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Stretching effects: High-intensity & moderate-duration vs. Low-intensity & long-duration

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Abstract:	This study examined whether a high-intensity, moderate-duration bout of stretching would produce the same acute effects as a low-intensity, long-duration bout of stretching. Seventeen volunteers performed two knee-flexor stretching protocols: a high-intensity (i.e., 100% of maximum tolerable passive torque) stretch with a moderate-duration (243.5±69.5-s); and a low-intensity (50% of tolerable passive torque) stretch with long-duration (900-s). Passive torque at a given sub-maximal angle, peak passive torque, maximal range of motion (ROM), and muscle activity were assessed before and 1, 30 and 60 mins after each stretching protocol. The maximal ROM and tolerable passive torque increased for all time points following the high-intensity stretching ($p<0.05$), but not after the low-intensity protocol ($p>0.05$). 1 min post stretching, the passive torque decreased in both protocols, but to a greater extent in the low-intensity protocol. 30 mins post test, torque returned to baseline for the low-intensity protocol, and had increased above the baseline for the high-intensity stretching. Conclusions: 1) A high-intensity stretching increases the maximal ROM and peak passive torque compared to the low-intensity stretching; 2) low-intensity, long-duration stretching is the best way to acutely decrease passive torque; and 3) a high-intensity, moderate-duration stretch increases passive torque above the baseline 30 mins after stretching.

Abstract:

This study examined whether a high-intensity, moderate-duration bout of stretching would produce the same acute effects as a low-intensity, long-duration bout of stretching. Seventeen volunteers performed two knee-flexor stretching protocols: a high-intensity stretch (~~i.e.,~~i.e. 100% of maximum tolerable passive torque) ~~stretch~~ with a moderate~~-~~ duration (243.5±69.5-s); and a low-intensity stretch (50% of tolerable passive torque) ~~stretch~~ with a long ~~-~~duration (900-s). Passive torque at a given sub-maximal angle, peak passive torque, maximal range of motion (ROM), and muscle activity were assessed before and ~~1, 30 and 60 mins~~ after each stretching protocol (at intervals of 1, 30 and 60 mins). The maximal ROM and tolerable passive torque increased for all time points following the high-intensity stretching (p<0.05), but not after the low-intensity protocol (p>0.05). ~~1 min~~One minute post~~-~~ ~~-~~stretching, the passive torque decreased in both protocols, but to a greater extent in the low-intensity protocol. ~~30~~ Thirty minute~~s~~s post~~-~~ ~~-~~test, torque returned to baseline for the low-intensity protocol~~,~~ and had increased above the baseline for the high-intensity ~~stretching~~stretches. Conclusions: 1) ~~A~~ H~~h~~igh-intensity stretching increases the maximal ROM and peak passive torque compared to ~~the~~ low-intensity stretching; 2) low-intensity, long-duration stretching is the best way to acutely decrease passive torque; and 3)~~ a~~ high-intensity, moderate-duration stretching increases passive torque above the baseline 30 mins after stretching.

Keywords: flexibility, hamstring, knee, passive torque-angle, stiffness

Introduction

The increase of joint range of motion (ROM) and decrease of resistance to stretch are often goals of stretching in sports medicine and exercise [10, 13, 15]. The acute decrement of joint passive torque after static stretching has been shown to be transient in time [15, 17, 23]. For instance, Magnusson et al. (1996) reported that the decrement in passive torque after five 90-second static stretching repetitions recovered within 1 hour [15]. Ryan et al. (2008) observed that passive torque in ankle dorsiflexion returned to baseline values within: a) 10 min after 2 min of static stretching, and b) 20 min after a 4- or 8-min stretch [23]. Mizuno et al. (2013) observed that passive ankle torque returned to baseline within 15 minutes, and the maximal dorsiflexion ROM was still increased for 60 mins after a 5 min bout of static stretching of the calf muscles [18]. Mizuno et al. (2013) recently observed that passive ankle torque recovery occurred within 10 min following ~~5~~ five ~~times of~~ 1-min bouts of static stretching [14]. However, these previous studies did not compare different stretching intensities; instead, they studied different stretching durations. To our knowledge, only one previous study has examined stretching intensity alone [28]. It ~~was~~ only observed the effects on maximal ROM and not on passive torque. They concluded that a higher intensity bout of stretching is advantageous for maximal ROM gains. Thus, it remains unknown if a higher stretch intensity would potentiate the passive torque decrements.

