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Affective responses to resistance exercise: Toward a consensus on the timing of assessments

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A R T I C L E I N F O

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A B S T R A C T

Tailoring exercise prescriptions aimed at improving affective responses to resistance exercise may promote pleasurable experiences and thus exercise adherence. The purpose of this study was to evaluate different timing protocols for administering rating scales for the assessment of affective valence (Feeling Scale, FS) and perceived activation (Felt Arousal Scale, FAS) during resistance exercise. Thirty-three experienced male exercisers (M = 36.42 ± 7.72 years) completed the FS and FAS at different times at three percentages of one-repetition maximum (%1RM) during two exercises (bench press, squat). No differences emerged among different assessment time points and %1RM. These findings suggest that the post-exercise "affective rebound" phenomenon found in aerobic exercise may not be as pronounced in resistance exercise. Therefore, the results support the use of FS and FAS in resistance exercise, administered immediately after a set, over a wide range of %1RM and exercises. Mounting evidence suggests that the use of these scales in resistance exercise could allow researchers and practitioners to evaluate affective responses that may be important for adherence.

1. Introduction

Resistance exercise has consistently ranked among the most popular exercise modalities in surveys of fitness trends over the past five years (Batrakoulis, 2019), and confers several benefits for health and well-being (American College of Sports Medicine, 2018). In order to best serve the interests of exercise participants, exercise professionals should base their practice on the best scientific evidence, aiming to provide individualized exercise prescriptions aligned with the participants' needs and characteristics (Rodrigues et al., 2019). However, the persistently high dropout rates reported in several studies (Buckworth et al., 2013; Sperandei et al., 2016) suggest that innovative approaches should be developed to better adjust training protocols to individual needs and thus enhance the exercise experience to facilitate adherence (Carraro et al., 2018; Cavarretta et al., 2018).

1.1. The hedonic approach to resistance exercise

Given the need to devise interventions that can promote exercise adherence, several psychological frameworks have been applied to exercise settings with the aim of encouraging behavioral maintenance and dropout avoidance (Ekkekakis & Dafermos, 2012; Ekkekakis & Zenko, 2016). In recent years, affective responses to bouts of exercise have been identified as predictors of future physical activity engagement and have, therefore, been targeted as constructs that should be considered in behavior-change strategies (Chen et al., 2020; Rhodes & Kates, 2015).

The hedonic approach to exercise postulates that participants tend to engage in activities that may bring about pleasure and avoid displeasure, and emerging evidence has supported these assumptions (e.g., Calder et al., 2020; Williams et al., 2008). The relation between exercise and affective responses is partly influenced by exercise intensity, with higher exercise intensities generally associated with lower scores of

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pleasure or increased displeasure (Evmenenko & Teixeira, 2020; Rhodes & Kates, 2015; Williams et al., 2008).

In the case of resistance training, few studies have focused on understanding the dynamics of intensity and pleasure/displeasure, and thus a considerable gap exists in the current knowledge of the affective consequences of resistance training. Given the worldwide popularity of resistance training, more research on this training modality and its affective consequences is urgently needed (Evmenenko & Teixeira, 2020).

A review by Cavarretta et al. (2018) focusing on the acute effects of resistance training on affect showed that eight of the 14 studies reported affective improvements. However, most of these studies only examined pre-to post-exercise changes, failing to assess how affective dynamics during the session are influenced by different exercise protocols. This is a limitation insofar as it has been proposed that how one feels *during* exercise is a predictor of future physical activity behavior, whereas affect ratings obtained after exercise are not (Greene & Petruzzello, 2015; Williams et al., 2008).

Of the 14 studies included in the review by Cavarretta et al. (2018), the majority measured affect with the Feeling Scale (FS; Hardy & Rejeski, 1989), which is a rating scale that assesses the dimension of affective valence, and the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985), which is rating scale that assesses the dimension of perceived activation. The advantage of using these two scales together repeatedly during an exercise session is that they allow plotting the trajectory of the affective response to a session of exercise within the two-dimensional "circumplex model" of affect (for a review, see Ekkekakis et al., 2011). However, Cavarretta et al. (2018) emphasized that, due to different measurement procedures (in particular, the timing of affect assessments), results based on FS/FAS measurements during sessions of resistance exercise should be viewed with caution, since measurement time points and procedures varied across studies.

