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Research article

Participant and Researcher Perceptions of Stretching Intensity and Muscle Tension in A Hamstrings and Shoulder Stretch in Healthy Young Adults

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Abstract

Stretching research and practice relies heavily on internal and clinical perceptions of stretching sensation to prescribe intensity due to the lack of equipment required. No research has assessed the relationship between internal and external perceptions of stretch intensity. The purpose of this study was to assess the relationship between participants' stretch sensation and researchers' perception of muscle tension in two passive stretches; supine hip flexion and shoulder extension. Training status and stretching experience were considered with the 18 young adult participants. Joint angles at which participants signaled initial stretch sensation and maximum tolerable stretch for each protocol were recorded by a secondary researcher. The blinded primary researcher recorded joint angles where initial tension and maximum tension were perceived as they executed passive stretching of the participant. While there was evidence of greater hip flexion ROM for women, athletes, participants with stretching experience, as well as with stretching to maximum versus initial point of discomfort, there were no significant differences between the participants and researcher's measurements at initial or maximum endpoints, however correlation and agreement between participant and researcher perceptions were variable. There was an overall large magnitude (eta^2 = 0.794), non-significant difference (p = 0.06) with researcher maximum (108.39° ± 17.22) hip flexion measurements higher than participants (98.6° ± 20.08). This mean difference was more apparent with the greater divergence with less trained individuals and stretching experience. Shoulder extension ROM did not reveal any group differences (i.e., sex, trained state, stretch experience). This research demonstrated excellent reliability overall of participant and researcher perceptions for hip flexion and shoulder stretches with lower correlations for sedentary and inexperienced individuals. Results highlight the need for training status and stretching experience to be considered in stretching intensity prescription and scale development.

Key words: Flexibility, static stretching, passive stretching, range of motion.

Introduction

An important aspect of stretching research and practice is the concept of stretching intensity. Throughout stretching literature there are many scales and definitions surrounding stretching intensity with little consensus (Bryant et al., 2023). Point of discomfort is a common stretching indicator used by researchers and exercise professionals when designing stretching protocols. The use of language in stretching protocols such as "until a point of mild discomfort" or "point of maximum tolerance" (LaRoche and Connolly, 2006) is pervasive throughout stretching literature (LaRoche and Connolly, 2006; Muanjai et al., 2017; Melo et al., 2021). Dynamometry is commonly used to quantify stretching intensity based on a combination of participant sensation and passive torque (LaRoche and Connolly, 2006; Cabido et al., 2014; Kataura et al., 2017; Beltrão et al., 2020). While useful in research and some clinical settings, dynamometry may not be as applicable and practical in real world applications of stretching prescription as this equipment is not readily available to the public, hence why a variety of perception-based scales and cues are commonly used in stretching literature. Using participant perceptions of stretch sensation remains a common technique when prescribing stretching in research, exercise, and clinical settings as it requires no equipment.

It is important to note the many different scales, cues, and definitions that are used in stretching research. This variability highlights the subjective nature of these tools and raises question about their validity. Many stretching studies make use of general pain perception scales which have not been specifically developed or validated for stretch-related discomfort (Beltrão et al., 2020; Nakamura et al., 2021). Multiple scales have been considered validated for stretching intensity such as the PERFLEX and the Stretching Intensity Scale (Dantas et al., 2008; Freitas et al., 2015). However, in studies assessing the validity of these intensity scales, neither training status nor stretching experience have been considered as variables (Dantas et al., 2008; Freitas et al., 2015).

In general, training status is frequently examined in many stretching studies as a variable, but stretching experience is often not considered (Konrad et al., 2024). Many stretching studies actively exclude individuals who are currently undertaking stretch training to control external variables (Bryant et al., 2023; Konrad et al., 2024). This approach excludes elite athletes resulting in limited research on individuals with extensive flexibility training. Consequently, understanding of how training status and stretching experience influence stretching intensity scales remains limited.

Another perspective that is used in stretching practice and research is an external individual's (e.g., researcher, coach, health professional, fellow athlete) perception of muscle tension in a muscle during passive stretching of a participant. For example, an external person's perception of tension in a muscle is used by exercise and healthcare professionals when determining range of motion (ROM) in passive tests (Davis et al., 2008). Also, the popular stretching technique of proprioceptive neuro-

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muscular facilitation (PNF) stretching requires an individual to stretch the participant, thus feeling tension in the muscle. While, both internal (participant) and external (researcher) perceptions are used in practice, no research has directly compared these two approaches or examined how variables such as training status and/or stretching experience may affect this relationship.

A recent commentary stated that a concerted research effort is required to clarify measurement of stretch intensity as consensual and objective quantifiable definitions of stretch discomfort do not exist, with perceptions varying widely (and may not be sensed in some populations) (Warneke et al. 2025). Hence, to examine stretching intensity perceptions from an internal and external perspective, both the upper and lower extremity stretches should be included to consider reliability of different body regions. Both hamstrings (van Doormaal et al., 2017; Liang et al., 2024; Worrell and Perrin, 1992; Opar et al., 2012; Davis et al., 2008) and shoulder (Marchetti et al., 2014; Behm et al., 2016) flexibility are frequently documented in stretching research However, despite their frequent use, no research has compared perceptions of stretching intensity between these two muscle groups.

The purpose of this study is to examine the relationship between participant perception of stretching sensation and researcher perception of tension during two passive stretches; supine hip flexion (hamstrings) and standing shoulder extension. Additionally, we aimed to assess the impact of training status and stretching experience on this relationship.