Others studies have examined stretching intensity and duration together, by comparing a high-intensity, short-duration static stretching bout with a low-intensity, long-duration bout [4, 13, 16, 19, 26, 27]. However, there were inconsistencies in their results regarding changes in joint mechanical properties. For instance, some studies support the use of high intensity, short duration stretching [13, 16, 27], whereas other studies support the use of low intensity, long duration stretching [4, 19, 26]. Thus~~,~~ the biomechanical effects of varying stretching duration and intensity are not clear. Some sources, such as the TERT formula (i.e. ROM changes = stretch intensity × duration × frequency) proposed by Jacobs & Sciascia (2011) [10], suggest stretching duration and intensity produce a directly equivalent effect on range of motion.~~ ~~ That is, equivalent lasting gains in range of motion can be obtained by either increasing stretching duration or intensity. It is known that both stretching intensity and duration are shown to increase the degree of tissue relaxation during stretching [15, 19, 23]. Thus~~,~~ both could contribute to passive torque decrease and increase in maximal ROM following a bout of stretching. This mechanical effect is thought to be the major factor for these acute effects [15], although some neural adaptations (e.g.~~,~~ h-reflex decrease) may also contribute to these responses [3]. Thus, according to the TERT formula, a low intensity, long duration versus a high intensity, short duration should induce similar results on maximal ROM and resistance to stretch. However, no previous study has examined ~~if~~ whether the TERT formula is valid for all range of stretching intensities, or if it i~~’~~s only valid for a range above a certain stretching intensity threshold. In addition, previous studies have only tested ~~clinical~~ populations ~~(i.e., mostly~~ with muscle ~~contracture~~tightness (i.e. low flexibility), and did not test the effects on joint passive torque-angle properties [4, 13, 26].

The objective of this study was to determine the acute effects within one hour after stretching with different intensities and durations on the resistance to stretching and maximal ROM. For this purpose, two stretching protocols were performed by inversely changing stretch intensity and stretch duration (~~i.e.,~~i.e. high stretch intensity with moderate stretch duration vs. low stretch intensity with long stretch duration). Based on the TERT formula [10], it was hypothesized that the torque-angle response would be similar between protocols.

Methods

Participants

Seventeen men (age: 22.1±2.7 years; height: 1.77±0.07m; weight: 70.5±7.5Kg; leg length: 37.5±1.6 cm) were recruited from a university population to participate in this study. All participants gave their written informed consent. Sample size was calculated based on the results of a previous reliability study [5]. Only male participants were recruited in order to eliminate any potential uncertainty due to gender difference [9, 12]. A low active knee extension flexibility (less than 160º, considering that 180º corresponds to full knee extension) was considered an inclusion criteria; and history of lower limb muscles and joint injuries as exclusion criteria. This study meets the ethical standards of the local Ethics Committee and the International Journal of Sports Medicine [6].

Procedures

A passive knee extension test for the right lower limb was used to observe the time course effect by two stretching protocols (~~i.e.,~~i.e. high intensity with moderate duration vs. low intensity with long duration) on knee extension maximal ROM, peak passive torque, passive torque at a given angle, and muscle activity (Fig. 1) [4]. Participants visited the laboratory on three occasions. During the first visit, a familiarization session was performed. In the next two sessions, the two stretching protocols were performed with a balanced order (to ensure that session order had no influence) and an interval time of 24 hours between protocols. ~~In the beginning~~ At the start of each session, the participant's skin was prepared for sEMG, reflective markers were placed, and the right ankle was immobilized in a static position with elastic tape (average ‘~~‘~~tibial internal tuberosity-internal malleolus-1st metatarsal head’~~’~~ angle of 140º). No warm-up or stretching exercises were performed before the stretching protocols. For the knee extension protocol, participants lay in a supine position with the right hip flexed at 90° and left lower limb stabilized in a neutral position (Fig. 1-A). The testing thigh (i.e. right, see Fig. 1) was fastened with an equal clamping force in the two sessions (≈78.5 N), to ensure that no transversal forces applied to the tissues would affect the torque measurement [5]. The leg was at 90° to the thigh in the starting test position. ~~.~~The angular velocity of all repetitions was set at 2°/s.