This issue was further addressed by Cavarretta et al. (2019a), who proposed that 'timing matters' when assessing the dynamics of affect during resistance exercise. In this study, the authors examined affective responses (measured only with the FS) in the beginning, during sets, between sets, and 5 and 30 min after exercise. The results underscored the importance of defining distinct measurement time points for the interpretation of the data. Specifically, measurements taken during sets resulted in lower FS scores compared to measurements taken between sets. This difference was also detected in the systematic review conducted by Evmenenko and Teixeira (2020), which aimed to explore the usefulness of the FS and FAS within the framework of the circumplex model of affect. In this systematic review, five studies were found to have used these scales in resistance-exercise settings. However, it was emphasized that "more evidence is needed to understand if intra-exercise measures should be made during sets, immediately after a set, after a bout of sets, and so on" (Evmenenko & Teixeira, 2020, p. 25). In another study, by Emanuel et al. (2020), which used the FS in a repetition-by-repetition analysis, it was reported that FS scores revealed differences between the last exercise repetition and a 10-s post-set measure, with the last measurement being higher (i.e., indicating more pleasure). Therefore, previous research has underscored the importance of the timing of assessments of affect in ensuring a fuller description and more accurate interpretation of the dynamics of affective responses to resistance exercise.

In resistance training, the percentage of the 1-Repetition Maximum (%1RM) is the metric commonly used to express exercise intensity (<30%: "very light"; 30% to < 50%": "light"; 50% to <70%: "moderate"; 70% to <85%: "vigorous"; ≥85%: "near maximal"; American College of Sports Medicine, 2018). Intensity is expected to influence how exercisers feel during training.

In a study by Greene and Petruzzello (2015), the results showed differences between the 70% and 100% 1RM in FS and FAS scores, with the higher %1RM resulting in lower affective valence and higher perceived activation during exercise. These results were supported in the review by Cavarretta et al. (2018), in which affective improvement was detected particularly when the %1RM was around 50–70%. In the study by Cavarretta et al. (2019b), the same trend emerged with the FS, with the affective valence response becoming less positive with higher %1RM. In addition, Emanuel et al. (2020) showed that the pattern of FS scores supported the same intensity-affect relationship (i.e., higher exercise %1RM – lower FS scores). With these results in mind, several authors have suggested that additional research is needed to clarify the role of differences between protocols, suggesting, for example, that moderate (i.e., <70% 1RM) and near maximal (80% and 90% 1RM) intensity conditions should also be tested for comparison, given the mixed results reported in previous literature (Bellezza et al., 2009; Emanuel et al., 2020; Greene & Petruzzello, 2015; Portugal et al., 2015).

1.2. Present research

Considering the results of previous studies, the pattern of affective valence and perceived activation responses obtained during sessions of resistance exercise warrants methodological clarification. If there is a link between how one feels during resistance exercise and the likelihood of sustaining the behavior, a proper methodological platform must be developed as a solid foundation for future investigations. The potential from developing such a platform is considerable and includes (a) training exercise professionals and exercisers on how to properly use and interpret rating scales of affective valence and perceived activation, (b) testing the reliability of patterns across different %1RM and exercises, and (c) standardizing a timing protocol for the administration of these scales that would allow research to advance while at the same time minimizing intrusion and safeguarding ecological validity (Duda, 1998; Evmenenko & Teixeira, 2020).

