Manual Therapy, Posturology & Rehabilitation Journal
ISSN: 2236-5435

RESEARCH ARTICLE

Inter-set stretch: a preliminary randomized controlled comparison of knee extension strength performance in recreationally trained individuals

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Abstract

Background: The administration of inter-set stretching appears to be an innovative strategy for increasing volume load (VL). However, the literature is still controversial about these effects. Furthermore, no study has evaluated the effects of inter-set stretching on training impulse (TRIMP) outcomes. **Objective:** To compare the effect of anterior chain stretching between sets on total repetition volume (TV) and VL and TRIMP in the knee extension exercise. **Methods:** Eleven men were recruited and performed 3 visits to the laboratory. In the first visit, a maximum repetition test was performed on both legs separately (1RM). In the second visit, the leg to be trained was randomly selected. After a 5-minute warm-up, each subject performed 4 sets at 70% of 1RM (passive rest). In the last visit, after warm-up, the subjects performed the same 4 sets at 70% of 1RM, however, differing only in the stretching between sets (2 min between sets). For the stretching protocol, the anterior chain was considered, 20 seconds, at maximum condition. The OMNI-res scale was applied. VL was calculated based on VT x external load and TRIMP based on VL x OMNI-Res. **Results:** The Kruskal-Wallis test showed no significant differences between the intervention groups ($p = 0.884$; $p = 0.564$; $p = 0.530$; $p = 0.947$; respectively for all 4 sets. The independent samples t-test showed no differences for the TV (34.3 ± 4.9 vs. 33.9 ± 6.3 repetitions; $p = 0.881$, respectively for no stretching vs. stretching). The independent t-test also showed no differences between the VL (1405.3 ± 515.8 vs. 1367.0 ± 454.0; $p = 0.855$, respectively for no stretching vs. stretching). The TRIMP did not show differences between the groups ($p = 0.182$), as well as the OMNI-RES ($p = 0.659$; $p = 0.100$; $p = 0.311$; $p = 0.635$, respectively for sets 1, 2, 3 and 4). **Conclusion:** 20 seconds of inter-set stretching did not influence the TV of the sets, the VL, the OMNI-Res and the TRIMP of the session.

Keywords: Flexibility; Resistance training; Physical Functional Performance.

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Received: 10 Jul, 2024.
Accepted: 08 Sept, 2024.
Published: 01 Nov, 2024.

BACKGROUND

Manipulation of strength training variables is recommended to promote adequate adaptive responses[1,2]. Depending on the training status of practitioners, the construction of different methods that propose a plateau break, allowing the achievement of a greater total volume of repetitions (TV) and volume load (VL), are established as a *sine qua non* condition for strength gains and evolution of muscular architecture[3-6].

Programming models combining multiple physical valences have been the subject of discussions in the literature as an additional stimulus mechanism for muscle development. Although there is no consensus, it seems that the use of stretching strategies between strength sets would allow for greater VL, and therefore greater thickness gains in certain muscle groups[7,8]. Furthermore, this combination would be projected as a relevant strategy for reducing the total session time compared to conventional resistance training, that is, a time-efficient strategy[9].

According to Evangelista et al.[7] and Souza et al.[8], the addition of inter-set stretching, in addition to suppressing the time dedicated to stretching sessions, also appears to maximize myofibrillar adaptations[10], since stretching can regulate anabolic signaling through active and passive force sensors, therefore increasing the potential for strength gains and hypertrophy[11,12]. However, despite this understanding, the literature is still incipient in understanding the practical outcomes of such strategies, because, despite having a positive impact on the total session time, it is known that stretching exercises, when improperly planned in relation to their volume, can culminate in a reduction in VL[13]. Therefore, according to the current body of evidence, it seems to us that the responses to inter-set stretching remain inconclusive regarding the outcomes of TV and VL, since recent studies, such as the studies by Brigatto et al.[21] and Padilha et al.[20], observed negative impacts on such variables after the application of stretching. Therefore, for better decision-making, there is a need for further investigations.

Therefore, the primary objective of the present study was to compare the effects of applying 20 seconds of stretching of the muscles of the anterior chain of the lower limbs performed between sets of knee extension strength exercises, on TV and VL, in addition to the total physiological impact derived from training (training impulse - TRIMP) in the knee extension exercise. As a hypothesis, it is expected that due to the short stretching execution time, it will not affect the outcomes of TV, VL and TRIMP.