Stretch intensity was considered as a percentage of the maximum tolerated joint passive torque (PT). The maximal ROM criterion was set to the point immediately before the onset of pain. Two combinations of stretch intensity and stretch duration were studied (Fig. 1-B): 1) 50% of PT and a duration of 900 sec (LILD: low intensity, long duration), and 2) 100% of PT with a maximum number of 90-sec repetitions without rest intervals between repetitions (HIMD: high intensity, moderate duration). In order to ensure that the maximum tolerable torque was achieved during the stretching bout, a maximum number of repetitions with no rest intervals (NRI) between repetitions were performed on the HIMD protocol. Thus~~,~~ after every 90~~ s~~ sec of stretching, participants were asked if they could stretch further with no pain. If they agreed, the knee angle was increased to a new ROM. If not, the stretching exercise was stopped (see example in Fig. 1-B). ~~Thus~~As a result, the number of 90-sec repetitions without rest intervals varied across participants due to their different degrees of stretching tolerance. This protocol was chosen since we previously observed that non-resting across repetitions induces greater ROM and peak torque increases than a conventional rest interval protocol [6]. For the LILD protocol, a preliminary repetition performed to the maximal ROM was performed 5 min before the stretching protocol to determine the knee angle that corresponded to 50% of the peak torque. After both stretching protocols, a repetition to the maximal ROM was performed at intervals of ~~at~~ 1, 30, and 60 min after stretching to observe the torque-angle time course effects. Participants performed normal tasks of daily living~~,~~ but without ~~doing~~ any kind of stretching or other type of exercise between the tests. At the end of each protocol session, three repetitions of 5-sec maximal voluntary isometric muscle contractions were performed for both knee extension and flexion, for the purposes of sEMG signal normalization.

[place Figure 1 here]

The knee passive torque-angle was assessed through a 2-D kinematic analysis and is a measurement of resistance to stretch described elsewhere [5]. A high score for test-retest reliability was previously observed using this method on maximal ROM [ICC=0.81 (0.59-0.91)], maximal tolerable passive torque [ICC=0.90 (0.77-0.96)], and passive torque at a given angle~~-~~ [ICC=0.87 (0.67-0.95)] [4].

121 Briefly, the knee angle was assessed using a digital camera (JVC, GR-DVL9800U) placed parallel to the sagittal plane and operating at 50 Hz. Reflective markers were placed over the medial femoral condyle and medial malleolus of the right lower limb as well as the greater trochanter of the left femur. To determine the knee angle, the Ariel Performance Analysis System® was used. The resistance to passive knee extension force was measured at 50 Hz with a force sensor (Platform Load Cell 1042, Sensor Techniques Ltd, UK) incorporated into a device that was fitted to the dynamometer (Biodex System 3 Research, Shirley, NY, USA) to mobilize the knee (Fig. 1). Passive torque was obtained by multiplying passive resistance to knee extension (in Newtons) by the leg length (in meters), and was corrected to gravity data using a cosine function [5].

130 The average amplitude of the surface electromyography (sEMG) was measured in the semitendinosus (ST) and vastus medialis (VM). The average amplitude of the EMG signal was measured during a window of 100 mS. Procedures were performed according to SENIAM guidelines [8]. Surface bipolar electrodes (Plux-Portugal, gain of 1000) were placed 20-mm center-to-center over the mid-portion of each muscle. The ground electrode was fixed over the left patella. The sEMG signals were amplified (Input Impedance > 100MΩ; CMRR=110dB) and A/D converted (MP100 – Biopac™ Systems, 16 bits) with a sample rate of 1000 Hz.

