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Affective responses to stretching exercises: Exploring the timing of assessments

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ABSTRACT

Affective responses during exercise have been identified as a predictor of exercise adherence. However, research has been mostly limited to aerobic and resistance exercise. Considering that stretching activities are also an important component of physical fitness, this quasi-experimental study was designed to: 1) compare affective responses during and immediately after stretching exercises in apparently healthy adults, and 2) assess the consistency and repeatability of affect ratings obtained one week apart. For this purpose, we analyzed the Feeling Scale (FS) and Felt Arousal Scale (FAS) ratings using Time (during and after stretching) x Intensity (light, moderate, vigorous) x Stretched Muscle Group (quadriceps, hamstrings, glutes, latissimus dorsi, triceps) with repeated measures analysis of variance (ANCOVA) in 34 participants (21 males; aged 32.8 ± 8.6 years). The repeatability of FS and FAS ratings was assessed using two-way random-effects models, Intraclass Correlation Coefficients (ICC), and Bland-Altman plots. FS scores were higher following the stretching exercises, whereas FAS scores were lower, particularly in the vigorous intensity. In general, the inter-day repeatability for FS and FAS measurements was good across muscle groups. ICC tended to be higher at vigorous intensities. Ratings of core affect can be collected during static passive stretches using the FAS and FAS in ecologically valid settings. These results suggest that an adequate assessment of core affective responses to stretching activities should be performed during the exercises.

Regular Physical Activity (PA) is associated with a variety of health benefits, including reduced risk of all-cause mortality and several medical conditions (Warburton & Bredin, 2017). However, despite the overwhelming evidence supporting the health benefits of PA, and international guidelines recommending 150 min/week of moderate-intensity aerobic activity or 75 min/week of vigorous-intensity aerobic activity, a considerable portion of the world population fails to perform sufficient PA to reach the minimum thresholds specified in these recommendations (American College of Sports Medicine, 2021; World Health Organization, 2020). In an effort to encourage more PA, proposals by several authors have emphasized that meaningful fitness and health benefits can also be accrued with lower levels of PA and/or intensity (Segar et al., 2020; Warburton & Bredin, 2016). Exercise prescriptions that take into account individual characteristics and needs, such as those focusing on the promotion of pleasure (i.e., 'feeling good' while exercising; see Ladwig et al., 2017), may have the potential to facilitate or encouraging behavior change (Rhodes & Kates, 2015; Williams, 2008).

1. Core affect and exercise adherence

Grounded on hedonic assumptions (i.e., that people are generally willing to partake in activities that make them feel better but tend to avoid activities that make them feel worse), core affective responses have increasingly attracted the interest of exercise psychologists as a possible contributor to behavior adoption or maintenance (Ekkekakis

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et al., 2011; Rhodes, McEwan, & Rebar, 2019ined as *"the most basic or elementary characteristic component of all valenced responses, positive or negative, pleasant or unpleasant, including, but not limited to, emotions and moods"* (Ekkekakis et al., 2005b, p. 478). Moreover, core affect can be conceptualized as a constant component of consciousness, one that can occur either in combination with cognitive appraisals or independently of cognitive appraisals (in "free-floating" form), and one that consists of two basic ingredients or elementary dimensions, namely affective valence and perceived activation or arousal: *"consciously accessible as a simple, nonreflective feeling that is an integral blend of hedonic (pleasure–displeasure) and arousal (sleepy–activated) values"* (Russell, 2003, p. 147).

Assessments of core affect in response to various exercise stimuli may be helpful to exercise professionals as a basis for creating individualized prescriptions or recommendations aimed at enhancing the affective experience of individuals and, in turn, facilitating adherence (Evmenenko & Teixeira, 2020). Two of the most commonly used scales for that purpose are the Feeling Scale (FS; Hardy & Rejeski, 1989) and the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985), used to assess affective valence (perceived pleasure/displeasure) and arousal (perceived activation), respectively. These scales can be plotted together, to represent a two-dimensional "map" of affective space (in a so-called "circumplex model"), which can be used to represent the complete trajectory of the affective response experienced during and after an exercise session (Evmenenko & Teixeira, 2020; Russell, 1980). The FS and FAS can capture the response to various exercise stimuli (Ekkekakis & Petruzzello, 2002), but have been mostly used to study aerobic exercise (Evmenenko & Teixeira, 2020; Rhodes & Kates, 2015) and, more recently, resistance training (e.g., Andrade et al., 2022; Bastos et al., 2022; Cavarretta et al., 2019).

2. Filling the research void: understanding affective responses to stretching exercise

Stretching activities represent an important component of physical fitness (American College of Sports Medicine, 2021; Behm et al., 2016). The physical benefits of stretching include improvements in flexibility and muscular endurance, increased balance both in middle-aged (Cruz-Ferreira et al., 2011) and older adults (Casonatto & Yamacita, 2020), and reduced muscle pain (Miyamoto et al., 2013). Some of the reported psychological benefits include reduced stress, anxiety, depression symptoms, and increased self-esteem (Wang et al., 2010). Stretching activities can be incorporated within various exercise modalities (e.g., Yoga, Pilates, Tai-Chi), integrated across different settings (e.g., group fitness classes in health and fitness centers), but can also form a standalone exercise regimen. Stretching activities are considered to entail low perceived barriers to participation, and to be safe, accessible, and engaging (Apostolopoulos et al., 2015; DiGiacomo et al., 2010). They also can provide a qualitatively different exercise experience, focusing on relaxation, body awareness, and control, which may be perceived as less strenuous and more pleasurable (Hagins et al., 2007). However, stretching can also be experienced as a high-intensity activity, with benefits to musculoskeletal fitness and health (Apostolopoulos et al., 2015), and as a key variable for sports performance (Behm, 2019). Therefore, it is not surprising that stretching activities continue to enjoy considerable popularity not only among exercise participants, but also within the research community, as indicated by the growing number of studies published in recent years (Wieland et al., 2021).

3. Present study

Affective responses to stretching activities have received relatively limited research attention, as shown by a recent review on the topic (Henriques & Teixeira, 2023). Overall, the included studies have demonstrated that stretching activities are integrated into a wide variety of exercise contexts (i.e., as individual stretches, in group classes, as part of the warm-up and cooldown portions of exercise sessions), take different forms (i.e., static, dynamic, passive, active), and that the attendant affective responses have been studied with heterogeneous measurement procedures, including the number and timing of affect assessments. Given the differences among these studies, reviewers have concluded that the assessment of the affective responses to stretching activities exhibited suboptimal methodological quality (e.g., poor standardization), thus limiting confidence in the conclusions. One particularly important question that should be explored refers to whether the way one feels *during* the stretch is different, or even has the opposite affective valence, compared to how one feels after the stretch, a phenomenon known as the "affective rebound effect" (Ekkekakis et al., 2011). This phenomenon has been reliably documented in aerobic exercise (Ekkekakis et al., 2011), and to a lesser extent in resistance training (Andrade et al., 2022; Cavarretta et al., 2019). In both cases, measuring affect during and after the execution of the exercise presented differences. These methodological assessment advancements helped understand the affective (positive and negative) peaks in each mode. Regarding stretching exercises, the demonstration of the affective rebound effect may depend on the timing of the assessments of affect (during vs. after the exercise), the intensity of the stretching (lower vs. higher), or possibly the muscle group being stretched (multi vs. single jointed muscles). However, these questions have not yet been examined empirically. Answering these interrogations could facilitate the individualization of stretching activities and, in turn, the improvement of affective experiences associated with stretching and, ultimately, the promotion of exercise adherence.