METHODS

Experimental Approach

This study followed the assumptions described in the STROBE-Statement guideline for randomized controlled cross-sectional study designs. The research was carried out from January to June 2024, and had a total duration of four months, following Resolution 466/2012 of the National Health Council, having been approved by the research ethics committee under no. (#1.220.339 - CAAE: 26916819.9.0000.5512). All participants obtained the necessary information about the study and had their questions answered. Those who accepted and were selected were given explanations about the risks inherent to the exercise, and then signed the free and informed consent form.

Sample

The population of this study consisted of practitioners in strength training, attending the gym of the Evangelical University of Goiás (UniEVANGELICA), males, aged between 18 and 30 years (young people and adults). They were recruited through a public call in the Physical Education course, and a sample of 11 individuals was randomly selected.

The inclusion criteria were: practicing strength training for at least 12 uninterrupted months, being familiar with the leg extension exercise and having the cognitive capacity to understand and perform the tests. The exclusion criteria adopted were: not having any significant bone, joint or ligament injury in the knee; not completing the proposed tests and using any type of anabolic steroids.

Study Design

Eleven male undergraduates (18 to 30 years old) were recruited and carried out 3 visits to the research laboratory. On the first visit, basic anthropometric procedures were performed, in addition to a maximum repetition (RM) test for one of the legs. The leg to be tested was randomized and defined by simple draw. On the second visit, after a 5-minute warm-up on a stationary bike, each subject underwent 4 sets of a knee extension exercise at an overload of 70% of 1RM (passive rest). On the last visit, after warming up, the subjects underwent the same 4 sets at 70% of 1RM, however, differing only by the stretching between sets (experimental moment).

The control procedures, without stretching and the experimental moment were randomized by simple draw. A time of 2 min was given between sets. To perform the stretching protocol, the entire anterior chain was considered (hip flexors, knee extensors and ankle extensors). The stretching time was 20 seconds under conditions of maximum pain perception, remaining at rest for 1 minute and 40 seconds. After each series, the Omni-res scale (perceived exertion scale - RPE) was used, as well as 20 minutes after the end of the session. All procedures were performed at the same time of day (morning) and with room temperature between 23 and 26º. Figure 1 shows the flow of participants entering and leaving.