Research with aerobic exercise has documented an *affective rebound* phenomenon, whereby a high percentage of participants experience a positive affective change immediately after the cessation of exercise that led to affective decline during the session, akin to an affective "rebound" or "relief effect" (Ekkekakis et al., 2011). If a similar phenomenon exists in resistance exercise, then affect should also be sampled during a set (i.e., while muscles are still under tension) rather than only before and immediately after the set (i.e., when muscles are no longer under tension). However, several concerns emerge from this suggestion, particularly given the following considerations. First, the literature on the topic is scarce, based on small samples, and lacking evidence of previous trainer-trainee preparation for proper application and interpretation of the FS and FAS (Evmenenko & Teixeira, 2020). Second, resistance exercise involves distinct physiological demands and results in different outcomes and adaptations compared to aerobic exercise, thus possibly entailing distinct trajectories of affective changes during the session (for example, given the inter-set rest period; Cavarretta et al., 2019a). Third, the instructions that accompany the administration of the FS (Hardy & Rejeski, 1989) and FAS (Svebak & Murgatroyd, 1985) inquire about "how one feels" and "how activated" the individual is in the present moment. Fourth, in "real-life" contexts (e.g., in gymnasia or health clubs), assessments during sets (i.e., during muscle contraction, when transitioning from the concentric to the eccentric phase, while the muscle is under tension), will likely be considered overly obtrusive and impractical, thus limiting the application of the FS/FAS and the circumplex model as a method of gauging and adjusting the intensity of training.

These limitations warrant attention if pragmatic interventions are to be developed with the aim of enhancing affective responses to resistance exercise and encouraging adherence. With this in mind, the main purpose of the present study was to evaluate different measurement time points for the administration of the FS and FAS across moderate to near-maximal resistance exercise in upper and lower-body exercises in a sample of male health club exercisers. For this purpose, a timing protocol was defined (see Procedures) with three intra-session measurement time points (intra-set; end-of-set; 10-s post-set recall) across three %1RM (60%, 75%, 90% 1RM) in upper (bench press) and lower-body (squat) exercises.

We hypothesized that no significant differences would exist between the intra-set and the end-of-set measurements, thus supporting the use of an *immediate* post-set measure as a sufficient measure of core affective responses to resistance exercise, questioning the presence of an "affective rebound" in the context of resistance exercise, contrary to what has been reported in some previous studies that utilized a variety of methods and measurement approaches (Evmenenko & Teixeira, 2020; Portugal et al., 2015). Moreover, we anticipated to confirm that the FS and FAS would show a decline in affective valence and an increase in perceived activation, respectively, across increasing %1RM in both upper and lower-body exercises, thus replicating past results (Cavarretta et al., 2019b; Elsangedy et al., 2018; Greene & Petruzzello, 2015).

2. Method

2.1. Participants

The sample size was determined through power calculations conducted with G*Power v.3.1 (Faul et al., 2009), using the following input parameters: medium anticipated effect size for a comparison between two dependent means ($d = 0.50$), statistical power $1\text{-}\beta = 0.80$, and $\alpha = 0.05$. Given that no study has presented results directly relevant to the effect being targeted in the present study, estimates of effect sizes pertaining to affective responses to similar experimental manipulations within the context of resistance exercise were used (e.g., Cavarretta et al., 2019b). Particularly, the comparison between muscles-under-tension vs. muscles-not-under-tension would be equivalent to the comparison between high-level resistance (e.g., 100% 10RM) vs. low-level resistance (e.g., 50% 10RM), albeit with affective ratings obtained after the repetitions. For the bench press and the squat, prior effect sizes in the reported study were found to be medium (Cavarretta et al., 2019b). Based on these calculations, the target sample size determined for present study was of 33 ($1\text{-}\beta = 0.795$) or 34 ($1\text{-}\beta = 0.808$).

A total of 33 participants were included following screening for eligibility criteria ($M_{\text{age}} = 36.42 \pm 7.72$ years; $M_{\text{experience}} = 12.05 \pm 7.27$ years; $M_{\text{BMI}} = 25.17 \pm 2.23$ kg/m^2). The inclusion criteria were the following: male volunteers aged 18–50 years, apparently healthy, free of injury or any contraindication to exercise, and engaging in a resistance training regimen regularly (>3 months of continuous participation). All participants read and signed an informed consent form prior to the experiment. This study protocol was approved by the Faculty of Physical Education and Sport of the Lusófona University institutional review board and was developed in accordance with the Helsinki Declaration and its later amendments.