Therefore, the aims of the present study were: 1) to compare affective responses during and immediately after stretching exercises in apparently healthy adults, with the goal of investigating whether an affective rebound does occur (and, in the process, shed light on the role of the timing of affect assessments), and 2) to examine the consistency and repeatability of the assessments of affective responses through repeated testing (i.e., test-retest) performed one week apart. It is hypothesized that: 1) an affective rebound will be present at all intensities of stretching, as evidenced by improved affective valence immediately after the stretch; 2) higher exercise intensities will result in more pronounced "affective rebounds," namely larger differences in affective valence between measurement time points (i.e., during vs. after the stretch); and 3) the assessment of affective responses to the stretching protocol will exhibit high temporal stability, thus supporting the test-retest reliability of the affect ratings and the measurement procedure followed in this study.

4. Method

4.1. Participants

To determine the appropriate sample size, we considered our primary outcome measure (i.e., ratings of affective valence) and our primary hypothesis (i.e., comparison between affective ratings obtained during and immediately after stretching exercises regardless of stretching intensity). There are no known previous studies that have investigated the same hypothesis. However, in two previous studies (Edwards et al., 2018; Sullivan et al., 2019), the same measure of affective valence (i.e., the Feeling Scale; see the section on "Instruments" below) was administered during sessions of passive stretching (though not during the stretching exercises) and after the sessions (though not immediately after but rather a few minutes after). These studies yielded effect sizes of $f = 0.26$ (Sullivan et al., 2019) and $f = 0.17$ (Edwards et al., 2018). Therefore, here we used the rounded-down average of these effects ($f = 0.21$) as the target effect size, along with $\alpha = 0.05$, and $1\text{-}\beta = 0.80$, for a repeated-measures ANOVA main effect of Time (during vs. after). This calculation, using G*Power v.3.1.9.7 (Faul et al., 2009), yielded a required sample size of at least 29 (or at least 33 with 15% oversampling for possible attrition).

Therefore, a total of 34 individuals (21 men, Age: 32.8 ± 8.6 years; *Body Mass Index:* 23.7 ± 2.7 kg/m^2; Experience: 12.5 ± 10.2 years; *Weekly exercise frequency:* 3.7 ± 1.5 days) were recruited from two locations in Lisbon (a university and a health club), to participate in this study. The inclusion criteria were as follows: volunteers aged 18–55 years, apparently healthy, free from injury or any contraindication to exercise, and regularly physically active (i.e., meeting WHO (2020) recommendations). Athletes and/or individuals engaged in professional activities involving regular flexibility exercises (e.g., dancing; gymnastics) were excluded. All participants read and signed an informed consent form prior to the start of the experiment. This study was approved by the institutional review board at the institution of the lead author and, the methods were developed in accordance with the Helsinki Declaration and its later amendments.

4.2. Procedures

4.2.1. Study protocol

Participants took part in two experimental sessions (one week apart). They were instructed to avoid vigorous exercise for at least 48 h prior to each session. At the beginning of the first session, participants completed a battery of sociodemographic and psychometric measures and were briefed about the upcoming activities. Following the guidelines suggested by the ACSM (2021) when prescribing exercise for apparently healthy individuals, some methodological aspects were considered for the development of the protocol. The warm-up was performed on a cycle ergometer (light-to-moderate intensity; 5–7 min) and was followed by five commonly used static passive stretching exercises, focused on most of the large muscle groups (quadriceps, hamstring, gluteus, latissimus dorsi), but also including one minor group (triceps). The routine was performed at three intensities, namely light, moderate, and vigorous, according to the following instructions: stretch until a light (first sensation of stretching), mild (feeling tightness/moderate stretch), or high (vigorous stretch) discomfort was felt in the targeted muscle. Participants were told to hold each respective position for 25 s. A rest of 15 s was given between each routine of five stretching exercises. The dominant side was selected for assessment in each participant, although performing the exercises on both sides. Self-report measures of affective valence (Feeling Scale) and perceived activation (Felt Arousal Scale) were administered halfway during each stretch (at the twelfth second) and immediately after each stretch (at the twenty-fifth second). To investigate the test-retest consistency and repeatability of these measurements, the same procedure was repeated one week later (Unick et al., 2015).

Two researchers were responsible for the data collection. Prior to the collection, they were trained in a small independent sample to ensure an adequate application of these psychometric instruments. Suggestions given by several authors in these scales applications were considered in this process (e.g., Duda, 1998; Ekkekakis & Petruzzello, 2002; Russell et al., 1989). No encouragement to the participants during the protocol implementation was given.

In both sessions, the warm-up was used to familiarize the participants with the FS and FAS. To better differentiate between them and to preserve their discriminant validity, the FS was presented horizontally, whereas the FAS was presented vertically. During the protocol, the researchers highlighted the importance of representing valence and activation experienced in the present moment (e.g., during the stretch).

4.3. Instruments

4.3.1. Feeling Scale and Felt Arousal Scale

The Feeling Scale (FS) Portuguese version (Brito et al., 2022) was used to assess affective valence. The instrument is an 11-point scale ranging from −5 ("very bad") to +5 ("very good"), and has been broadly used to evaluate affective valence during exercise. The Felt Arousal Scale (FAS) Portuguese version (Brito et al., 2022) was used to assess perceived activation. It is composed of a 6-point single-item rating scale, ranging from 1 ("low arousal") to 6 ("high arousal"). The FS and FAS have been used together to assess the two dimensions of the circumplex model (i.e., perceived activation and affective valence) (Evmenenko & Teixeira, 2020; Russell, 1980).

4.4. Statistical analyses

Descriptive statistics were calculated for all variables, and the mean and standard deviation scores presented. Normality and homoscedasticity were evaluated using the Shapiro-Wilk and Levene's tests, respectively. The analysis began with an omnibus analysis of covariance (ANCOVA), with the following within-participants factors: 2 (time: during, post-exercise) by 3 (intensity: light, moderate, vigorous) by 5 (stretching exercises: quadriceps, hamstring, gluteus, latissimus dorsi, and triceps), and sex as a covariate. If violations of sphericity were present for the second and third factors, the degrees of freedom were adjusted using the Greenhouse-Geisser correction (indicated by the presence of decimal figures). Significant main effects and interactions were followed up with pairwise comparisons (Bonferroni for the main effects and Fisher's Least Significant Difference for the interactions). To facilitate interpretation, the uncorrected p values from the pairwise comparisons were multiplied by the number of comparisons, to allow the application of the customary criterion of $p < .05$. For main effects and interactions, partial eta-square (η_p^2) effect sizes were calculated, and the conventional benchmarks suggested by Cohen (1988) were used for interpretation (i.e., "small" effect = 0.01, "medium" effect = 0.06, "large" effect = 0.14). For comparisons between paired means, Cohen's d was calculated (Cohen, 1988) using the formula presented in section 2.3.5 (p. 48), and the respective benchmarks were used for interpretation (i.e., "small" effect = 0.20, "medium" effect = 0.50, "large" effect = 0.80).