Methods

Participants

An a priori statistical power analysis (G*Power; University of Dusseldorf) was conducted (F test, with repeated measures ANOVA, effect size f = 0.5, p = 0.05, power = 0.8, number of groups = 2, number of measures = 2, correlation among measures = 0.5, non-sphericity correction = 1). This calculation to measure stretch intensity (Freitas et al. 2015, Kataura et al. 2017, Nakamura et al. 2021) indicated that 12 participants should provide the appropriate statistical power. To ensure adequate power, this study included data from 18 participants ranging in age from 20-26 years, with the average age being 22.3 ± 1.7 years. There were 11 females (height: 166.4 ± 4.9 cm, weight: 72.2 ± 21.1 kg) and 7 males participants (height: 175.2 ± 2.0 cm, weight 82.6 ± 9.6 kg). Participants self-reported a range of training statuses and stretching experience. Training status was classified into four categories; sedentary (n = 3), recreationally active (n = 4), trained (n = 6), and competitive athlete (n = 5). Stretching experience was classified into three categories; 1) no experience (n = 3), 2) present (stretching one or more times per week over the last year) and past experience (n = 9), and 3) only past experience (minimum weekly stretching prior to the last year) (n = 6). Sex by training status and stretching experience breakdown can be seen in Table 1. The researcher involved in the ROM testing was a former national artistic swimming (synchronized swimming) team member and presently a coach with extensive experience stretching these athletes.

Inclusion criteria were individuals aged 18 - 30 years who fulfilled the Physical Activity Readiness Questionnaire Plus (PAR-Q+) assessment of health and readiness to participate (Warburton et al. 2011). Participants were instructed to avoid intense physical activity 24h before the testing session. Exclusion criteria were participants with diseases or injuries of their extremity muscles or joints or neurological issues impacting sensation. The study was approved by the institutional ethics board: Interdisciplinary Committee on Ethics in Human Research (20251229-HK) and in accordance with the Declaration of Helsinki (2024). All participants were verbally informed of the procedures and risks as well as reading and signing a fully disclosed consent form before commencing the experiment.

Procedure

Participants participated in one 45-minute session involving two stretches: passive supine hip flexion and passive shoulder extension. Figure 1 displays experimental setup for these two stretches. Upon arrival, participants completed an informed consent form and PAR-Q+ questionnaire to confirm readiness. Age, sex, height, body mass, training status, and stretching experience were recorded. Participants were familiarized with the two stretching protocols and the stretch end points (initial and maximum) they would signal during their perception trials. Dominant arm and leg were determined; in some cases, (i.e., injury) the non-dominant side was preferred for the protocol and allowed. Participants performed a brief aerobic warm-up of 5 minutes consisting of cycling on a stationary bike (Monark® cycle ergometer, Monark, Stockholm, Sweden) with a cadence between 60 and 70 rpm against 4 kiloponds of resistance.

The order in which participants completed the two stretches was randomized. For each stretch, two tests were executed, one for participant perceptions and one for researcher perceptions. Within each test there were three trials, and within each trial two ROM measurements were taken at defined initial and maximum endpoints. All ROM measurements were taken using a digital goniometer (EasyAngle®, Meloq, Stockholm, Sweden). The first test for both stretches assessed participant perceptions of stretching sensation. In each trial, participants were passively stretched until they signaled their initial endpoint, and then immediately the stretch was repeated until the participant signaled their maximum endpoint. Participants were blindfolded for hip flexion trials so that they would not be influenced by visual cues of where their leg was positioned, whereas this was not necessary for shoulder extension as the arm was outside of the field of

Table 1. Participants' training status and stretching experience.

	Training Status (n)				Stretching Experience (n)		
	Sedentary	Recreationally Active	Trained	Athlete	None	Past Only	Present + Past
Females	3	2	3	3	0	4	7
Males	0	2	3	2	3	2	2

"N" refers to the number of participants in each category.

Figure 1. **Passive supine hip flexion (L) and passive standing shoulder extension (R).**

view for the entirety of the stretch regardless of flexibility. Participant perception trials were administered by a second researcher to ensure that the primary researcher remained blinded to participants' ROM values.

After a 2-minute rest, researcher trials were conducted. The researcher trial followed the same procedure, with the researcher signaling initial and maximum endpoints. Participants were instructed to remain silent during researcher trials; however, they were informed of their right to discontinue any trial that exceeded their tolerance. All data was recorded by the second researcher to further blind the researcher. A 4-minute break was taken following participant and researcher tests for the first stretch before repeating the process for the second stretch. Figure 2 displays the full experimental design.

Training status and stretching experience classification

Training status was classified into four categories based on participant descriptors; sedentary (no weekly activity), recreationally active (1-2 sessions of activity per week), trained (≥3 sessions of organized activity in a week), and athlete (≥3 training sessions per week plus participation in competition during the most recent sporting season). Participants self-selected their category based on activity over the last year. Stretching experience was classified based on two questions: 1) Have you stretched on a regular basis (minimum on a weekly basis) over the past year? 2) Have you stretched on a regular basis (minimum on a weekly basis) at any other point in your life (>1 year)? With their response to these stretching experience questions, participants were allocated into three groups: 1) no stretching experience, 2) present (within the last week) and past experience or 3) only past stretching experience (regular weekly stretching, but not within the past year).

Passive supine hip flexion stretch

The passive supine hip flexion stretch began with the participant lying supine with the lower extremities extended. The non-dominant leg was held down with a strap. The researcher flexed the dominant hip, holding the knee extended, until reaching the appropriate endpoint (i.e., participant or researcher perception) for the assessment. The digital goniometer was aligned with the length of the femur along the lateral side of the leg.