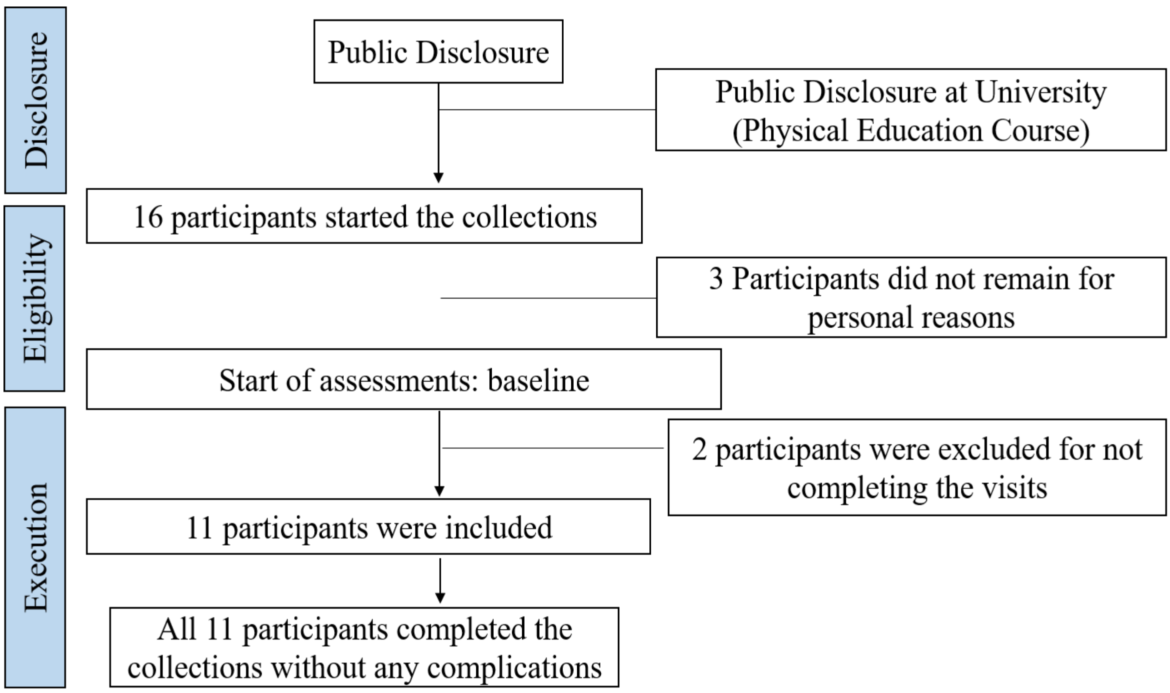

Figure 1. Input and output flow of study participants

Procedures

Anthropometric Procedures

Body height was measured with a stadiometer (SECA® GmbH, Hamburg, Germany) with the volunteer standing barefoot, with the ankles, calves, buttocks, scapula and head resting against the wall. The head position followed the Frankfurt plane and height was measured at the moment of air inspiration. Body mass was measured using an electronic scale (Toledo 2096 PP, São Bernardo do Campo (SP), Brazil) while the participants wore light clothing. All measurements followed the recommendations proposed by the International Society for Advancement of Kinanthropometry (ISAK).

Maximum Repetition Test (RM)

To determine the 1 RM test, the participants underwent a load progression and a maximum of three attempts with a five-minute interval between them. For the unilateral knee extension movement, the participants were seated on the extension chair with the knee flexed at 90º. The concentric phase consisted of raising the extension chair apparatus positioned on the ankle to an angle of 180º, aligning the ankle and knee. Attempts in which the participants were unable to establish the alignment position at maximum extension were not considered. Before the three attempts, the participants were underwent to a load progression that occurred as follows: a) standard warm-up with 12 to 15 repetitions, with only the weight corresponding to 50% of the estimated by the participant (; b) a series of six reps with 75% of the maximum load estimated by the volunteer, followed by3-minutes rest interval); c) a series of two reps with 85% of the estimated maximum load, followed by 5-min rest interval). After progression, actual 1RM attempts began. Verbal encouragement was provided for all strength measurements.

Stretching Procedure

The stretching procedure was carried out only for the experimental group. 20 seconds of static stretching were performed simultaneously for hip flexors, knee extensors and ankle extensors, between each series performed. After positioning on a unipedal support base, the stretching of the muscles of the anterior chain of the lower limb on the tested side occurred with external assistance from one of the evaluators, raising the limb to the maximum point of pain perception. Figure 2 shows the stretching positioning performed.

Figure 2. Stretch of the anterior chain

Note: the arrows indicate the positioning vector to achieve maximum anterior chain elongation.

OMINI-RES Scale

The OMNI-RES scale represented in Figure 3 was used to measure the RPE of each participant, using a perception scale from 0 to 10, where 0 means very easy and 10 means extremely difficult. The scale was applied at the end of each series, as well as 20 minutes after the end of the strength session. Participants were already familiar with the RPE scales, so familiarization was not required.