For the second objective, we used a two-way random-effects absolute agreement Intraclass Correlation Coefficients (ICC (2,1)) and Bland-Altman plots, as proposed by several authors (Berchtold, 2016; Koo & Li, 2016). The ICC was interpreted as: poor <.50, moderate = 0.50 to 0.74, good = 0.75 to 0.90, and excellent >0.90 (Koo & Li, 2016). All analyses were performed using IBM SPSS v. 27.0. Pre to post-affective scores and Bland-Altman plots were drawn with the ggplot2 package (Wickham, 2022) for R v. 4.0.

5. Results

5.1. Affective responses

Initial screening of the FS and FAS data revealed no outliers or random responses. Descriptive statistics are presented in Tables 1 and 2, and in Figure 1. FS ratings were higher immediately after exercise compared to during exercise. The differences between the two time points were higher across increasing levels of intensity, suggesting that larger declines during stretches of vigorous intensity were followed by larger affective rebounds. For FAS, the ratings were higher during than after exercise, with increasing activation across higher intensity conditions.

The results for the repeated-measures ANCOVAs for FS and FAS ratings in week 1 are presented in Table 3. A main effect of time was present for FS ([F(1, 32) = 14.132, p = .001, η_p^2 = .304]). The examination of the marginal means showed a lower score during exercise (1.331, 95% CI, 0.809 to 1.853) compared to post-exercise (2.461, 95% CI, 1.982 to 2.940). For FAS, the main effects of time ([F(1, 32) = 14.247, p = .001, η_p^2 = .308]), intensity ([F(2, 42.57) = 21.184, p < .001, η_p^2 = .398]), and exercise ([F(4, 128) = 3.511, p = .009, η_p^2 = .099]) were significant. The marginal means showed a higher score during exercise (3.553, 95% CI, 3.147 to 3.959) than post-exercise (2.598, 95% CI, 2.204 to 2.992); a higher mean for vigorous intensity (3.815, 95% CI, 3.359 to 4.270) than moderate (3.059, 95% CI, 2.640 to 3.477) and light

Table 1
Descriptive statistics (*M*±*SD*) of FS ratings for each muscle group, time point, and intensity.

FS	Week 1				Week 2			
	During (12″)	Post (25″)	Δ	*d* intra-end	During (12″)	Post (25″)	Δ	*d* intra-end
	M±*SD*				*M*±*SD*			
Quadriceps								
Light	1.9 ± 1.7	2.4 ± 2.0	−0.5	−0.27	1.8 ± 1.8	1.8 ± 1.8	0	0
Moderate	2.4 ± 1.9	2.9 ± 1.9	−0.5	−0.26	2.0 ± 1.7	2.4 ± 1.6	−0.4	−0.24
Vigorous	0.8 ± 2.4	2.5 ± 1.8	−1.7	−0.8	0.6 ± 2.6	2.1 ± 1.8	−1.5	−0.67
Hamstrings								
Light	1.6 ± 1.7	2.3 ± 1.8	−0.7	−0.4	1.4 ± 1.9	1.7 ± 1.6	−0.3	−0.17
Moderate	1.8 ± 2.0	2.6 ± 1.7	−0.8	−0.43	1.0 ± 2.4	1.9 ± 1.9	−0.9	−0.42
Vigorous	−0.2 ± 2.8	2.1 ± 2.1	−2.3	−0.93	−0.5 ± 2.7	2.1 ± 1.9	−2.6	−1.11
Glutes								
Light	1.9 ± 2.1	2.6 ± 1.9	−0.7	−0.3	1.7 ± 1.6	1.9 ± 1.5	−0.2	−0.13
Moderate	2.1 ± 2.0	2.6 ± 1.8	−0.5	−0.26	1.9 ± 2.0	2.4 ± 1.8	−0.5	−0.26
Vigorous	1.0 ± 2.3	2.4 ± 1.8	−1.4	−0.68	0.9 ± 2.4	2.3 ± 1.8	−1.4	−0.66
Latissimus Dorsi								
Light	1,6 ± 2,1	2.4 ± 1.8	−0.8	−0.41	1.3 ± 2.0	2.0 ± 1.7	−0.7	−0.38
Moderate	1,6 ± 2,4	2.5 ± 1.9	−0.9	−0.42	0.9 ± 2.1	2.1 ± 1.6	−1.2	−0.64
Vigorous	−0,1 ± 2.6	2.2 ± 2.0	−2.3	−0.99	−0.3 ± 2.7	1.8 ± 2.0	−2.1	−0.88
Triceps								
Light	1.8 ± 1.8	2.6 ± 1.7	−0.8	−0.46	1.5 ± 1.7	2.2 ± 1.6	−0.7	−0.42
Moderate	1.4 ± 2.2	2.4 ± 1.8	−1.0	−0.5	1.2 ± 2.1	2.1 ± 1.6	−0.9	−0.48
Vigorous	0.4 ± 2.7	2.4 ± 2.2	−2.0	−0.81	0.3 ± 2.4	2.2 ± 1.9	−1.9	−0.88

Note. Δ = raw mean differences; *d* intra-end = Cohen's *d*.

Table 2
Descriptive statistics (*M*±*SD*) for FAS ratings for each muscle group, time point, and intensity.

FAS	Week 1				Week 2			
	During	Post	Δ	*d* intra-end	During	Post	Δ	*d* intra-end
	M±*SD*				*M*±*SD*			
Quadriceps								
Light	2.3 ± 1.0	2.4 ± 0.9	−0.1	−0.11	2.1 ± 1.0	1.7 ± .9	0.4	0.42
Moderate	3.3 ± 1.5	2.5 ± 1.4	0.8	0.55	3.0 ± 1.1	2.1 ± 1.6	0.9	0.66
Vigorous	4.3 ± 1.4	3.1 ± 1.4	1.2	0.86	4.1 ± 1.6	2.9 ± 1.8	1.2	0.7
Hamstrings								
Light	2.8 ± 1.7	1.9 ± 1.1	0.3	0.13	2.4 ± 1.0	2.0 ± 1.0	0.4	0.4
Moderate	3.4 ± 1.5	2.6 ± 1.4	0.8	0.55	3.2 ± 1.3	2.4 ± 1.1	0.8	0.66
Vigorous	4.7 ± 1.5	2.1 ± 1.6	2.6	1.68	4.5 ± 1.4	3.0 ± 1.5	1.5	1.03
Glutes								
Light	2.6 ± 1.2	1.9 ± 1.1	0.7	0.61	2.1 ± 1.0	1.7 ± 0.9	0.4	0.42
Moderate	3.4 ± 1.4	2.5 ± 1.4	0.9	0.64	2.9 ± 1.0	2.2 ± 1.0	0.7	0.7
Vigorous	4.1 ± 1.4	3.0 ± 1.5	1.1	0.76	3.9 ± 1.3	2.8 ± 1.3	1.1	0.85
Latissimus Dorsi								
Light	3.0 ± 1.4	2.1 ± 1.2	1.1	0.84	2.5 ± 1.1	2.0 ± 1.0	0.5	0.48
Moderate	3.8 ± 1.3	2.8 ± 1.3	−1.0	0.77	3.3 ± 1.2	2.4 ± 1.1	0.9	0.78
Vigorous	4.8 ± 1.5	3.4 ± 1.6	1.4	0.9	4.4 ± 1.4	3.2 ± 1.4	1.2	0.86
Triceps								
Light	2.9 ± 1.3	2.3 ± 1.2	0.6	0.48	2.2 ± 0.8	1.8 ± 0.8	0.4	0.5
Moderate	3.6 ± 1.3	2.7 ± 1.3	0.9	0.69	3.2 ± 1.2	2.5 ± 1.0	0.7	0.63
Vigorous	4.4 ± 1.5	3.2 ± 1.5	1.2	0.8	4.1 ± 1.5	3.2 ± 1.3	0.9	0.64

Note. Δ = raw mean differences; *d* intra-end = Cohen's *d*.