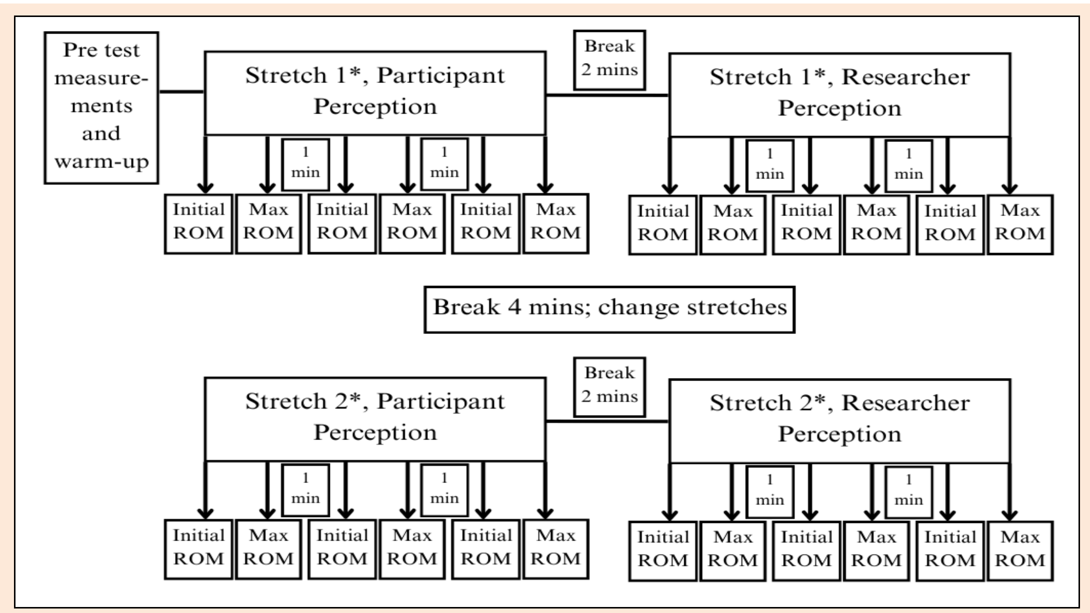

Figure 2. **Experimental design.** *Stretches (Supine Hip Flexion and Standing Shoulder Extension) are randomized. "ROM" refers to range of motion, "Initial" refers to participant perception of initial sensation of stretch and researcher perception of initial tension in the muscle, "Max" refers to participant perception of maximum tolerable sensation of stretch and researcher perception of maximum tension in the muscle.

Passive standing shoulder extension stretch

The passive standing shoulder extension stretch began with the participant standing with their back against a board with their arms extended by their sides with their palms facing inwards. The participants' chest was secured against the board with a strap. Feet were standardized at shoulder width. The researcher extended the arm by placing one hand on the participants' shoulder and the other on the lower arm as rotation occurred, until reaching the appropriate endpoint for the assessment. The digital goniometer was aligned with the humerus along the lateral side of the arm.

Participant and researcher endpoints

Participants were familiarized with the definitions of the initial and maximum stretch endpoints. The initial endpoint was defined as the point at which the participant first perceived a stretch sensation in the limb. The maximum endpoint was defined as the point at which maximum tolerable stretch was sensed.

The initial endpoint for the primary researcher was defined as the point at which initial resistance (tension) was sensed in the muscle. The maximum endpoint was defined as the point at which maximum tension was sensed in the muscle.

Statistical analysis

Statistical analysis was performed using SPSS software (Version 30.0.0, SPSS, Inc., Chicago, IL, USA). Separate one-way repeated measures ANOVAs were used to analyze participant and researcher-led ROM data and sex, training status, and stretching experience. Bonferroni post hoc corrections were applied to detect significant main effect differences, and for significant interactions Bonferroni post hoc t-tests were used to correct for multiple comparisons to determine any differences between values. Effect sizes were interpreted using eta-squared (ηp^2): small ($0.01 \leq eta^2 > < 0.06$), medium ($0.06 \leq eta^2 < 0.14$), and large ($eta^2 \geq 0.14$) (Richardson, 2011). Pearson's correlation coefficient (PCC) was used to assess correlation between researcher and participant measures with results being interpreted as very high (|0.9 - 1.00|), high (|0.7 - 0.9|), moderate (|0.5 - 0.7|), low (|0.3 - 0.5|), and negligible (|0.0 - 0.3|) (Mukaka, 2012). Intraclass correlation coefficients (ICC) for average measures of absolute agreement was used with a two-way random effects model to assess absolute agreement between researcher and participant measures. Results were interpreted as excellent (>0.9), good (0.75 - 0.9), moderate (0.5 - 0.75), or poor (<0.5) (Koo and Li, 2016). Cronbach's alpha was used to assess internal consistency of measurements between trials for participants and researchers with results being interpreted as excellent (>0.9), good (>0.8), acceptable (>0.7), questionable (>0.6), poor (>0.5), and unacceptable (<0.5) (George and Mallery, 2003). Statistical significance was set at $p \leq 0.05$ for all measures. Data presented as means and standard deviations.

Results

Hip flexion ROM

A significant main effect for testing conditions for the hamstrings ROM ($F_{(3,48)} = 61.6$, $p < 0.001$, $\eta p^2 = 0.794$, Observed Power (OP) = 1.00) was evident (comparing participant perception of initial sensation (PPIn), participant perception of maximum tolerance (PPMax), researcher perception of initial tension (RPIn), and researcher perception of maximum tension (RPMax)). PPIn values were significantly less than both PPMax and RPMax across all participants ($p < 0.001$). RPIn was significantly lower than RPMax across all participants ($p < 0.001$), but not significantly different from PPMax ($p = 0.06$). Table 2 displays PCC and ICC for absolute agreement between RPIn and PPIn as between RPMax and PPMax for hip flexion.

There was a significant between-subjects sex effect ($F_{(1,16)} = 4.63$, $p = 0.047$, $\eta p^2 = 0.225$, OP = 1.00). Females demonstrated significantly greater ROM across all measurements than males (Females: 92.47 ± 5.21°, Males: 74.46 ± 6.65°). A significant effect of training status difference was found ($F_{(3,14)}=3.23$, $p < 0.05$, $\eta p^2 = 0.409$, OP = 0.613), with post-hoc t-tests revealing that athletes had significantly greater ROM than sedentary ($p = 0.02$), recreationally active ($p < 0.001$), and trained participants ($p = 0.04$) (Table 3). A significant stretching experience difference was found ($F_{(2,15)} = 8.15$, $p = 0.004$, $\eta p^2 = 0.521$, OP = 0.913), with post-hoc t-tests showing that participants with present and past stretching experience had significantly greater ROM than participants with no experience ($p < 0.001$) and only past experience ($p < 0.001$) (Table 4). Notably, PPMax tended to be lower than RPMax across all participants ($p = 0.06$). Table 3 shows that the ROM difference between RPMax and PPMax narrows with higher training status and greater stretching experience.

