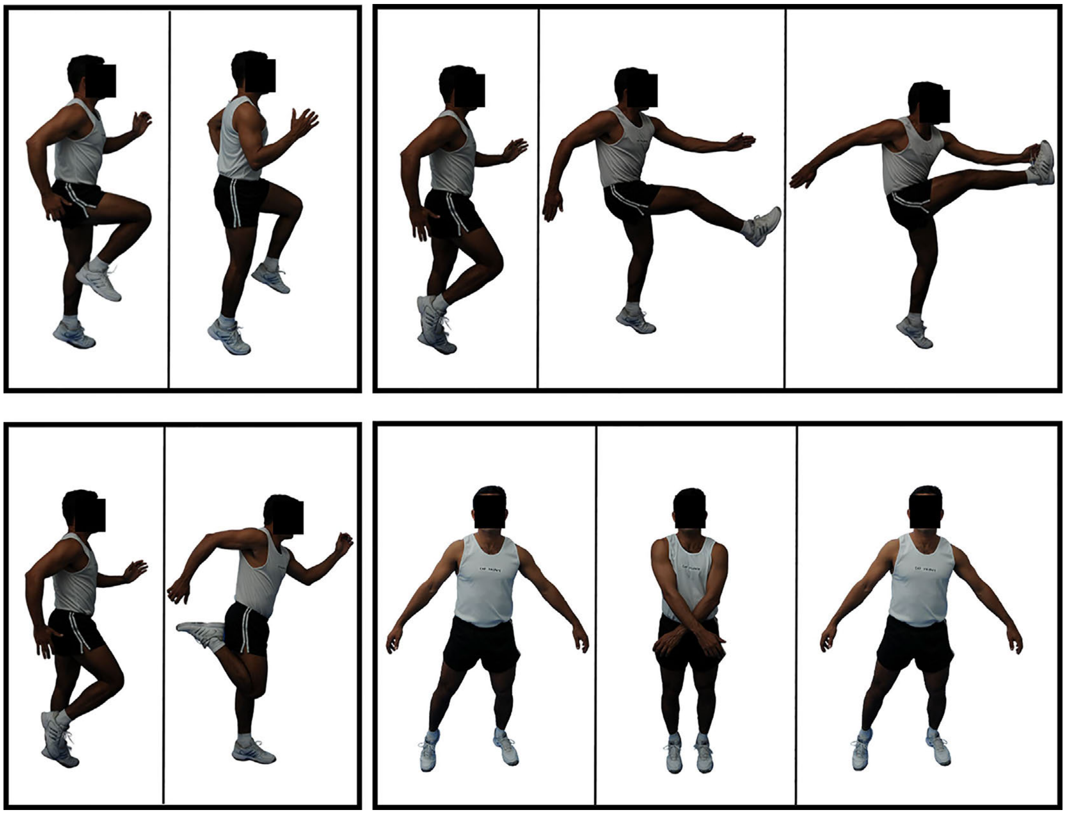

Figure 2 - Localized-effect exercise protocol. Source: Brazil (2015).

epicondyle of the femur, a bone reference for the biological axis of the knee joint[33]. Next, the isokinetic strength, extension movement, and knee flexion, concentric/concentric, test was performed in the dominant limb. Three sets of 5 maximum repetitions were performed, with a 60 s interval, at a speed of 60°/s. All evaluations were performed by the same researcher and the volunteers were verbally encouraged to perform maximum strength throughout the test.

Statistical analysis

The data were presented in mean values, standard deviation (SD), and standard error (SE). The normality test (Shapiro-Wilk) was applied and the data did show normal behavior ($p \geq 0.05$). The parametric paired *t*-test was used to compare the profile of maximum Peak Torque variables between the moments (baseline and post-test), and the independent *t*-test was used to compare the difference between the groups of the knee extensors and flexors on the active warm-up structure with and without static stretching. $p \leq 0.05$ was adopted.

Results

Table 1 shows the sample descriptive characteristics. Both groups were similar in age and anthropometric parameters.