(2.353, 95% CI, 2.028 to 2.678) intensities; and significant differences between quadriceps and hamstring, latissimus dorsi and triceps; hamstring and latissimus dorsi; and glutes, latissimus dorsi and triceps. Specifically, marginal means were higher for latissimus dorsi (3.319, 95% CI, 2.916 to 3.721) than triceps (3.196, 95% CI, 2.795 to 3.597), hamstrings (3.108, 95% CI, 2.715 to 3.500), glutes (2.907, 95% CI, 2.519 to 3.295) and quadriceps (2.848, 95% CI, 2.493 to 3.203). Additionally, one two-way interaction was present in FAS (intensity by exercise; [F(8, 186,81) = 2.551, $p = .022$, $\eta_p^2 = .074$]). Post-hoc analysis showed that the FAS scores were different as intensity increased within each exercise, and in all exercises (all $p < .001$); additionally, when examining differences in FAS ratings in response to each exercise at each level of intensity, differences emerged only in light (quadriceps vs. latissimus dorsi and triceps) and vigorous intensities (exercise quadriceps vs. latissimus dorsi; glutes vs. latissimus dorsi). Finally, sex as a covariate did not yield any significant results, with the sole exception of time by intensity ($p = .03$).

5.1.1. *Interclass correlation coefficients*

The test-retest interclass correlation coefficients are presented in Tables 4 and 5. Overall, the inter-day repeatability for FS and FAS measurements can be characterized as moderate to good across stretched muscle groups. Within each stretched muscle group, the ICC tended to be higher as intensity increased. Specifically, for FS, the ICC for quadriceps stretching performed at light intensity was significantly lower than those obtained from moderate or vigorous intensities. For the FAS, the ICC for quadriceps, hamstrings, glutes, and triceps stretching at light intensities were significantly lower than those obtained from moderate and vigorous intensities. Regarding post-exercise ICC, differences were detected for FAS in quadriceps, glutes, and triceps stretching

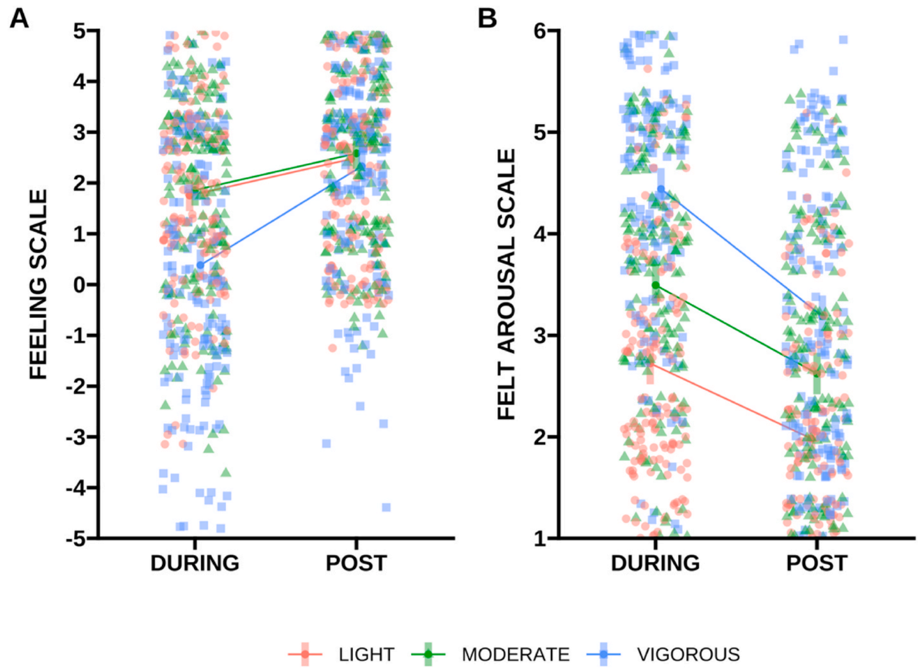

Figure 1. FS (A) and FAS (B) ratings during and following stretching exercises at different intensities.

Table 3
Repeated measures ANCOVA in week 1 for the FS and FAS.

	Week 1					
	ε	df1	df2	F	*p*	η_p^2
Feeling Scale (FS)						
Main effect of time	1	1	32	14.132	.001	.304
Main effect of intensity	.74	2	48.79	1.681	.209	.049
Main effect of exercise	.642	4	84.86	1.667	.196	.048
Time * intensity	.701	2	46.29	1.693	.193	.052
Time * exercise	.869	4	132	1.400	.252	.041
Intensity * exercise	.694	8	264	1.340	.240	.039
Time * Intensity * exercise	.693	8	184.26	.457	.832	.014
Felt Arousal Scale (FAS)						
Main effect of time	1	1	32	14.247	.001	.308
Main effect of intensity	.667	2	42.57	21.184	<.001	.398
Main effect of exercise	.848	4	128	3.511	.009	.099
Time * intensity	.722	2	46.22	1.748	.192	.052
Time * exercise	.960	4	128	1.339	.259	.040
Intensity * exercise	.730	8	186.81	2.551	.022	.074
Time * intensity * exercise	.723	8	256	.570	.802	.018

Note. ε = Greenhouse-Geisser epsilon indicating the severity of the violation of the assumption of sphericity; df_1 = degrees of freedom for the numerator of the F ratio; df_2 = degrees of freedom for the denominator (error) of the F ratio; F = value of the F ratio; *p* = probability of F; η_p^2 = partial eta-squared effect size.

Table 4
Inter-day repeatability statistics for FS measurements for each muscle group stretched at different time points and intensities.

FS	Week 1 vs. week 2 during stretch			Week 1 vs. week 2 after stretch		
	ICC	Lower 95%CI	Upper 95%CI	ICC	Lower 95%CI	Upper 95%CI
Quadriceps						
Light	.605	.201	.803	.660	.326	.829
Moderate	.825	.655	.913	.698	.397	.849
Vigorous	.882	.763	.941	.812	.625	.906
Hamstrings						
Light	.810	.619	.905	.807	.578	.908
Moderate	.827	.603	.919	.740	.430	.876
Vigorous	.862	.726	.931	.777	.551	.889
Glutes						
Light	.799	.600	.900	.707	.382	.857
Moderate	.810	.62	.905	.704	.407	.852
Vigorous	.896	.791	.948	.825	.651	.913
Latissimus Dorsi						
Light	.824	.651	.912	.785	.571	.893
Moderate	.801	.571	.904	.747	.498	.873
Vigorous	.844	.689	.922	.830	.659	.915
Triceps						
Light	.814	.630	.906	.790	.583	.895
Moderate	.888	.778	.944	.876	.753	.938
Vigorous	.892	.781	.947	.897	.795	.948

Note. ICC = Intraclass correlation coefficient; CI = Confidence Intervals.

performed at light intensities compared to moderate (quadriceps and glutes) and vigorous intensities (quadriceps, glutes, and triceps). Light intensity for FS, but particularly for FAS, was associated with the lowest ICC. Intra-exercise assessment, on average, were associated with higher ICC.