Table 4 displays ICC for absolute agreement for hamstrings RPMax vs. PPMax by training status and stretching experience. The group with no stretching experience had no significant correlation. Combined with a small sample size (n = 3), this resulted in a negative ICC value which cannot be interpreted.

Table 2. Pearson's correlation coefficient and intraclass correlation coefficient for absolute agreement for all hip flexion measurements.

	Correlation			Absolute Agreement			
	PCC	Interpretation	Sig. (p)	ICC	95% C.I.	Interpretation	Sig. (p)
RPIn v PPIn	0.598	Moderate	0.009	0.743	(0.313, 0.904)	Moderate	0.04
RPMax v PPMax	0.943	Very High	<0.001	0.928	(0.714, 0.977)	Excellent	<0.001

"PCC" refers to Pearson's correlation coefficient, "Sig." refers to significance, "ICC" refers to intraclass correlation, "C.I." refers to confidence interval, "RPIn v PPIn" refers to comparing researcher perception of initial tension in a stretch with participant perception of initial sensation of stretch, "RPMax v PPMax" refers to comparing researcher perception of maximum tension in a stretch with participant perception of maximum tolerable stretch. Intraclass correlation coefficients are for absolute agreement using average measures and a two-way random effects model. Significance considered at $p \leq 0.05$.

Table 3. RPMax and PPMax hamstrings ROM means and standard deviation by training status and stretching experience.

Activity Level	N	Condition	Mean ROM (°)	SD	RPMax - PPMax (°)
Sedentary	3	RPMax	106.6667	11.02018	16.778
		PPMax	89.8889	6.07667	
Recreationally Active	4	RPMax	94.2500	13.39811	18.1667
		PPMax	76.0833	15.32457	
Trained	6	RPMax	103.0000	21.06076	8.5556
		PPMax	99.4444	27.95605	
Athlete	5	RPMax	129.6667	23.42956	0.6667
		PPMax	129.0000	30.98656	
Stretching Experience					
None	3	RPMax	92.8889	4.50103	15.1111
		PPMax	77.7778	4.43889	
Past Only	6	RPMax	93.5000	14.27157	13.3333
		PPMax	80.1667	14.42182	
Past + Present	9	RPMax	124.8519	19.01470	2.4815
		PPMax	122.3704	27.16485	

"N" refers to the number of participants in each group, "ROM" refers to range of motion, "SD" refers to standard deviation, "RPMax" refers to researcher perception of maximum tension in the muscle, "PPMax" refers to participant perception of maximum tolerable stretch.

Table 4. Intraclass correlation coefficient for absolute agreement for hamstrings RPMax vs. PPMax by training status and stretching experience.

Training Status	N	ICC	95% C.I.	Sig. (p=)	Interpretation
Sedentary	3	0.390	(-0.188, 0.969)	0.177	Poor
Recreationally Active	4	0.696	(-0.053,0.976)	0.006	Moderate
Trained	6	0.944	(0.645, 0.992)	0.004	Excellent
Athlete	5	0.972	(0.715, 0.997)	0.003	Excellent
Stretching Experience					
None	3	-0.387	N/A	0.990	N/A
Past Only	6	0.798	(-0.107, 0.974)	<0.001	Good
Present + Past	9	0.917	(0.640, 0.981)	0.001	Excellent

"ICC" refers to intraclass correlation, "C.I." refers to confidence interval, "Sig." refers to significance. Intraclass correlation coefficients are for absolute agreement using average measures and a two-way random effects model. Negative intraclass correlation coefficient for absolute agreement in such a small sample size will not be interpreted, this is represented by "N/A". Significance considered at $p \leq 0.05$.

Table 5. Pearson's correlation coefficient and intraclass correlation coefficient for absolute agreement for all shoulder extension measurements.

	Correlation			Absolute Agreement		
	PCC	Interpretation	Sig. (p=)	ICC for Absolute Agreement	Interpretation	Sig. (p=)
RPIn v PPIn	0.074	Negligible	0.769	0.120	Poor	0.387
RPMax v PPMax	0.519	Moderate	0.027	0.689	Moderate	0.012

"PCC" refers to Pearson's correlation coefficient, "Sig." refers to significance, "ICC" refers to intraclass correlation, "RPIn v PPIn" refers to comparing researcher perception of initial tension in a stretch with participant perception of initial sensation of stretch, "RPMax v PPMax" refers to comparing researcher perception of maximum tension in a stretch with participant perception of maximum tolerable stretch. Intraclass correlation coefficients are for absolute agreement using average measures and a two-way random effects model. Significance considered at $p \leq 0.05$.

Table 6. Internal reliability (Cronbach's alpha) of participant and researcher ROM measurements and perceptions for hip flexion and shoulder stretches.

	Hip ROM				Shoulder ROM			
Condition	PPIn	PPMax	RPIn	RPMax	PPIn	PPMax	RPIn	RPMax
Cronbach's α	0.963	0.991	0.966	0.985	0.867	0.969	0.977	0.990
Interpretation	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent	Excellent

"ROM" refers to range of motion, "Hip" refers to passive supine hip flexion stretch, "Shoulder" refers to passive standing shoulder extension, "PP" refers to participant perception, "RP" refers to researcher perception, "In" refers to participant perception of initial sensation of stretch and researcher perception of initial tension in the muscle, "Max" refers to participant perception of maximum tolerable stretch and researcher perception of maximum tension in the muscle.

Shoulder extension ROM

A significant main effect for testing conditions was found for the shoulder extension ROM ($F_{(3,48)} = 30.46$, $p < 0.001$, $\eta p^2 = 0.656$, OP = 1.00). PPIn was significantly lower than PPMax and RPMax ($p < 0.001$). RPIn was significantly less than RPMax ($p < 0.001$) and PPMax ($p = 0.002$). There were no significant sex differences for shoulder ROM across all measurements (Females: 72.86 ± 3.43°, Males: 67.04 ± 4.31°). There was no significant training status or stretching experience differences. Table 5 displays PCC and ICC for absolute agreement between RPIn and PPIn as well as RPMax and PPMax for shoulder extension.