137 ***Data processing***

138 The data was processed similar to Freitas et al. (2013) [5]. Briefly, all data were synchronized and recorded using the BIOPAC MP100 Acquisition System (Santa Barbara, USA), with the exception of the knee angle data, which was obtained by digital camera. A manual trigger was sent to the A/D converter to synchronize the angle data. The data was processed by an automatic routine using MATLAB® v12.0 software (The Mathworks Inc., Natick, Massachusetts, USA). The routine first filtered the force from the sensor using a Butterworth second-order low-pass filter (10 Hz). Then, passive knee torque was calculated and gravity-corrected.

145 To ensure the quality of the sEMG signals, the International Society of Electrophysiology

and Kinesiology norms for EMG signal inspection were followed [8]. T~~hen, t~~hey were then digitally band-pass filtered (25-490 Hz), full-wave rectified, and low-pass filtered with a Butterworth fourth-order and a frequency cut-off of 12 Hz. The sEMG signals were normalized to the maximal sEMG obtained in the MVIC for knee extension and flexion, and reported as a percentage (%) of the MVIC.

Statistical analysis

Data was analyzed using IBM SPSS Statistics v20 (SPSS Inc., Chicago, IL). Normal distribution was assessed by Shapiro-Wilk test. All variables were first normalized to the baseline value (~~i.e.,~~i.e. first repetition). The peak torque, maximal ROM and passive torque variables were used for analysis. The average ROM and peak torque of all HIMD repetitions was determined in order to calculate the average intensity performed during ~~the~~ stretching. The passive torque was compared at ten given knee angles, which were determined based on the percentiles of maximal ROM performed by each participant in the first repetition (~~i.e.,~~i.e. baseline). A two-way ANOVA [protocols (HIMD, LILD) × torque percentile (10, 20, 30, 40, 50, 60, 80, 90, 100)] was performed for the absolute passive torque in the first repetition of both protocols, in order to confirm that participants were tested in the same initial condition. A two-way ANOVA [protocols (HIMD, LILD) × time (pre-, 1-min post, 30-min post, 60-min post)] was performed for maximal ROM, peak torque and sEMG. A two-way ANOVA [time (pre-, 1-min post, 30-min post, 60-min post) × torque percentile (10, 20, 30, 40, 50, 60, 80, 90, 100)] was performed for the analysis of passive torque in each stretching protocol. These ANOVAs were followed by a post-hoc analysis with Bonferroni test when appropriate. Paired t-tests were performed to compare the passive torque in each percentile of ROM between protocols in the same testing time. Statistical significance was set at 0.05 for all tests.

RESULTS

sEMG. No significant effect for time (p>0.09) or protocol (p>0.62) was found on sEMG in either muscle. The muscle activity of both ST and VM muscles was lower than 3% during the HIMD stretching, and lower than 1.5% during the LILD protocol. At the testing ~~moments~~ intervals before and after stretching (1, 30, and 60 min), the average sEMG was below 1.6% in both muscles.

The number of repetitions in the HIMD protocol varied between subjects (n=8 for 2NRI, n= 6 for 3NRI, n=3 for 4NRI). ~~Thus,~~T ~~t~~he stretch duration for HIMD was thus 243.5±69.5-s. The average intensity during the HIMD protocol was 109.2±10.4% of initial peak torque and 107.3±7.6% of initial maximal ROM. Neither a significant effect of protocols ($p=0.12$) nor a protocols × torque percentile interaction ($p=0.486$) was found for the torque percentiles on the first repetition; however, a significant effect was found for the torque percentile ($p<0.001$). A typical example of the torque-ROM curves before and at 1, 30 and 60 min after the two stretching interventions is depicted in Figure 2-A.

The passive torque at the baseline percentiles before and at 1, 30 and 60 min following the two stretching protocols is depicted in Figure 2-B. A significant interaction (time × percentile) was observed for passive torque in both HIMD ($p<0.001$) and LILD ($p=0.003$) protocols. A significant time effect was observed for passive torque in both HIMD ($p<0.001$) and LILD ($p=0.028$) stretching protocols. A significant percentile effect was observed for passive torque in both HIMD ($p=0.01$) and LILD ($p<0.001$) stretching protocols.