2.2. Procedures

2.2.1. Study protocol

Study participants took part in two experimental sessions. All participants were instructed to avoid vigorous exercise for at least 48 h prior to each session. No verbal encouragement was provided during the sessions, in order to standardize the experimental conditions and limit the influence of the researcher on perceptual and affective responses.

In the first session, participants were briefed about the upcoming procedures, completed questionnaires, and were tested to estimate their 1-repetition maximum (1RM) for the bench press and squat exercises, following the regression equations developed by Reynolds et al. (2006) for 4- to 8-RM. Based on individual performances, 60% (moderate), 75% (vigorous), and 90% (near maximal) of 1RM were then calculated (American College of Sports Medicine, 2018). This was done after a brief general warm-up on a treadmill (low-to-moderate intensity; 5–7 min), and a specific warm-up for the two resistance exercises (adjusted for 8–10 repetitions).

The second session started with the same general and specific warm-up procedures as the first. The exercise volume for the three %1RM conditions was equated based on the interaction of sets x repetitions x load (total volume ranged between 1800 and 2250 kg). Specifically, for 60% 1RM, there were 2 sets of 15–17 repetitions, for 75% 1RM, there were 3 sets of 8–10 repetitions, and for 90% 1RM, there were 4 sets of 5–6 repetitions, following the recommendations of previous studies (e.g., Cavarretta et al., 2019a). The intra-set measurement time point was taken near the midpoint of the volume determined for each %1RM condition. Specifically, affect was sampled at the 14th-to-15th repetition of the first set for 60% 1RM, at the 4th-to-5th repetition of the second set for 75% 1RM, and at the 4th-to-5th repetition of the second set for 90% 1RM. A second measurement was taken immediately after the end of the last set of each %1RM condition. A 10-s post-set affective-recall measurement was also collected. The rest period was 90 s between sets and 3 min between %1RM conditions. The exercise cadence was defined at 2:2. The upper body exercises were performed first for all %1RM conditions (ordered from lower to higher: 60%, 75%, 90%).

Following the recommendations by Duda (1998) and Evmenenko and Teixeira (2020) on the use of psychometric scales, the standardized instructions and item stems were read to the participants, and several examples were given to explain what the instruments were intended to assess. In the examples, the exercisers were asked to recall activities they were using in their current training that would approximate the extreme and the middle parts of the bipolar rating scales (i.e., the FAS and FS). Additionally, the warm-up activities used in the first and second sessions (e.g., prior to the determination of %1RM in the first session), were used to familiarize the participants with the psychometric instruments, emphasizing that the ratings of affective valence and perceived activation should represent these feelings experienced *in the present moment* (e.g., immediately after the set).

During warm-up activities, the researchers explained how and when the measures of affective valence (FS) and perceived activation (FAS) would be administered. Specifically, ratings were collected at three time points during each %1RM condition for each exercise, including (a) an intra-set measurement (obtained during a brief pause with the muscles still under tension and at the point of transition from the concentric to the eccentric phase), (b) an end-of-set measurement (taken immediately after load removal), and (c) a recall measurement (obtained 5–10 s post-set, with the instruction "how did you feel during this last set?").

Data collection was carried out by two of the researchers. Both were trained on the administration of the psychometric instruments on a small independent sample prior to the beginning of the study, following the instructions provided by the developers of the instruments, as well as other relevant studies pertaining to related psychometric assessments (e.g., Russell et al., 1989).

2.3. Instruments

2.3.1. Feeling Scale and Felt Arousal Scale

Affective valence was measured with the Feeling Scale (FS; Hardy & Rejeski, 1989). The FS is an 11-point bipolar rating scale ranging from −5 (I feel "very bad") to +5 (I feel "very good"). The FS has been widely used to assess affective valence during exercise and has demonstrated satisfactory validity (Hardy & Rejeski, 1989) through correlations with other measures of affective valence (Evmenenko & Teixeira, 2020). Perceived activation was measured with the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985). The FAS is a 6-point single-item bipolar rating scale, ranging from 1 to 6 with verbal anchors of (1) "low arousal" and (6) "high arousal." The FAS has been used in exercise research in conjunction with the FS (Evmenenko & Teixeira, 2020) to assess the two dimensions of the circumplex model (i.e., perceived activation and affective valence, respectively). Both scales were translated to Portuguese and were found to demonstrate acceptable validity (Brito et al., in press).