Reliability

Table 6 displays the generally excellent reliability of participant and researcher perceptions as assessed with Cronbach's alpha.

Discussion

Both participant perceptions of stretching sensation and researcher tests of tension, exhibited good to excellent consistency across supine hip flexion and standing shoulder extension passive stretches. Therefore, internal perceptions of stretching sensation and external perceptions of muscle tension are reliable methods to use to achieve consistent intensity if the same method is employed. However, it is important to note that the lower correlations seen with sedentary and less stretch experienced individuals highlights the need for training status and stretching experience to be considered in stretching intensity prescription.

Initial and maximum measurements

That PPIn and RPIn produced significantly lower ROM values than all maximum measurements were an expected outcome. The lone exception was a large magnitude but non-significant difference for supine hip flexion, in which RPIn tended to be lower than PPMax ($eta^2 = 0.794$, $p = 0.06$). Hence, within perception category (PP or RP), all initial measures of muscle tension were significantly lower than their corresponding maximum measures. This validates our cues as initial sensation of stretch/initial perception of tension should be at a lower ROM than maximum tolerable stretch/maximum tension.

When considering researcher and participant correlation and absolute agreement within initial and maximum measurements, passive supine hip flexion displayed stronger correlation and absolute agreement between researcher and participant than the shoulder extension ROM. While RPIn and PPIn were not found to be significantly different for either hip flexion or shoulder extension, hip flexion still displayed moderate correlation (PCC = 0.598) and moderate absolute agreement (ICC = 0.743). In contrast, shoulder extension showed negligible correlation (PCC = 0.074) and poor absolute agreement (0.120). This finding highlights an important concept that while measures were not significantly different for either hip flexion or shoulder extension, participant and researcher perceptions cannot be considered interchangeable given the modest levels of correlation and agreement.

RPMax and PPMax for shoulder extension were not found to be significantly different, and there was moderate correlation (PCC = 0.519) and absolute agreement (ICC = 0.689). Considering sample size, it cannot be confidently concluded based on these findings that participant perceptions of maximum tolerable stretch can be used interchangeably with researcher perceptions of maximum tension for the shoulder. At the hip, there was very high correlation between RPIn and PPIn and good/excellent ICC absolute agreement, which could lead to an assumption that these measurements may potentially be reliably interchanged. However, a difference approaching significance ($p = 0.06$) between RPMax and PPMax emerged for the passive supine hip flexion, warranting further analysis of this relationship based on training status and stretching experience.

Sex differences

Finding that females have significantly greater hamstrings ROM than males in this study was expected. It has been reported that on average females have a greater ROM than males in many upper and lower body joints (Bell and Hoshizaki, 1981; Soucie et al., 2011). In studies considering ROM, hip flexion is very commonly assessed (Bell and Hoshizaki, 1981; Law et al., 2009; Soucie et al., 2011; Lempke et al., 2018). Shoulder extension is not a common stretch measure in research, and in studies comparing sex and ROM, shoulder extension is not a standard ROM to assess (Bell and Hoshizaki, 1981; Soucie et al., 2011). There is insufficient literature on sex differences in shoulder extension ROM and our study also did not find any such differences. However, other upper limb ROM assessments have reported sex differences (Bell and Hoshizaki, 1981; Soucie et al., 2011), and further research in this area is warranted.

Training status differences

For the passive supine hip flexion stretch, significant differences were seen between athletes and all other groups (sedentary, recreationally active, trained). Pain threshold, the point beyond which pain is felt in response to a stimulus, and pain tolerance, an individual's ability to endure pain, differ from each other. In particular, pain tolerance is more closely tied to clinical pain than pain threshold (Gelfand, 1964), which makes it especially relevant in interpreting stretching responses. Research has shown that athletes have increased pain tolerance than non-athletes, even when non-athletes are active individuals, and further, athletes in contact sports have greater pain tolerance than athletes in non-contact sports (Ryan and Kovacic, 1966; Tesarz et al., 2012). When comparing hip flexion RPMax and PPMax by training status, greater reliability was more closely related to higher training status. This finding of greater agreement within higher training status is supported by literature on increased pain tolerance in athletes. Individuals with higher training status likely have higher global pain tolerance, enabling them to more accurately identify their maximum tolerable stretch. Maximum tension was achieved when the researcher could not move the limb further due to tension. Individuals with lower training status underestimated their pain tolerance for hip flexion, resulting in greater ROM when stretched by a researcher than when self-stretched.

Stretching experience differences

Significant stretching experience differences were seen between participants with present and past stretching experience and all other groups (no experience and past experience only) in the supine hip flexion stretch. Stretch tolerance is defined as the ability to tolerate the discomfort related to stretching (Støve et al., 2019). In acute and chronic stretching, ROM gains have been connected in part to increases in pain tolerance. These transient changes have been attributed to various pain modulation theories such as gate control theory (Melzack and Wall, 1965; Moayedi and Davis, 2013) and diffuse noxious inhibitory control (DNIC) (Le Bars et al., 1992). This stretch tolerance has been associated with more general sensory pain tolerance (Behm et al., 2021). Participants in this study had a high degree of reliability for perception of stretching sensation and maximum tolerance which suggests acute pain modulation was not a factor in stretch tolerance during the measurement trials. Further, our finding that individuals with present and past stretching experience had greater agreement between RPMax and PPMax for hip flexion is in line with findings that chronic stretching leads to increased stretch tolerance, as individuals self-selected the ROM for maximum tolerable stretch closer to the ROM where maximum tension was felt. As seen with training status, individuals with lower stretching experience underestimated their pain tolerance for hip flexion, deviating further from researcher maximum tension trials where they tolerated greater range of motion than their self-selected maximums. Some athletic individuals in this study had more extreme ROM as they were presently or previously involved in extreme ROM sports such as artistic swimming (synchronized swimming) and gymnastics.