Table 2 shows the mean and standard deviation values of torque peaks in knee extension and flexion. No statistically significant differences were observed between the peak torque between the EG and the TG at baseline, both in the extension ($p = 0.995$) and in the flexion ($p = 0.805$). No significant differences were found between the EG and the TG after the exercise both in extension ($p = 0.699$) and in flexion ($p = 0.241$). The percentage of increase in variation between baseline and post-test in knee extension was mean of 14.00% in EG and 12.00% in TG, and in knee flexion was 7.08% in EG and 3.05% in TG. No significant difference was found in the percentage of variation between the groups in both extensions ($p = 0.494$) and flexion ($p = 0.311$). The peak torque in the TG for knee extension was significantly higher after the protocol when compared with the baseline

Table 1 - Descriptive characteristics of the sample.

Variable	TG	EG	p-value
Age (years)	18.9 ± 0.5	18.9 ± 0.2	0.50
Body mass (kg)	69.3 ± 6.7	97.5 ± 8.4	0.25
Height (m)	1.76 ± 0.02	1.75 ± 0.04	0.18
BMI (kg/m^2)	22.5 ± 2.3	22 ± 2.5	0.25

TG: Traditional Group; EG: Experimental group; BMI: Body Mass Index.

Table 2 - Mean and standard deviation values of the isokinetic torque peak.

Variable	TG		EG	
	Pre	Post	Pre	Post
Knee extension (N.m)	209.14 (34.27)	239.38 (36.17)*	209.80 (21.36)	243.98 (30.35)*
Knee flexion (N.m)	129.23 (18.43)	133.66 (13.20)	130.86 (18.63)	142.41 (25.92)*

TG: Traditional Group; EG: Experimental group. *Significantly higher values than the Pre ($p \leq 0.05$).

(TG = 239.38 ± 36.17; SE = 9.04 and EG: = 209.14 ± 34.27; SE = 8.57), t(15) = -7.71, p = 0.001. On average, there was no significant difference in TG in knee flexion after the protocol (Mean = 133.66 ± 13.20; SE = 3.30) and baseline (Mean = 129.23 ± 18.43; SE = 4.61), t(15) = -1.08, p = 0.297 (Table 2).

The peak torque in the EG for knee extension was significantly higher after the protocol (Mean = 243.98 ± 30.35; EP = 7,59) when compared with the baseline (Mean = 209.08 ± 21.36; SE = 5.34), t(15) = -10.08, p = 0.001. The peak torque in the EG for knee flexion was significantly higher after the protocol (Mean = 142.41 ± 25.92; SE = 6.48) when compared with the baseline (Mean = 130.86 ± 18.63; SE = 4.66), t(15) = -3.22, p = 0.006 (Table 2).

Discussion

Our study aimed to compare the acute response of static stretching inclusion on the general warm-up on the subsequent performance of isokinetic muscle strength in knee extension and knee flexion movement. Significant strength gains were found in the peak torque of knee extension and flexion in the EG, the group that performed the warm-up with the SS procedure.

The results of our study contradict most authors, who found significant decreases in muscle strength preceded by SS[23,24].

Regarding the effects of SS on isokinetic strength specifically, a decrease in the peak concentric torque in the knee extension at a speed of 60°/s was found in a protocol similar to ours[34]. Despite the similarity with the protocol of our study, the results were different due to the performance of exercises of localized effect after the SS.

Regarding the posterior chain, a 7% decrease in concentric muscle strength in knee flexion has already been reported after the performance of SS[35]. In these studies, the SS total time was large, ranging from 2 to 20 min. It is known that the longer the SS, the greater the acute adaptations in the musculotendinous unit (MTU), and its effects on muscle properties can remain for more than one day[36]. There is evidence that applying SS for more than 60 s causes losses of 4 to 7.5% in muscle strength[15]. Previous studies that applied stretching for less than 60 s reported no significant reductions in muscle strength in the same exercises evaluated in our study, both in knee flexion[37], and knee extension[20].