5.1.2. Bland-Altman plots

The test-retest agreement results based on Bland-Altman plots can be seen in Tables 6 and 7, and in Figures 2 and 3. The mean bias in FS and FAS repeated measurements is small, the slopes are low, but the limits of agreement (LOA) are rather large, with some measurements falling outside the 95% LOA. This could be concerning in certain settings. For example, FS during quads stretching at light intensity was scored as much as 4 units below and 4 units above the mean bias. However, proportional bias was not observed in repeated FS measurements and was only occasionally observed in repeated FAS measurements (e.g., stretching of the triceps at light intensity and stretching of the glutes at moderate intensity), suggesting that differences increased as mean FAS scores increased. It is not evident that time of measurement or the stretched muscle group influenced the agreement between the FS and FAS repeated measurements. However, proportional bias is evident in some repeated FAS measurements during and after stretching exercises performed at moderate intensity (Figure 3), but not in FS (Figure 2).

The solid orange line shows the mean bias for each comparison. Dashed lines represent the limits of agreement (95% confidence interval) around the mean bias (±1.96 standard deviation [SD]). The solid

Table 5
Inter-day repeatability statistics for FAS measurements for each muscle group stretched at different time points and intensities.

FAS	Week 1 vs. week 2 during stretch			Week 1 vs. week 2 after stretch		
	ICC	Lower 95%CI	Upper 95%CI	ICC	Lower 95%CI	Upper 95%CI
Quadriceps						
Light	.525	.053	.763	.269	−.493	.638
Moderate	.818	.627	.910	.832	.650	.918
Vigorous	.884	.770	.942	.886	.773	.943
Hamstrings						
Light	.700	.385	.852	.649	.290	.825
Moderate	.857	.717	.929	.681	.366	.840
Vigorous	.927	.854	.963	.817	.636	.908
Glutes						
Light	.422	−.106	.705	.581	.169	.790
Moderate	.804	.477	.915	.837	.667	.919
Vigorous	.894	.789	.947	.858	.718	.929
Latissimus Dorsi						
Light	.753	.436	.884	.749	.501	.874
Moderate	.860	.594	.941	.870	.667	.942
Vigorous	.874	.715	.941	.763	.528	.881
Triceps						
Light	.605	.030	.823	.657	.263	.835
Moderate	.843	.678	.923	.812	.627	.906
Vigorous	.905	.798	.954	.883	.766	.942

Note. ICC = Intraclass correlation coefficient; CI = Confidence Intervals.

blue line shows the linear relationship between the mean and difference, with shaded gray showing the 95% confidence interval for this relationship. Pearson's correlation (r) and p value are reported for the correlation between the mean and the difference.

The solid orange line shows the mean bias for each comparison. Dashed lines represent the limits of agreement (95% confidence interval) around the mean bias (±1.96 standard deviation [SD]). Solid blue line shows the linear relationship between the mean and difference, with shaded gray showing the 95% confidence interval for this relationship. Pearson's correlation (r) and p value are reported for the correlation between the mean and the difference.

6. Discussion

The purpose of this study was to 1) compare affective responses during and immediately after stretching exercises in apparently healthy adults, and 2) assess the consistency and repeatability of the affective responses through repeated testing conducted one week apart. An affective rebound effect was detected at all intensities. Although in light and moderate intensities the participants perceived positive affective responses both during and immediately after the stretch, the results were higher after the stretch terminated, indicating a small, but nonetheless existing, affective rebound. For vigorous intensity, this difference was more pronounced (i.e., higher difference in ratings of affective valence during the vigorous-intensity stretch, when compared to immediately after). These results underscore the value of using measures of affective valence to monitor and understand the affective experiences associated with stretching, and clarify that when aiming to promote an improved affective response, how the participant feels during the stretch is paramount, particularly as intensity increases. Additionally, the consistency and repeatability data generally demonstrate temporal stability and, by extension, the test-retest reliability of the measurements and the used method, thus reinforcing previously presented recommendations for the use of the FS and FAS, as for their adequacy in affective responses assessments (Evmenenko & Teixeira, 2020).

6.1. *The timing of affect assessments*

How one feels during an exercise and after the end of an exercise can be substantially different. This realization has led to intensified recent efforts to better understand how this difference should be documented and interpreted, considering the technical challenges associated with obtaining valid ratings from exercisers while the exercise, especially high-intensity exercise, is ongoing (Bastos et al., 2022; Ekkekakis et al., 2011; Ekkekakis et al., 2023a; Ekkekakis et al., 2023b; Henriques & Teixeira, 2023). Although the phenomenon of "affective rebound" (an immediate improvement in the affective response after the cessation of the exercise) has been reliably demonstrated in the context of aerobic exercise (Ekkekakis et al., 2011), and more recently tested in resistance exercise (Andrade et al., 2022), it had not been explored in the context of stretching activities. This has been highlighted in a review on this topic (Henriques & Teixeira, 2023), where no apparent methodological standardization regarding *when* or *how* to obtain ratings of affect in this mode of exercise could be found. Therefore, much confusion remains when trying to interpret the implications of affective response for the important outcomes of adherence and well-being.

Table 6
Summary of Bland-Altman results for inter-day FS measurements for each muscle group stretched at different time points and intensities.

FS	DURING				*p*	POST				*p*
	Δ	95% Lower LOA	95% Upper LOA	Slope		Δ	95% Lower LOA	95% Upper LOA	Slope	
Quadriceps										
Light	.12	−3.55	3.78	−.13	.57	.65	−3.12	4.41	.14	.48
Moderate	.41	−2.28	3.10	.10	.50	.52	−2.49	3.55	.04	.83
Vigorous	.12	−3.07	3.31	−.07	.57	.41	−2.36	3.19	−.05	.77
Hamstrings										
Light	.24	−2.63	2.92	−.14	.37	.59	−1.97	3.14	.12	.43
Moderate	.76	−2.29	3.81	−.21	.13	.73	−2.25	3.72	−.16	.33
Vigorous	.35	−3.44	4.14	.04	.76	−.03	−3.42	3.36	.13	.43
Glutes										
Light	.20	−2.76	3.17	.30	.06	.71	−2.37	3.78	.31	.08
Moderate	.15	−3.06	3.35	−.004	.98	.21	−3.20	3.61	.004	.98
Vigorous	.06	−2.75	2.87	−.05	.67	.14	−2.59	2.88	−.03	.86
Latissimus Dorsi										
Light	.35	−2.69	3.40	.08	.61	.44	−2.42	3.30	.10	.53
Moderate	.76	−2.65	4.18	.19	.20	.41	−2.61	3.43	.22	.21
Vigorous	.24	−3.57	4.03	−.03	.86	.44	−2.50	3.38	.05	.75
Triceps										
Light	.29	−2.37	2.96	.05	.76	.36	−2.33	3.03	.07	.68
Moderate	.26	−2.39	2.92	.02	.87	.26	−2.01	2.54	.06	.64
Vigorous	.06	−3.11	3.23	.13	.26	.21	−2.24	2.66	.16	.15

Note. Δ = difference between paired scores; LOA = Limits of agreement; Slope = beta value of the regression between mean and average values; *p* = p-value of the correlation between mean and average values.