[place Figure 2 here]

The maximal ROM and peak torque before and at 1, 30 and 60 min following the stretching for both protocols are depicted in Figure 3. A significant interaction (protocol × time) was observed for maximal ROM ($p=0.005$) and peak torque ($p=0.009$). A significant effect for time was found for maximal ROM ($p<0.001$) and peak torque ($p<0.001$). A significant effect for protocol was seen for maximal ROM ($p=0.003$) and peak torque ($p=0.025$).

[place Figure 3 here]

DISCUSSION

The present study compared two stretching protocols with a reverse proportion of stretch intensity and duration (~~i.e.,~~i.e. high intensity with moderate duration vs. low intensity with long duration). The sEMG was lower than 3% for both protocols; ~~thus~~for this reason, we assumed that passive torque measurements were not affected by muscle activity [15]. Also, there was no significant difference in passive torque and maximal ROM of the first repetition between protocols, suggesting that the participants were in the same condition at the beginning of the stretching interventions. The intensity achieved by the HIMD was higher than the initial (~~i.e.,~~i.e. compared to the first repetition), and the stretch duration was lower due to the lower number of 90-sec repetitions. Consequently, stretch intensity (peak torque: 109.2±10.4% vs 50%; ROM: 107.3±7.6% vs 71.9±4.2%) and duration (243.5±69.5 vs. 900-sec) were applied in an inverse mode among protocols.

The stretching protocols produced different responses in torque and angle one hour after stretching. An increase of peak passive torque and maximal ROM was observed only in HIMD, for all ~~moments~~ tests at intervals ~~tested~~ after stretch (Fig. 3). No significant increases were observed for LILD, despite the longer stretch duration. This indicates that in order to increase the maximum tolerable torque and ROM, the stretch intensity should be between 50% of the tolerable torque and the maximal tolerable torque ~~[21]~~, independently of the stretch duration, since a lower relative physical stress may be insufficient to induce a biological response [21]. The stretching intensity threshold at which the maximal ROM acutely increases should be examined in a future study. This stretching threshold should be considered in the TERT formula [10], which indicates that stretch duration and intensity produce a directly equivalent effect on ROM (i.e. meaning that increasing intensity or duration in a stretch will lead to an increase of maximal ROM). Such a formula may only be valid for a range of stretch intensities above an intensity threshold that is higher than 50%

of the tolerable torque ~~[21]~~. Thus~~,~~ such intensity threshold should be determined. On the other hand, the present results support the studies that suggest a higher stretching intensity may increase maximal ROM [13, 16, 27]. In addition, the peak torque-angle outcomes with the HIMD protocol still increased at 30 and 60 min after stretching despite the fact that passive torque returned to baseline values. This result is in accordance with previous studies [17, ~~-~~18]. We think that this is due to an acute increase in tolerance to stretch ~~-~~[15, 18~~],~~], which only occurs at a certain degree of tissues lengthening; however, we do not know if this adaptation is due to either mechanical or neural mechanisms.

Regarding the effects of stretching on the torque-angle curve, a different response was observed post-stretching between protocols. Both stretching protocols decreased the passive torque 1 min after stretching; however, a greater torque decline was observed for LILD in the initial portion of the knee ROM. This suggests that stretch duration provides a more acute torque decline than stretching intensity. Again, this suggests the importance of duration for decreasing the resistance to stretch in the TERT formula [10]. We think that this occurred due to the tissues stress relaxation phenomenon and the tissues viscoelastic response, ~~that~~ which are dependent on the time under stretching [16, 23]. Both factors are favorable ~~to~~ for ~~the~~ connective tissue remodeling [16]. Moreover, at 30 mins post~~-~~stretching, an increase of passive torque above the baseline was observed for the HIMD in the initial torque-angle curve range, but not for LILD. The increased passive torque for HIMD was still observed 60 mins after stretching, and was significantly different from the LILD passive torque. These results were unexpected, and to our knowledge this is the first study to report a passive torque increase after high-intensity stretching. Mizuno et al. (2013) found a similar response for stiffness (~~i.e.,~~i.e. slope of the torque-angle curve) 30 mins after static stretching of the calf muscles with five repetitions of 1 min each (see Fig. 4 of Mizuno et al.) [18]. However, they did not report a statistical difference. This result may have occurred because they used a rest interval stretching protocol, and thus produced a lower stretching intensity. We have previously observed that non-resting between repetitions induces a higher ROM and peak torque than static stretching with rest between repetitions [6]. In the present study, no resting was performed between the 90-sec repetitions for the HIMD, and consequently a higher intensity was achieved. ~~Thus, we~~ We therefore suspect that the higher intensity causes the passive torque increase.