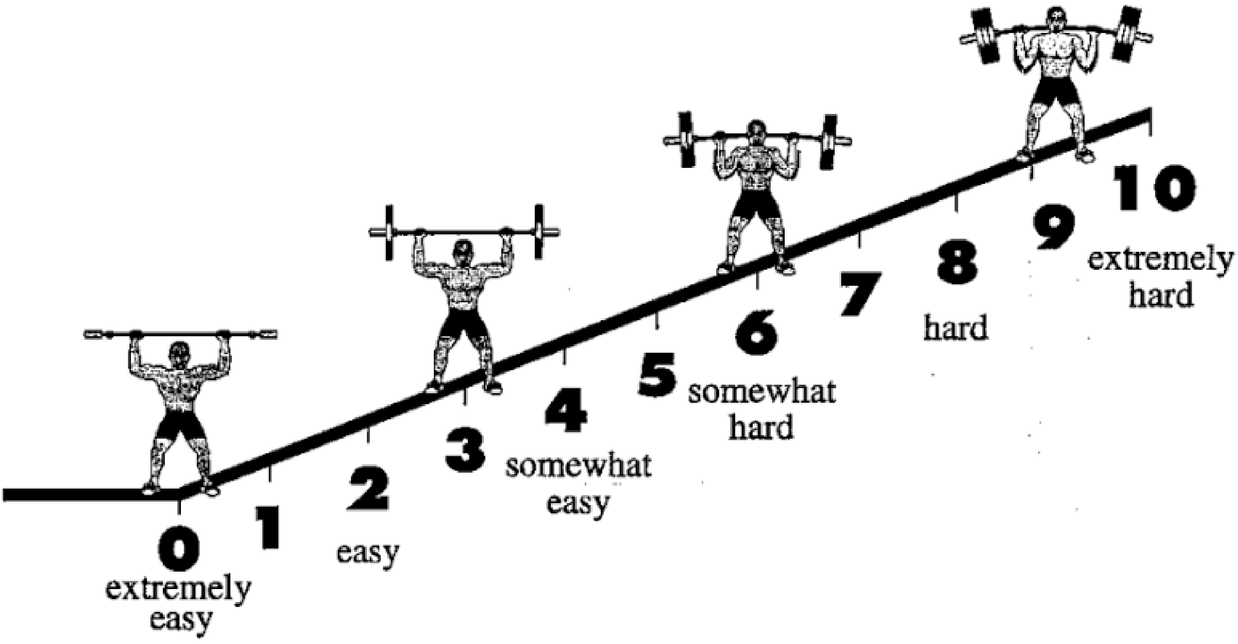

Figure 3. Representation of the OMINI-RES scale

Calculation of Volume Load and Training Impulse (TRIMP)

The VL was calculated based on the total work carried out in the four sets, using the following formula: total VL = [total number of repetitions × external load at 70% of 1RM (kg)], as suggested by Peterson et al.[14]. Only repetitions completed within the previously established required range of motion were counted. TRIMP was calculated from the product of VL (external load) x RPE (internal load - OMNI-res), according to Gardner et al.[15].

Randomization Procedure

During the second visit, a simple draw was made, where each participant drew a number from 1 to 2 from an envelope, where the number "1" meant control condition and the number "2" meant experimental condition. By exclusion, the number drawn would already indicate the next session to be performed. The same occurred to define the leg to perform the RM test, however, with the letter "D" representing the right leg and the letter "E" the left.

Data Analysis and Treatment

To avoid possible biases in the analysis, the data were collected by two different researchers associated with the project and the research group (D.P. and P.A). A third evaluator was responsible for the data analysis. The researcher responsible for the data analysis remained blind throughout the data collection process (group leader A.S).

Statistical Analysis

After analyzing the statistical assumptions, the sample characterization data, as well as the performance data, were described by mean and standard deviation (SD). The median was used for data groups with non-normal distribution. For comparison between sample groups for multiple series, a Kruskal-Wallis test was used. TV and VL were analyzed parametrically using a Student's t-test for independent samples. Finally, TRIMP was compared using a Mann-Whitney U test. All analyses considered a significance level of $p < 0.05$. The SPSS statistical package (version 20) was used for data analysis and the GraphPad Prism software (version 8.0.21) created the graphs.

RESULTS

Table 1 presents the anthropometric sample characterization and experience with the strength training modality.

Table 1. Sample characterization

	Age (years)	Height (cm)	Body mass (kg)	BMI (kg/m²)	Experience (months)
Mean	27.3	173.5	74.6	24.6	37.9
SD	8.2	8.8	16.2	3.5	11.9

Note: BMI = body mass index; SD = standard deviation of the mean.

Table 2. Strength performance for knee extension

	RM Performance (kg)	RM 70% (kg)
Mean	57.7	40.8
SD	17.1	12.0

Note: RM = maximum repetition; SD = standard deviation of the mean.

The previous analysis of the assumptions showed that series 1 to 4 for both groups did not demonstrate normality ($p < 0.05$), therefore, they were analyzed using non-parametric tests. However, the composite variables of TV and VL demonstrated normal behavior. Table 3 presents the performance per series and accumulated for both intervention groups, without and with stretching between series.

Table 3. Knee extension performance without and with stretching between sets

	Control				Experimental			
	Med	**Mean**	**SD**	**(CI$^{95\%}$)**	**Med**	**Mean**	**SD**	**(CI$^{95\%}$)**
Set 1	10.0	9.4	1.6	(8.3-10.4)	10.0	9.7	0.6	(9.2-10.1)
Set 2	9.0	8.9	1.4	(7.9-9.8)	10.0	9.1	1.4	(8.1-10.0)
Set 3	8.0	8.5	1.4	(7.5-9.5)	8.0	7.9	2.3	(6.3-9.4)
Set 4	7.0	7.5	1.9	(6.1-8.7)	8.0	7.2	2.5	(5.4-8.8)
TV	-	34.3	4.9	(30.9-37.5)	-	33.9	6.3	(29.7-38.1)
VL	-	1405.3	515.8	(1058-1751)	-	1367.0	454.0	(1061-1672)
TRIMP	-	10120.8	4319.4		-	9582.6	4478.5	

Note: Med = median; SD = standard deviation of the mean; CI$^{95\%}$ = confidence interval; TV = total volume of repetitions; VL = volume load; TRIMP = training impulse.