The duration, type, intensity, or frequency of stretching experience was not recorded. Some participants noted stretching experiences ranging from physiotherapy prescribed stretching related to injury rehabilitation all the way through to rigorous stretching practice to achieve and maintain a high degree of flexibility (i.e., splits), however, these specifics were not recorded. Therefore, specific stretching variables other than weekly participation presently, in the past, or not at all were not considered.

Shoulder ROM

This study did not find significant sex, training status, or stretching experience differences for standing supine shoulder extension. There are no research articles using the exact protocol used in this study. While stretching shoulder extension is not common, some activities of daily living require shoulder extension such as tucking in a shirt or unhooking a bra (Putz et al., 2017). It has been suggested that between 40 - 45° of shoulder extension is necessary for activities of daily living and normal shoulder function (Namdari et al., 2012; Hochreiter et al., 2022). In our protocol, participants' perception of initial stretching sensation across all groups was on average 52.6°. This maximum ROM goes beyond the suggested shoulder extension required for daily living and normal shoulder function. The novelty of this stretch ROM therefore is hypothesized to be the common factor that could have eliminated the differences seen in the supine hip flexion stretch. Additionally, the weaker correlations and agreement between RPIn and PPIn and RPMax and PPMax in the shoulder extension stretch when compared with the hip flexion stretch, can again be hypothesized to be tied to the extent of ROM and therefore lack of familiarity with this stretch ROM.

Reliability

All Cronbach's alpha values fell within the good or excellent categories. This reveals that participants and the researcher had good-excellent test/retest reliability, with a high level of consistency in the range of motion signaled for each cue (initial or maximum) between trials for both stretches. The primary researcher (CB) has extensive experience in passively stretching others and executed all researcher perception trials. These results indicate that individuals with extensive experience in passively stretching others can reliably sense initial and maximum tension when stretching a participant. Additionally, the protocol for this study was designed with knowledge of pain modulation theories (gate control theory and DNIC) as well as the thixotropic effect (exercise-induced internal temperature increases decrease viscosity in the muscles and increase ROM) in mind (Behm, 2024).

Study considerations (Limitations)

It is important to note that all participants classified as athletes (n = 5) also were classified as having past and present stretching experience. However, not all participants who had present and past stretching experience (n = 9) were athletes, this group also included trained (n = 3) and sedentary (n = 1) participants. A larger sample could further differentiate what factors most impact results such as absolute agreement between participants and researchers. Additionally, the use of self-reporting for training status and stretching experience has inherent limitations.

While every effort was made to avoid order effects, including sufficient rest and randomization of conditions, there is still a possibility of some practice and fatigue effects.

The novelty of the standing shoulder extension stretch may explain why sex, training status, and stretching experience did not produce ROM differences. Repeating this protocol with a more familiar upper body stretching protocol could provide more generalizable results on sex, training status, and stretching experience differences in the upper limb.

The interactions in this study were limited by a sample size of 18 participants. The non-significant, large magnitude effect size finding that PPMax is less than RPMax in supine hip flexion was driven by decreasing agreement between RPMax and PPMax with decreasing training status and stretching experience. Further studies should be conducted to investigate the relationship between maximum stretch tolerance and maximum tension in different training status and stretching experience categories. Additionally, due to the sample size, the type of training/sports undertaken was not expanded upon and neither was the type of stretching experience. Hence, while the statistical main effect results generally demonstrated strong observed power, the interactions with their smaller sample sizes should be considered as exploratory findings that should initiate further research. Future research in stretching intensity should classify individuals based on stretching experience and training status in order to identify further patterns. With larger study sizes, variables such as type, frequency, and duration of stretching practice as well as activity/sport type and training load can be considered to identify what variables may be the most influential in affecting participant perceptions of stretching sensation. This study assessed one researcher's perceptions of tension. Further research could address multiple external testers with mixed levels of experience in passively stretching others and the effect on perception of tension.

Conclusion

In tests of participant perceptions of stretching sensation and researcher tests of tension, participants and researchers displayed good to excellent consistency in their perception across supine hip flexion and standing shoulder extension passive stretches. Therefore, internal perceptions of stretching sensation and external perceptions of muscle tension are each reliable method for achieving consistent stretch intensity when used independently and consistently.

No significant differences were found between RPIn and PPIn for either hip or shoulder stretches. Likewise, no significant difference was found between RPMax and PPMax for the shoulder. However, correlation and absolute agreement between these measures varied, highlighting that based on this data internal (participant) and external (researcher) perceptions cannot be used interchangeably to achieve the same ROM and intensity.

Supine hip flexion RPMax and PPMax had very high correlation (PCC = 0.943) and excellent absolute agreement (ICC = 0.928) across all participants. However, a non-significant, large magnitude effect size was found ($eta^2 = 0.794$, $p = 0.06$) between RPMax and PPMax in hip flexion. This difference appeared to be driven by reduced absolute agreement in participants with lower training status and less stretching experience. This relationship is supported by research reporting that athletes have higher pain tolerance than non-athletes and research reporting that chronic stretching results in greater stretch tolerance and overall sensory pain tolerance.

This research provides valuable insight into how individuals perceive their own stretching capacity and highlights factors that may influence their ability to reach their desired maximal intensity in stretching protocols. Additionally, this study highlights the need for training status and stretching experience to be considered in stretching intensity prescription and scale development. Coaches and clinicians need to provide more extensive stretching familiarization to inexperienced individuals to ensure suitable and consistent stretch intensities are administered. Further research with larger sample sizes is needed to clarify how training status and stretching experience influence the relationship between internal stretch perceptions and external tension perceptions.

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We thank the participants for their time. The author reports no actual or potential conflicts of interest. While the datasets generated and analyzed in this study are not publicly available, they can be obtained from the corresponding author upon reasonable request. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was carried out. The authors declare that no Generative AI or AI-assisted technologies were used in the writing of this manuscript.