The mechanism underlying the passive torque increase 30-60 minutes after the HIMD is unknown. We speculate four possible situations. Recently, Schleip et al. (2012) reported an increase of water content in mice lumbodorsal fascia above baseline values after high-intensity stretching ~~-~~[24]. ~~Thus~~It~~, it~~ is thus possible that a high-intensity stretch might induce overcompensation in the water content of the connective tissue being stretched, since the extracellular matrix is largely responsible for the viscoelastic characteristics of connective tissue [14]. Thus, joint passive torque might have increased as a consequence. A second hypothesis is related to muscle damage. Previous studies suggest that static stretching induces more relative deformation of muscle components than of the tendon among repetitions [1, 2, 22]. Thus, a higher-intensity stretch might have induced some damage in the muscle component, since there is some evidence suggesting that static stretching induces muscle damage [26]. In addition, it is known that eccentric muscle contractions induce a high muscle strain; ~~thus,~~ comparisons can thus be made between the eccentric contractions and a high intensity bout of stretching. Whitehead and colleagues (2003) found that passive tension of the cat's gastrocnemius muscle increased above baseline values 40 min after eccentric contractions [29]. We do not know if the NRI stretching protocol overstretches the muscle fibers and consequently produces structural damage to the fibers' membranes. If such a situation does occur, it might increase intracellular calcium concentration and thus increased tension in the muscle. The third hypothesis can be related to an increase of muscle tone as a consequence of higher reflex activity; however, it has been shown that reflex activity decreases after static stretching [4], and in addition no differences were observed in the muscle sEMG baseline values between testing ~~moments~~intervals. Hence, we assume that neural factors had no influence on the passive torque increase. Finally, the fourth hypothesis relates to the mechanical effects in the muscle-tendon complex; however, the results of previous studies on the immediate acute changes in tendon stiffness, fascicles length, and fascicles angle after the static stretch are controversial [11, 18, 20]; ~~but~~ however, it should be considered that these studies were performed on the ankle and not the knee.

This study had some limitations. The stretching intensity in the HIMD protocol was progressive during ~~the~~ stretching, and not constant (~~i.e.,~~i.e. constant angle). Thus~~,~~ the sEMG may not have been sensitive enough to detect changes in the muscle reflex activity after intense stretching. A future study ~~may~~ might examine this issue. Furthermore, the positions of the pelvis bones were not controlled during the tests; however, there were no significant changes in the hip reflective marker. This issue also should be examined in the future, since bone position affects muscle-tendon unit length, which in turn affects torque measurement.

In conclusion, it was observed that the time course of the joint torque-angle response after stretching differs between a high-intensity, moderate-duration stretch and a low-intensity, long-duration stretch. The increase in peak torque and maximal ROM was observed for 60 min after stretching for the higher-intensity stretch. On the other hand, the protocol with a longer duration induced a more acute decrease in passive torque. Thus~~,~~ stretch intensity was seen as more important for ROM increase, whereas duration appears to be more important for acute passive torque decline. In addition, the stretching with the highest intensity increased the passive torque above the baseline 30 and 60 mins after the stretch. Future studies should investigate the long-term effects of stretching with different intensities and durations.

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Figures Legend

Figure 1. (A) Experimental passive knee extension setup with the subject in the starting position, with the right hip flexed at 90° and left lower limb stabilized in a neutral position (Reprinted with permission from Freitas et al., 2013. © Institute of Physics and Engineering in Medicine. Reproduced with permission of IOP Publishing. All rights reserved); (B) Example for one participant of stretching protocol with high intensity and moderate duration (above) and with a low intensity and long duration (be~~l~~low).

Note: In figure 1-A, the clamping force to fixate the right thigh was measured.