The Kruskal-Wallis test did not show significant differences between the intervention groups (p = 0.884; p = 0.564; p = 0.530; p = 0.947; respectively for series 1, 2, 3 and 4 between groups). The Student's t-test for independent samples did not show significant differences for the TV performed between intervention groups, assuming equality of variance (p = 0.881). For the VL analysis, the Student's t-test for independent samples also did not point out significant differences between sample groups, assuming equality of variance (p = 0.855).

When analyzing the assumptions for TRIMP (VL x OMNI-Res of the session), no normal distribution of data was observed (p = 0.003; p = 0.007, respectively for the intervention group without stretching and with stretching). Therefore, the Mann-Whitney test was used in the analysis, indicating no significant differences between sample groups (p = 0.182). Figure 4 shows TRIMP for both sample groups.

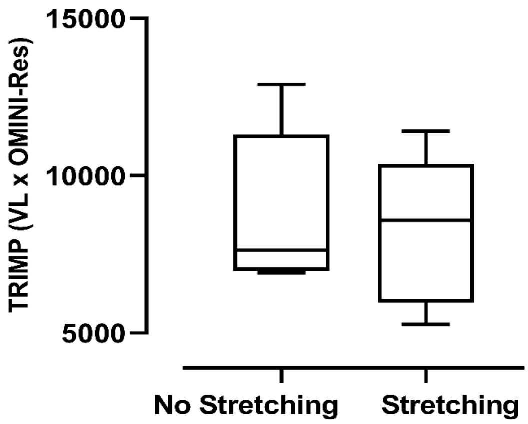

Figure 4. Representation of TRIMP among the different proposed interventions

When analyzing the OMNI-Res scales by series, the nonparametric test for "K" independent samples did not demonstrate significant differences between work groups (p = 0.659; p = 0.100; p = 0.311; p = 0.635, respectively for series 1, 2, 3 and 4). Figure 5 presents the effort results for both treatments.

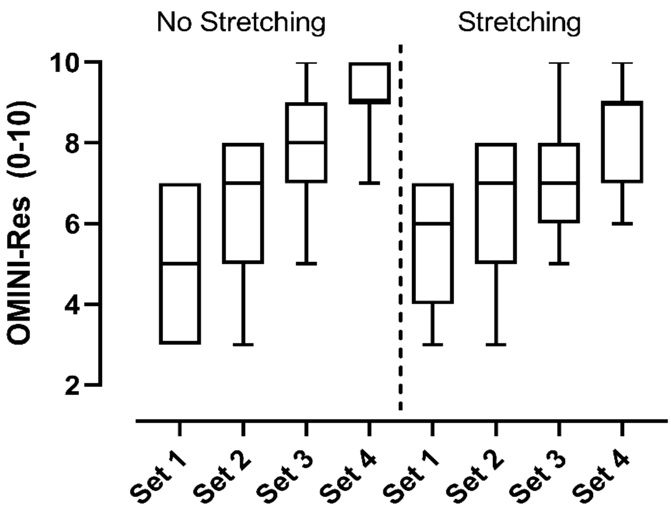

Figure 5. Effort responses to treatments, without and with stretching between sets

DISCUSSION

Our primary objective was to evaluate the effects of applying 20 seconds of static stretching on the anterior chain between strength sets, on TV, VL, in addition to TRIMP in the knee extension exercise. As the main finding, our outcomes were not impacted by the static stretching strategy between sets, therefore, accepting the initial hypothesis.

Historically, there is a consistent evidence base indicating that performing static stretching before or during a strength endurance task can reduce both repetition volume and explosive strength development[16-18]. This immediate decrease in the ability to generate muscle force after static stretching can be attributed to mechanical or neural factors, such as reduced activation of motor units and changes in the length-tension relationship of muscle fibers[16,18].