References

Beltrão, N. B., Ximenes Santos, C., de Oliveira, V. M. A., Pirauá, A. L. T., Behm, D. G., Pitangui, A. C. R. and de Araújo, R. C. (2020) Effects of a 12-week chronic stretch training program at different intensities on joint and muscle mechanical responses: A randomized clinical trial. *Journal of Sport Rehabilitation* **29(7)**, 904-912. https://doi.org/10.1123/jsr.2018-0443

Behm, D. G. (2024) The science and physiology of flexibility and stretching: Implications and applications in sport performance and health. *Routledge*. https://doi.org/10.4324/9781032709086

Behm, D. G., Cavanaugh, T., Quigley, P., Reid, J. C., Nardi, P. S. M., and Marchetti, P. H. (2016) Acute bouts of upper and lower body static and dynamic stretching increase non-local joint range of motion. *European Journal of Applied Physiology* **116(2)**, 241-249. https://doi.org/10.1007/s00421-015-3270-1

Behm, D. G., Kay, A. D., Trajano, G. S., Alizadeh, S., and Blazevich, A. J. (2021) Effects of acute and chronic stretching on pain control. *Journal of Clinical Exercise Physiology* **10(4)**, 150-159. https://doi.org/10.31189/2165-6193-10.4.150

Bell, R. D., and Hoshizaki, T. B. (1981) Relationships of age and sex with range of motion of seventeen joint actions in humans. *Canadian Journal of Applied Sport Sciences* **6(4)**, 202-206.

Bryant, J., Cooper, D. J., Peters, D. M., and Cook, M. D. (2023) The effects of static stretching intensity on range of motion and strength: A systematic review. *Journal of Functional Morphology and Kinesiology* **8(2)**, 37. https://doi.org/10.3390/jfmk8020037

Cabido, C. E. T., Bergamini, J. C., Andrade, A. G. P., Lima, F. V., Menzel, H. J., and Chagas, M. H. (2014) Acute effect of constant torque and angle stretching on range of motion, muscle passive properties, and stretch discomfort perception. *The Journal of Strength & Conditioning Research* **28(4)**, 1050-1057. https://doi.org/10.1519/JSC.0000000000000241

Dantas, E. H. M., Salomão, P. T., de Souza Vale, R. G., Achour Júnior, A., Simão, R., and de Figueiredo, N. M. A. (2008) Scale of perceived exertion in the flexibility (PERFLEX): A dimensionless tool to evaluate the intensity? *Fitness & Performance Journal* **7(5)**, 289-294. https://doi.org/10.3900/fpj.7.5.289.e

Davis, D. S., Quinn, R. O., Whiteman, C. T., Williams, J. D., and Young, C. R. (2008) Concurrent validity of four clinical tests used to measure hamstring flexibility. *The Journal of Strength & Conditioning Research* **22(2)**, 583-588. https://doi.org/10.1519/JSC.0b013e31816359f2

van Doormaal, M. C. M., van der Horst, N., Backx, F. J. G., Smits, D.-W., and Huisstede, B. M. A. (2017) No relationship between hamstring flexibility and hamstring injuries in male amateur soccer players: A prospective study. *The American Journal of Sports Medicine* **45(1)**, 121-126. https://doi.org/10.1177/0363546516664162

Freitas, S. R., Vaz, J. R., Gomes, L., Silvestre, R., Hilário, E., Cordeiro, N., Carnide, F., Pezarat-Correia, P. and Mil-Homens, P. (2015) A new tool to assess the perception of stretching intensity. *The Journal of Strength & Conditioning Research* **29(10)**, 2666-2673. https://doi.org/10.1519/JSC.0000000000000926

Gelfand, S. (1964) The relationship of experimental pain tolerance to pain threshold. *Canadian Journal of Psychology* **18(1)**, 36-42. https://doi.org/10.1037/h0083283

Hochreiter, B., Wyss, S., and Gerber, C. (2022) Extension of the shoulder is essential for functional internal rotation after reverse total shoulder arthroplasty. *Journal of Shoulder and Elbow Surgery* **31(6)**, 1166-1174. https://doi.org/10.1016/j.jse.2021.11.006

Kataura, S., Suzuki, S., Matsuo, S., Hatano, G., Iwata, M., Yokoi, K., Tsuchida, W., Banno, Y. and Asai, Y. (2017) Acute effects of the different intensity of static stretching on flexibility and isometric muscle force. *The Journal of Strength & Conditioning Research* **31(12)**, 3403-3410. https://doi.org/10.1519/JSC.0000000000001752

Konrad, A., Alizadeh, S., Daneshjoo, A., Hadjizadeh Anvar, S., Graham, A., Zahiri, A., Goudini, R., Edwards, C., Scharf, C. and Behm, D. G. (2024) Chronic effects of stretching on range of motion with consideration of potential moderating variables: A systematic review with meta-analysis. *Journal of Sport and Health Science* **13(2)**, 186-194. https://doi.org/10.1016/j.jshs.2023.06.002

Koo, T. K. and Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine* **15(2),** 155-163. https://doi.org/10.1016/j.jcm.2016.02.012

LaRoche, D. P., and Connolly, D. A. J. (2006) Effects of stretching on passive muscle tension and response to eccentric exercise. *The American Journal of Sports Medicine* **34(6)**, 1000-1007. https://doi.org/10.1177/0363546505284238

Law, R. Y. W., Harvey, L. A., Nicholas, M. K., Tonkin, L., De Sousa, M., and Finniss, D. G. (2009) Stretch exercises increase tolerance to stretch in patients with chronic musculoskeletal pain: A randomized controlled trial. *Physical Therapy* **89(10)**, 1016-1026. https://doi.org/10.2522/ptj.20090056

Le Bars, D., Villanueva, L., Bouhassira, D., and Willer, J. C. (1992) Diffuse noxious inhibitory controls (DNIC) in animals and in man. *Patologicheskaia Fiziologiia I Eksperimental'naia Terapiia*, **(1)**, 55-65.