Table 7
Summary of Bland-Altman results for inter-day FAS measurements for each muscle group stretched at different time points and intensities.

FAS	DURING				*p*	POST				*p*
	Δ	95% Lower LOA	95% Upper LOA	Slope		Δ	95% Lower LOA	95% Upper LOA	Slope	
Quadriceps										
Light	.17	−2.05	2.41	−.01	.97	−.06	−2.47	2.35	.02	.95
Moderate	.35	−1.57	2.28	.30	.033	.35	−1.44	2.15	.27	.048
Vigorous	.17	−1.72	2.07	−.09	.45	.15	−1.53	1.83	.16	.17
Hamstrings										
Light	.44	−1.67	2.55	.25	.17	−.06	−2.21	2.09	.10	.63
Moderate	.18	−1.72	2.07	.18	.16	.24	−2.23	2.69	.35	.08
Vigorous	.18	−1.30	1.66	.07	.48	.26	−2.06	2.59	.07	.66
Glutes										
Light	.50	−2.11	3.11	.27	.30	.21	−1.89	2.30	.30	.18
Moderate	.53	−1.16	2.21	.40	.002	.29	−1.41	2.00	.37	.005
Vigorous	.21	−1.38	1.79	.07	.52	.24	−1.70	2.17	.21	.11
Latissimus Dorsi										
Light	.53	−1.47	2.53	.27	.09	.18	−1.72	2.07	.25	.16
Moderate	.50	−1.04	2.04	.09	.45	.41	−1.05	1.86	.23	.04
Vigorous	.41	−1.34	2.16	.09	.46	.21	−2.38	2.79	.19	.28
Triceps										
Light	.74	−1.33	2.79	.51	.006	.50	−1.45	2.45	.43	.002
Moderate	.32	−1.46	2.11	.09	.52	.24	−1.57	2.04	.29	.052
Vigorous	.33	−1.32	1.98	.006	.95	−.03	−1.86	1.80	.13	.30

Note. Δ = difference between paired scores; LOA = Limits of agreement; Slope = beta value of the regression between mean and average values; p = p-value of the correlation between mean and average values.

The present results suggest that a rebound effect is evident during static passive stretching exercises at different intensities and multiple muscle groups, supporting our first hypothesis. This effect was of a larger magnitude (i.e., there was an improvement in the affective response after the stretch ended, when compared to the during-stretch measure) in response to vigorous-intensity stretching, possibly due to greater discomfort emanating from afferent signals (e.g., mechanoreceptors) at this intensity. In the context of aerobic exercise, Ekkekakis et al. (2008) had reported that the post-exercise rebounds in ratings of affective valence were similarly progressively larger following runs below, at, and above the intensity of the ventilatory threshold (0.83, 1.20, 2.63 F S units, respectively) and these were strongly and inversely correlated with the magnitude of during-exercise declines (−0.83, −0.82, −0.82, respectively). Previous recommendations indicated that, to faithfully reflect the contribution of interoceptive and homeostatic disturbances to the affective state, assessments of core affective valence and perceived activation (e.g., feeling good or bad, pleasure or displeasure) should be obtained in a manner that entails relatively low contribution from reflective thought and relevant cognitive appraisals. This implies that the assessments must be obtained as temporarily close to the activity as possible (Ekkekakis et al., 2011; Hardy & Rejeski, 1989). The present results support these recommendations.

These results should also serve as a cautionary note regarding the interpretation of results obtained from previous investigations of affective response to stretching activities. As noted in a recent review on this subject (Henriques & Teixeira, 2023), there is a striking lack of consistency in the timing of assessments of affect in previous studies. The present study results are consistent with results obtained from aerobic and resistance exercise, in suggesting that ratings obtained at different moments during and after the exercise or the exercise session may reflect different constructs besides the core affective response directly emanating from stretching. Thus, this work highlights that the timing of the assessment is crucial, and it seems reasonable to assume that a measurement obtained during the stretch would reflect core affect more accurately compared to a measurement taken after the stretch, even immediately after the exercise.

6.2. *Intensity and the affective response*

The present results also demonstrate the importance of exercise intensity, consistent with data obtained from other exercise modes (Andrade et al., 2022; Ekkekakis et al., 2011; Stevens et al., 2020; Teixeira et al., 2022). In turn, these data have clear and important implications for practitioners wishing to develop exercise options that promote positive affective experiences. As reported, an increase in intensity tends to facilitate increases in pleasure only up to a point, beyond which variability is likely to emerge, with some individuals reporting further increases in pleasure but others reporting the beginning of declines, with a timing and magnitude dependent on relevant individual differences (Ekkekakis et al., 2011; Ladwig et al., 2017). Although it may be reasonable to hypothesize a similar pattern in response to stretching activities, there is a striking paucity of empirical data on this point.

During stretching, the results demonstrated that light and moderate intensities generally resulted in more positive affective responses compared to vigorous intensity, aligning with theoretical assumptions. Moreover, the differences between assessments obtained during and post-exercise were larger for both the FS and FAS as the intensity increased, thus partially supporting the second hypothesis, according to which higher exercise intensities were expected to yield larger differences in the affective valence from during to after each stretch. It should be noted that the main effect of intensity on FS ratings was not significant. Examination of the descriptive data (Table 3 and Figure 1) reveals that FS ratings obtained at light and moderate intensities, both during and post-exercise, were similar, which was not the case for the FAS. A post-hoc comparison between paired observations (not included in the results) showed that FS ratings obtained at the light and moderate intensities did not differ statistically, but both of these conditions differed significantly from the vigorous intensity. This would suggest that these two initial intensities, probably, would not significantly influence the affective state of the participants, and could be used more routinely by professionals concerned with promoting positive affective experiences through exercise.

Perceived activation is also an important component of the affective state, necessary in differentiating between states of the same valence that differ in the degree of perceived activation (e.g., invigoration vs. calmness). The present results are consistent with the expected dose-response relation. As intensity increases, so does perceived activation, and this relation holds both during and following each stretch and across both weeks of testing. As can be seen from the sample characteristics and inclusion criteria, all participants had previous exercise experience and were accustomed to stretching exercises performed at different levels of intensity. This prior experience is important because it allowed