In our study, the total stretching time was 120 s, divided into 4 sets of the 30 s, interspersing quadriceps, and ischiotibais, in this order. Contrary to other results with similar SS time, there was a significant gain in knee extension and flexion. It has been reported that the application of SS up to 60 s, after exercises of a localized effect, seems to provoke a protective effect against the loss of muscle strength[38]. Our results suggest that the inversion of the order, that is, starting the preparation protocol with SS, followed by exercises of a localized effect, also allows that there is no loss of strength, even with 120 s of stretching.

On the other hand, a study also with a sample of military personnel, with age and level of similar physical activities, in which volunteers were subjected to warm up with and without SS, the authors found a significant loss of isokinetic force, at the speed of 60°/s, in knee flexion, but not in extension, even with the volunteers performing only two sets of the 20 s of SS[3]. The main difference between that study and ours is in warm-up exercises. In that study, a specific warm-up was performed in the isokinetic, at the speed of 120°/s, preceded by SS. In our study, in turn, we applied the protocol with a set of general exercises of dynamic localized effects for lower limbs. In other words, the SS preceding exercises that are not related to the specific motor gesture of the force task to be performed do not decrease performance.

On the other hand, a study with a protocol similar to ours, in which 15 min of cycle ergometer was performed, followed by 90 s of quadriceps and hamstrings SS, as a general warm-up strategy, a significant loss of isokinetic muscle strength was observed, both in knee extension and flexion[39]. Even with the exercise time much longer than that of our study (15 min and 4 min 30 s, respectively), having performed SS after the cycle ergometer may have been the cause for the difference between the results.

Warming up causes adaptations such as increased body temperature, improvement of the central nervous system, and increased recruitment of motor units, which can provide benefits in muscle strength performance[40]. In the TG, the group that performed warmup with exercises with localized effects of ILL without SS, there were significant gains in isokinetic strength in the extension; however, without influence on knee flexion. Other studies that conducted warm-up protocols performing general or specific exercises, without SS, found no influence on muscle strength performance[3,39,41]. Therefore, warming up with general or specific localized effect exercises, without SS, does not seem to influence, or provide fewer gains, in strength performance. On the other hand, our results suggest that performing SS before general localized effect exercises may even increase performance both in extension and in the flexion of isokinetic strength. In general, the explanation for this phenomenon is alterations caused in the viscoelastic properties of the musculoskeletal unit (MSU)[41] Thus, SS could impair MSU's ability to store and use elastic energy by providing excessive relaxation[42]. Indeed, there are indications that the use of SS after a general warm-up exercise may more rapidly decrease MSU passive energy absorption[43] with acute negative consequences on muscle strength. However, our results indicate that this does not occur when SS is performed before localized effect exercises and is not directly related to the specific motor gesture of the force task. Further studies should be conducted to help clarify the mechanisms that lead to this phenomenon.

Our study had limitations the division of the groups was random and counterbalanced according to isokinetic strength level, not checking the level of flexibility of the volunteers, which could influence the results. Another possible limitation was the longer warming-up duration of the EG when compared with the TG, but it is worth mentioning that our study hypothesis was based on the evidence that SS could decrease muscle strength. In other words, even with the increase in warm-up time, the SS would cause impairments to muscle strength, which did not occur.

Nevertheless, our study is relevant because it combined SS exercises with localized-effect exercises in the warm-up to perform muscle strength tasks. Many athletes and individuals that perform regular physical activities perform similar protocols as preparation for training, being research close to the reality of academies and training centers. Few studies have been conducted with the combination of SS and exercises of localized effect as preparation for performance in a task that requires muscle strength.

Conclusion

We concluded that a warm-up protocol composed of the inclusion of static stretching in the quadriceps and hamstring muscles, preceding general localized effect exercises, did not harm and even improved muscle strength performance in knee extension and flexion in Brazilian Army military personnel. Therefore, trainers and those that practice physical exercisers may consider using the SS combination and general localized effect exercises before strength exercises, without the concern with performance loss.

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