Lempke, L., Wilkinson, R., Murray, C., and Stanek, J. (2018) The effectiveness of PNF versus static stretching on increasing hip-flexion range of motion. *Journal of Sport Rehabilitation* **27(3)**, 289-294. https://doi.org/10.1123/jsr.2016-0098

Liang, F., Hongfeng, H., and Ying, Z. (2024) The effects of eccentric training on hamstring flexibility and strength in young dance students. *Scientific Reports* **14(1)**, 3692. https://doi.org/10.1038/s41598-024-53987-0

Mukaka, M. M. (2012) Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Medicine Journal* **24(3),** 69-71

Putz, C., Erhard, S., Fiethen, K., Geisbüsch, A., Thielen, M., Wolf, S. I., Dreher, T., Maier, M. W., Thielen, M., Bruckner, T., Zeifang, F. and Raiss, P. (2017) Three-dimensional motion analysis for validation of shoulder internal rotation. *Archives of Orthopaedic and Trauma Surgery* **137(5)**, 735-741. https://doi.org/10.1007/s00402-017-2656-4

Marchetti, P. H., de Oliveira Silva, F. H. D., Soares, E. G., Serpa, E. P., Nardi, P. S. M., Vilela, G. B. and Behm, D. G. (2014) Upper limb static-stretching protocol decreases maximal concentric jump performance. *Journal of Sports Science & Medicine* **13(4)**, 945-950. https://pubmed.ncbi.nlm.nih.gov/25435789/

Melo, R. R. V., Cerqueira, M. S., Barbosa, G. M., Laurentino, A. L. B. A., Franca, I. M., Souza, T. O. and Brito Vieira, W. H. (2021) Static stretching at pain-tolerated intensity is not necessary to increase knee range of motion in amateur soccer players: A randomized trial. *Muscle Ligaments and Tendons Journal* **11(4)**, 536-543. https://doi.org/10.32098/mltj.03.2021.19

Melzack, R., and Wall, P. D. (1965) Pain mechanisms: A new theory. *Science* **150(3699)**, 971-979. https://doi.org/10.1126/science.150.3699.971

Moayedi, M., and Davis, K. D. (2013) Theories of pain: From specificity to gate control. *Journal of Neurophysiology* **109(1)**, 5-12. https://doi.org/10.1152/jn.00457.2012

Muanjai, P., Jones, D. A., Mickevicius, M., Satkunskiene, D., Snieckus, A., Skurvydas, A. and Kamandulis, S. (2017) The acute benefits and risks of passive stretching to the point of pain. *European Journal of Applied Physiology* **117(6)**, 1217-1226. https://doi.org/10.1007/s00421-017-3608-y

Nakamura, M., Yoshida, R., Sato, S., Yahata, K., Murakami, Y., Kasahara, K., Fukaya, T., Takeuchi, K. and Nunes, J. P. (2021) Comparison between high- and low-intensity static stretching training program on active and passive properties of plantar flexors. *Frontiers in Physiology* **12**. https://doi.org/10.3389/fphys.2021.796497

Namdari, S., Yagnik, G., Ebaugh, D. D., Nagda, S., Ramsey, M. L., Williams, G. R. Jr., and Mehta, S. (2012) Defining functional shoulder range of motion for activities of daily living. *Journal of Shoulder and Elbow Surgery* **21(9)**, 1177-1183. https://doi.org/10.1016/j.jse.2011.07.032

Opar, D. A., Williams, M. D., and Shield, A. J. (2012) Hamstring strain injuries: Factors that lead to injury and re-injury. *Sports Medicine* **42(3)**, 209-226. https://doi.org/10.2165/11594800-000000000-00000

Richardson, J. T. E. (2011). Eta squared and partial eta squared as measures of effect size in educational research. Educational Research Review **6,** 135–147.

Ryan, E. D., and Kovacic, C. R. (1966) Pain tolerance and athletic participation. *Perceptual and Motor Skills* **22(2)**, 383-390. https://doi.org/10.2466/pms.1966.22.2.383

Soucie, J. M., Wang, C., Forsyth, A., Funk, S., Denny, M., Roach, K. E. and Boone, D. (2011) Range of motion measurements: Reference values and a database for comparison studies. *Haemophilia* **17(3)**, 500-507. https://doi.org/10.1111/j.1365-2516.2010.02399.x

Støve, M. P., Hirata, R. P., and Palsson, T. S. (2019) Muscle stretching - The potential role of endogenous pain inhibitory modulation on stretch tolerance. *Scandinavian Journal of Pain* **19(2)**, 415-422. https://doi.org/10.1515/sjpain-2018-0334

Tesarz, J., Schuster, A. K., Hartmann, M., Gerhardt, A., and Eich, W. (2012) Pain perception in athletes compared to normally active controls: A systematic review with meta-analysis. *Pain* **153(6)**, 1253-1262. https://doi.org/10.1016/j.pain.2012.03.005

Warburton, D. E. R., Jamnik, V. K., Bredin, S. S. D. and Gledhill, N. (2011). The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and electronic Physical Activity Readiness Medical Examination (ePARmed-X+). *Health & Fitness Journal of Canada* **4(2),** 3-23.

Warneke, K., Blazevich, A., Jochum, D., Behm, D. G., Thomas, E., Nakamura, M., and Afonso, J. (2025) Perception-based methods and beyond: A current opinion on how to assess static stretching intensity. *Sports Medicine*. Advance online publication. https://doi.org/10.1007/s40279-025-02307-1

Worrell, T. W., and Perrin, D. H. (1992) Hamstring muscle injury: The influence of strength, flexibility, warm-up, and fatigue. *Journal of Orthopaedic & Sports Physical Therapy* **16(1)**, 12-18. https://doi.org/10.2519/jospt.1992.16.1.12

Key points

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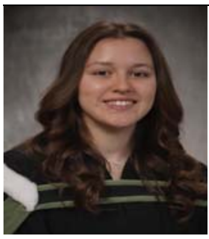

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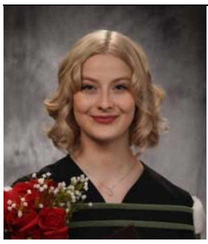

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