Figure 2. (A) Typical example for one participant of a passive torque-ROM response; (B) absolute; and (C) relative (~~i.e.,~~i.e. normalized to baseline values) changes for all participants of the passive torque at 1, 30, and 60 min after the high-intensity and moderate-duration stretching protocol (HIMD) and the low-intensity and long-duration protocol (LILD).

Note: 1) X-axis is the % of maximal ROM obtained in the first repetition (~~i.e.,~~i.e. pre-condition); 2) error bars are not shown in Fig. 2-B for better image legibility.

* – Statistical difference from baseline condition ($p<0.05$).

– Statistical difference between protocols for the same percentage of ROM ($p<0.05$).

Figure 3.~~-~~ (A) Absolute and (B) relative values of maximal range of motion (left) and passive peak torque (right) before and at 1, 30 and 60 min after the two stretching protocols.

Values are normalized to the baseline (~~i.e.,~~i.e. first repetition) condition.

* – Statistical difference from baseline condition ($p<0.05$).

391 # – Statistical difference between protocols ($p<0.05$).

Fig 3

For clarity, I suggest that the author replace the term “Moments” (2x) with “Intervals” on the X-axis of the two charts (below) in the figure.

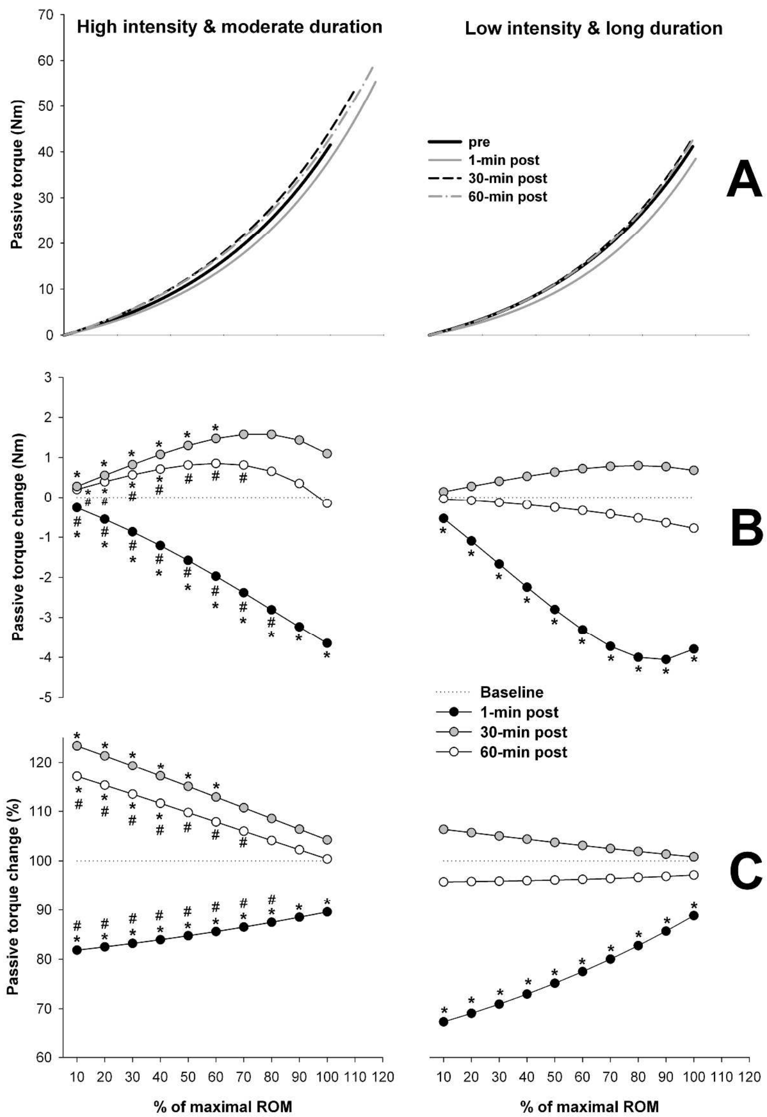

Fig. 2 (A) Typical example for one participant of a passive torque-ROM response; (B) absolute; and (C) relative (i.e., normalized to baseline values) changes for all participants of the passive torque at 1, 30, and 60 min after the high-intensity and moderate-duration stretching protocol (HIMD) and the low-intensity and long-duration protocol (LILD).