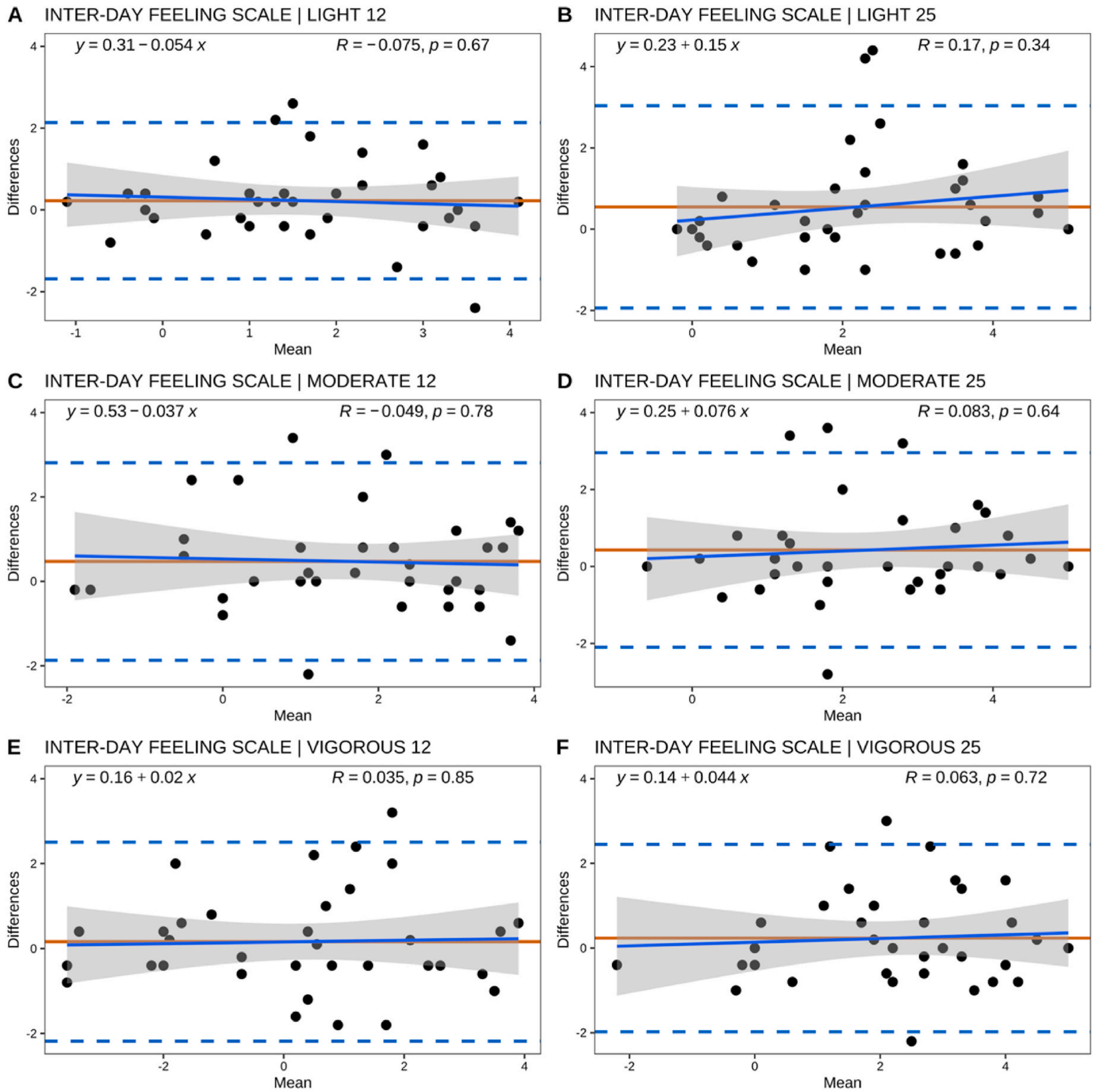

Figure 2. Bland-Altman plots for inter-day FS measurements during and after stretching exercises performed at different intensities.

participants to understand the instructions pertaining to the three levels of intensity (i.e., how to experience the physical strain and sensation of stretching to match the intended intensity). Although it is important to distinguish the construct of perceived activation from the intensity of affective states or the level of perceived exertion or effort, the FAS data suggest that the participants were able to meaningfully implement the instructions they received.

6.3. Test-retest consistency and repeatability

It is important that assessments of affective valence and perceived activation show high consistency across time points and intensities. When keeping the environmental and contextual conditions constant (as much as possible within ecologically valid conditions), a higher degree of score consistency and repeatability indicates that the assessments mainly reflect the constructs the measures are purported to measure rather than random measurement error. This is the logic underpinning the use of test-retest protocols as an indirect indication of measurement reliability (a concept that cannot be quantified directly). In the context of aerobic exercise, allowing participants to self-select their intensity as a way of promoting a positive affective state, assessed via the FS, has been shown to have reasonably high consistency across trials (Hamlyn-Williams et al., 2015; Rose & Parfitt, 2008). However, this question has remained unexplored in the context of stretching activities.

The study results indicate that the inter-day ICC at different intensities of stretching was, in general, moderate to good, with a tendency for higher consistency during vigorous-intensity stretching. FS and FAS ratings during some during-exercise assessments at light intensity were less consistent. Corroborating the results pertaining to main effects for intensity on FS ratings from the repeated-measures ANCOVA, there was no apparent differentiation between the light and moderate intensities. Nevertheless, some indications of a dose-response pattern emerged (i.e., the moderate intensity being associated with slightly more positive FS ratings than light intensity), although the pattern was clearer for FAS. This may suggest that at this intensity (i.e., light) described to the participants as the beginning of the sensation of muscle stretching, there may be insufficient stimulus strength for some participants to experience noticeable effects on affective valence (e.g., interindividual differences in muscle stiffness), thus accounting for the higher variability in both FS and FAS ratings.