Furthermore, we found studies in the literature on stretching prior to strength exercises, reducing strength and power endurance performance, and directly impacting TV[20]. However, there is a consensus that such results are dependent on the TV of stretching performed, negatively affecting the force production of the stretched muscle group[18]. The literature also reports that interventions with longer stretching durations can increase the magnitude of the acute reduction in strength endurance performance[18], potentially affecting the VL. Understanding this, our protocol was designed to overcome such limitations and our findings align with part of the literature, not observing significant reductions on TV and VL when including the inter-set static stretching strategy[8]. The same results seem to replicate up to an intervention time of 30 seconds, as suggested by Evangelista et al.[7]. Therefore, it seems acceptable to us to include this strategy until that time, that is, up to 30 seconds, so that there is no loss in the total work carried out.

Similar to our study, Padilha et al.[21] used inter-set quadriceps stretching for the knee extension movement and showed reductions in total work with this protocol (11823 ± 1735 Joules), compared to control training with 40 s of recovery (13976 ± 2378 Joules) and traditional strength training with 120 s of recovery (15511 ± 2251 Joules). However, the inter-set stretching time performed in this study[21] was 25 seconds, which conflicted with our results and with previous statements. The possible explanation may be related to the way of measuring strength, through isokinetic equipment, which differs substantially in the sensitivity of the results. Thus, the results produced in the study by Padilha et al.[21], were computed by the concentric contraction of the anterior muscles, such as the posterior thigh, which can produce greater muscle wear, thus reverberating in a reduction in muscular performance. It is worth mentioning that this exercise type (isokinetic) is not a natural muscle activity.

The research carried out by Brigatto et al.[22] shows us that when the stretching time was increased (45 sec), the inter-set stretching strategy reduced the total load lifted for the stretching group (without stretching: 979 ± 251 Kgf vs. stretching group: 687 ± 313 Kgf), in addition to reducing the total number of repetitions performed (without stretching: 32.8 ± 6.5 reps vs. with stretching: 21.9 ± 7.6 reps)[22]. Additionally, the authors showed a reduction in TRIMP for the inter-set stretching group (215 ± 74 Ua vs. 279 ± 67 Ua, respectively for stretching and control conditions), which also differed from our study. This reduction was mainly justified by the lower total work performed in the stretching group (Δ = 29.9%)

and not by the internal load response. It is worth noting that the exercise performed and the target group to be stimulated with stretching differed from our study (pectoralis major), which makes them methodologically distinct and difficult to compare.

A difference in our study was the application of stretching across the entire anterior chain (hip flexors, knee extensors and ankle extensors). We conceived this perspective since the rectus femoris muscle exhibits a connection between two different joints. Among the studies mentioned to date, Padrilha et al.[21] used the same stretching strategy, however, without indication of concomitant stretching of hip flexors, only the apparent stabilization of the same in a neutral position. Our participants were instructed and monitored to project the hip as much as possible to a posteroanterior vector (Figure 1), performing the stretch to the limit of pain. Other studies performed isolated stretches on the target muscles, which would make direct comparisons difficult. Thus, we showed that the application of the stretching strategy in adjacent joints simultaneously with the stretching of the target joint did not impair strength endurance performance.

Finally, the approach of including an additional physical valence in the strength training program ratifies the practical scenario of seeking engagement in programs that are optimized[9,23]. Time is a barrier to exercise adherence[24], therefore, optimization greatly facilitates the inclusion of practitioners in the strength training modality. Thus, from a time-efficient perspective, our study indicates that static stretching of the entire anterior chain of the lower limb, simultaneously, can be used as a complementary strategy without negatively impacting VL and without increasing the TRIMP of the session.

CONCLUSION

Twenty seconds of stretching of the muscles of the anterior chain of the lower limbs performed between sets of knee extensor muscle strength did not influence the TV of sets, the VL, the OMNI-Res and the TRIMP of the session. The results found in the present study encourage the use of the inter-set stretching strategy, since the inclusion of another physical capacity together with strength training could complement and make training viable from a time-efficient perspective.

Acknowledgments: We would like to thank the State University of Goiás and the Graduate Program in Environment and Society for the resources from Pró-Programas UEG/2023.

Author Contributions: JPS, DPL, PAI, RASS, DFF, RDB, ACAR, DAC, LDFM contributed to the initial drafting and the collection process, RALM, MMS, ASSF their contribution was intended for the final analysis of the data, review of the manuscript and proofreading of the drafting in English.

Financial Support: We do not declare any type of external financial or third-party resource or support for the construction of this research.

Conflict of Interest: We declare no conflict of interest.

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