Note: 1) X-axis is the % of maximal ROM obtained in the first repetition (i.e., pre condition); 2) error bars are not shown in Fig. 2-B for better image legibility.

* – Statistical difference from baseline condition ($p<0.05$).

– Statistical difference between protocols for the same percentage of ROM ($p<0.05$).

299x447mm (300 x 300 DPI)

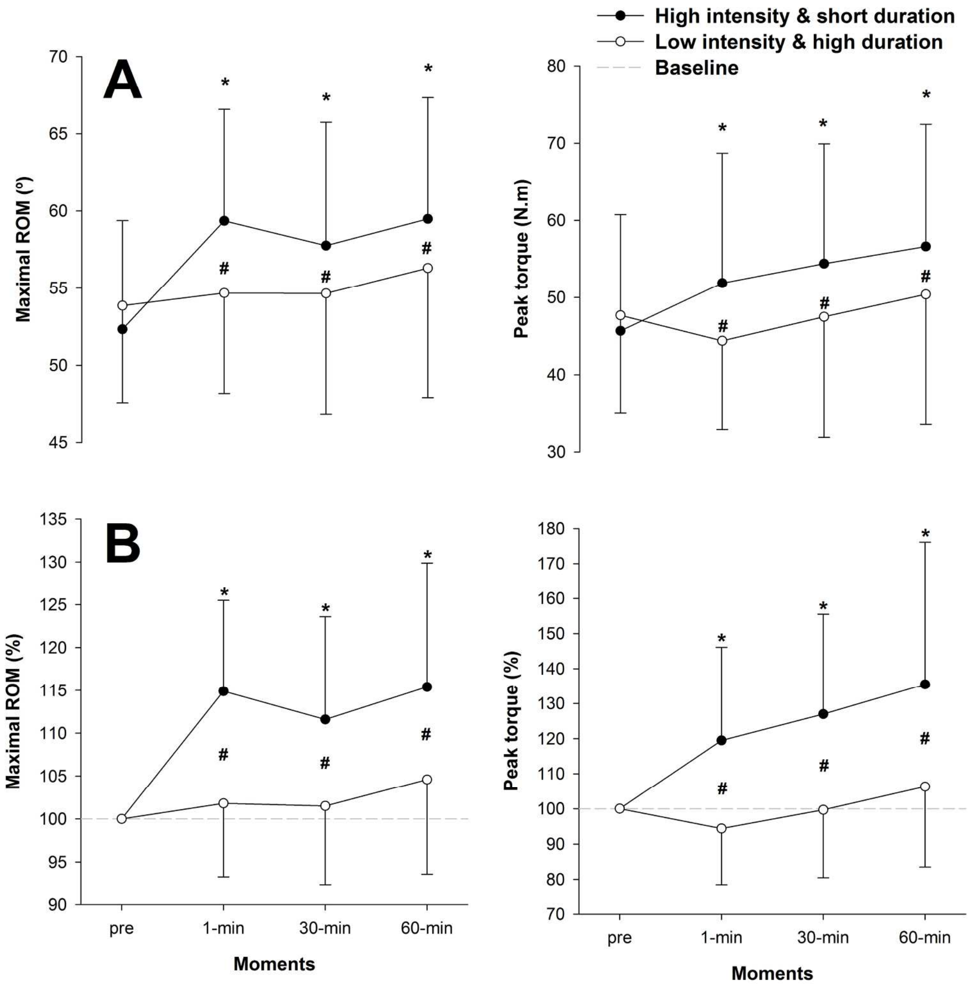

Fig. 3 (A) Absolute and (B) relative values of maximal range of motion (left) and passive peak torque (right) before and at 1, 30 and 60 min after the two stretching protocols.
Values are normalized to the baseline (i.e., first repetition) condition.
* – Statistical difference from baseline condition ($p<0.05$).
# – Statistical difference between protocols ($p<0.05$).

207x207mm (300 x 300 DPI)