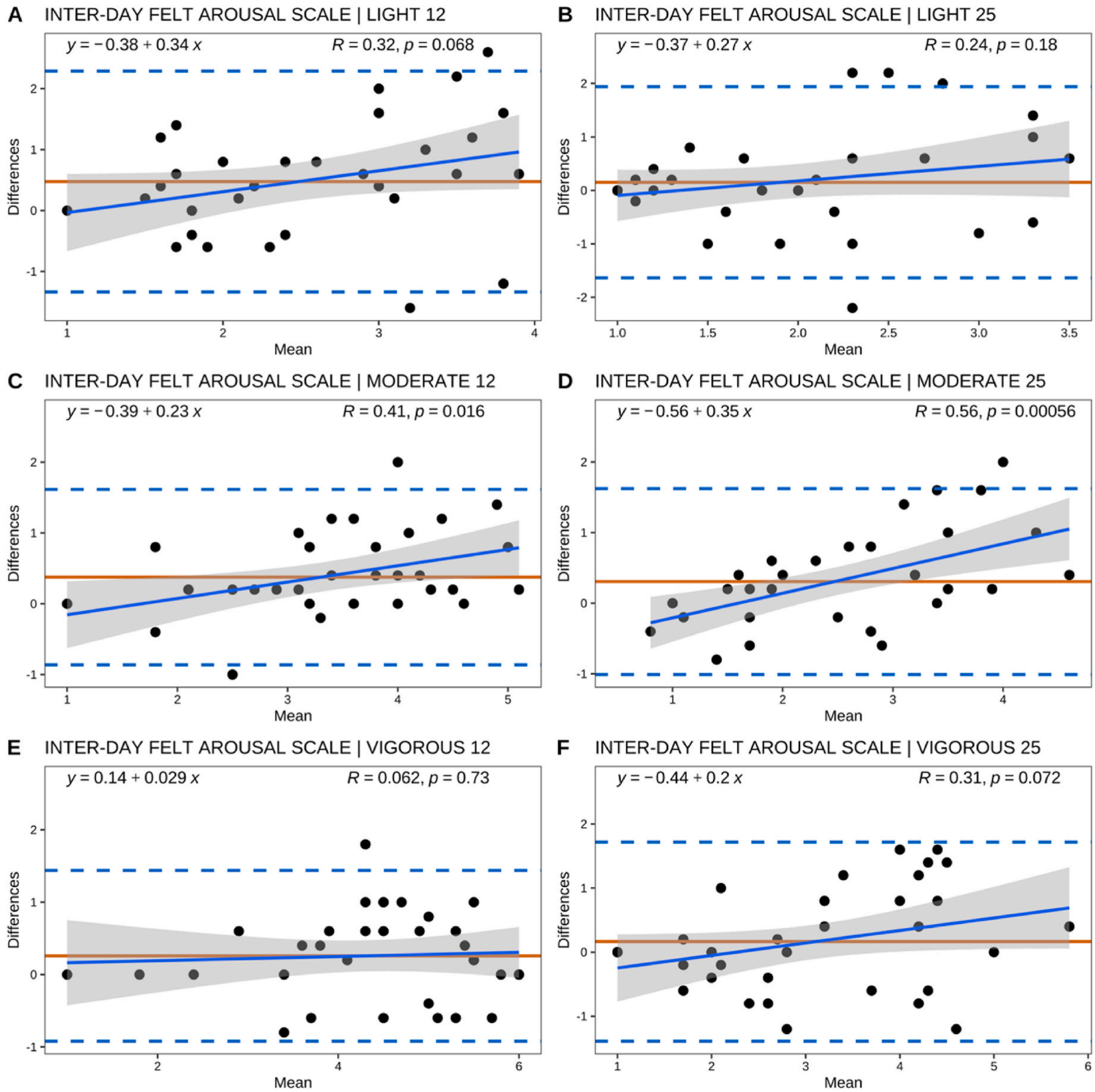

Figure 3. Bland-Altman plots for inter-day FAS measurements during and after stretching exercises performed at different intensities.

The Bland-Altman analysis (Berchtold, 2016) showed that the ratings of affective valence were variable between individuals, as indicated by the high standard deviations and wide confidence intervals, particularly at light and moderate stretching intensities. Moreover, some LOA were rather large. In these cases, participants rated their affective state as much as 4 F S units below and 4 F S units above the mean bias, and the standard deviation of FS ratings during stretching was consistently higher than the mean value. Nevertheless, most of the measurement points were within the LOA. As recommended by Giavarina (2015), the LOA range should be interpreted based on "analytical, biological or clinical goals," thus helping to determine the usefulness of the measurement instruments and research methods used. A study using a similar assessment protocol and the same measurement instruments but with resistance exercise (Andrade et al., 2022) also found that the standard deviation of FS ratings was considerably larger the mean score. This suggests that the large LOA observed in the present study should not be considered surprising.

The test-retest results were partially expected. It is well established that individuals differ in the intensity of exercise they prefer and can tolerate (Ekkekakis et al., 2005a; Hall et al., 2014; Teixeira et al., 2022). These individual differences manifest themselves in that, in response to levels of intensity that pose an appreciable but manageable challenge, some individuals continue feeling good, whereas others begin to feel worse (Evmenenko & Teixeira, 2020; Ladwig et al., 2017). In the present study, since the intensity of the stretches was defined by the degree of discomfort felt during the stretch, it was expected that some variations would exist in the degree of stretching across sessions and between participants, an issue that future studies could try to address. Furthermore, due to inevitable logistical constraints, not all individuals could be tested at the exact same time over the two consecutive weeks. For example, it is reasonable to expect that the ability to stretch could exhibit minor circadian variation, where morning workouts, particularly with stretching exercises in the proximity of the waking time, may be limited given some rigidity resulting of the night motionless period (Gifford, 1987; Teo et al., 2011). This would probably not occur several hours after waking up. Thus, contemplating the time of day and possible contextual and individual characteristics that may be needed for test consistency and repeatability, are relevant for future efforts on the topic and results interpretation. Conceivably, when taken together, these factors could account for part of the observed variability in FS and FAS ratings. Nevertheless, in general, the obtained results tend to support the reliability of the measurements (i.e., psychometric instruments and data-collection procedures), and seem in line with the variation in affective valence and perceived activation that can be expected across time and intensity levels. Therefore, the results reported herein partially support the third hypothesis, according to which the assessments of affective response assessments were expected to exhibit temporal stability.

6.4. Limitations and future directions

Although the present study advanced the current understanding of affective responses to stretching activities, some limitations and areas of future research efforts should be noted. Regarding the sample characteristics, the conclusions are limited by the fact that only apparently healthy and experienced exercisers were enrolled. Thus, caution is warranted when extrapolating results from the present investigation to other populations. For example, limitations related to musculoskeletal pain may confound the interpretation of FS and FAS ratings, given that the exercisers may be more prone to report lower FS and higher FAS scores. On another relevant consideration, exercise (in)experience may accentuate the dose-effect pattern, particularly at lower intensities (i.e., feeling lower pleasure), something the present study could not ascertain, and that may add relevance to the assessment of the affective response throughout the exercises.

Another issue that deserves attention pertains to the study design. First, an objectively defined stretching intensity (e.g., through goniometry), could have been used, operationalizing each intensity as a percentage of the respective range of motion. Additionally, a cross-over, fully counterbalanced design could have been used. In this study, the intensities always progressed from light to moderate to vigorous. It is, therefore, unclear whether or to what extent the present results reflect an order effect. This decision was dictated by two considerations. First, if a sequence of intensity conditions started with vigorous stretches, it is reasonable to suggest that the initial affective responses would have influenced the data obtained during the subsequent conditions (i.e., light and moderate). Second, avoiding or minimizing such carry-over effects would have required pauses long enough to compromise the ecological validity of the investigation (i.e., the procedure would not have resembled common practice). Therefore, to properly address the issue of the possible order effects, future investigations should use either a randomized parallel-group approach or a within-participant design with multiple sessions, each involving only one level of intensity, performed on different days, with the order of the days randomized and counterbalanced.

Moreover, the order of stretches, the choice of muscles (larger muscle groups vs. smaller muscle groups), and the type of stretching (static vs. dynamic; active vs. passive; individually performed vs. in a group class) should be considered in future studies on this topic. Although largely understudied, it is conceivable that some muscle groups would depict distinct affective responses, according to individual characteristics and adaptations, as seen for example, in the hamstrings and latissimus dorsi results during high-intensity stretching (both with negative scores and high standard deviations). If this hypothesis comes to be true, then the order of the exercises could also be relevant when promoting a positive affective experience during exercise, given that promoting positive end-session feelings is suggested to be relevant for exercise promotion (Hutchinson et al., 2023; Zenko et al., 2016). Additionally, different types of stretching may impose different experienced intensities. It is reasonable to assume that static active stretching would depict a similar trend in results, although with different magnitudes, considering that it is harder in that exercise mode to approximate the maximal range of motion.

Finally, it is noteworthy that, although all participants were regular exercisers and familiar with the stretching techniques that were used, it is possible that they might have controlled the intensity during vigorous stretching, because mean FS ratings only seldom reached negative values. This may suggest that most participants remained within their “comfort zone” during vigorous-intensity stretching. Although it is not uncommon to see concurrent low FS and high FAS ratings (for a review, see Ekkekakis et al., 2011; Evmenenko & Teixeira, 2020), besides an objectively defined level of stretching intensity, the addition of an assessment on the degree or proximity to maximal stretching effort may help shed some light on this issue.

In conclusion, the timing of the assessment of affect ratings in response to stretching activities matters. The present results showed that an affective rebound was present at all intensity levels, although its magnitude was amplified in vigorous-intensity stretching exercises. For adequate assessment of core affective responses, ratings must be obtained during the stretches. Furthermore, the present results provided evidence in support of the test-retest reliability of affect measurements (i.e., self-report instruments and assessment protocol) in response to stretching activities.

Declaration of competing interest

The authors have no conflicts of interest.

Data availability

Data will be made available on request.

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