2.4. Data analysis

Descriptive statistics (means and standard deviations) were calculated for all variables. The Shapiro-Wilk and Levene's tests were used to verify normality and equal variances, respectively. A 2 (exercises: bench press, squat) by 3 (%1RM: 60%, 75%, 90%) by 3 (time points: intra-set, end-of-set, post-set) repeated-measures ANOVA was conducted to examine differences in the dependent variables (FS, FAS). For these analyses, Mauchly's test was used to examine the assumption of sphericity for the two independent variables with three levels (i.e., %1RM, time). In case of sphericity violations, ANOVA results based on Greenhouse-Geisser-adjusted degrees of freedom are reported, as suggested by Ho (2014), and are indicated by decimal degrees of freedom. The Greenhouse-Geisser adjustment was selected because it is more conservative compared to the Huynh-Feldt. Significant ANOVA main effects and interactions were followed up by Bonferroni-adjusted post-hoc tests to analyze pairwise comparisons. It should be noted that, for ease of interpretation, the uncorrected p values resulting from the pairwise comparisons were multiplied by the number of pairwise comparisons, so the reported p values can be evaluated by the customary criterion of $p < 0.05$. Finally, η_p^2 effect sizes were calculated for the ANOVAs ("small" effect = 0.01, "medium" effect = 0.06, "large" effect = 0.14; Cohen, 1988). For comparisons between means, we used d based on the formulas proposed by Cohen (1988, Section 2.3.5, p. 48) for one-sample differences between paired observations ("small" effect = 0.20, "medium" effect = 0.50, "large" effect = 0.80). Specifically:

$$d_{rm} = \frac{\bar{x}_1 - \bar{x}_2}{S_{rm}}$$

where

$$S_{rm} = \frac{S_z}{\sqrt{2(1-r)}}$$

And, in turn,

$$S_z = \sqrt{S_1^2 + S_2^2 - 2rS_1S_2}$$

3. Results

A preliminary examination revealed no missing values. In addition, no violations of the assumption of distributional normality were detected, since the results from Shapiro-Wilk tests were higher than 0.05, ensuring appropriate conditions for the use of parametric tests (Ho, 2014).

The characteristics of the participants are presented in Table 1. As can be seen, the male exercisers in the present sample had a mean age of 36 years, averaged over 12 years of experience, and had slightly above-normal body mass index. Additionally, their mean 1RM bench-press performance reflected an excellent ratio (1.19) of weight pushed to body weight (American College of Sports Medicine, 2018). The corresponding squat ratio was 1.57 (no normative values exist for this test for recreational exercisers).

The descriptive statistics related to FS and FAS ratings during the experimental conditions are presented in Table 2. The end-of-set FS and FAS ratings across the three %1RM conditions were compared as a manipulation check (Table 2). The FS and FAS differed significantly among the %1RM conditions for both exercises (all $p < 0.001$). Bonferroni-adjusted comparisons showed that the only non-significant comparison was for the FAS between 75% 1RM and 90% 1RM (mean difference = −0.424, $p = 0.225$).

Table 1
Descriptive statistics (means, standard deviations) for participant characteristics.

	M	SD
Age (years)	36.42	7.72
Body mass (kg)	77.88	8.20
Body Mass Index (kg/m^2)	25.17	2.23
Experience (years)	12.05	7.27
1RM bench press (kg)	95.66	9.52
1RM squat (kg)	122.27	15.13

Table 2
Means (± standard deviations) of Feeling Scale (FS) and Felt Arousal Scale (FAS) ratings for all experimental conditions. Raw-score differences (Δ) and Cohen's effect sizes (d) for the mean differences between the intra-set and end-of-set ratings are also shown.

		Intra-set	End-of-set	Post-set	*Δ*, *d* intra-end
Feeling Scale (FS)					
Bench-press	60% 1RM	1.61 ± 1.54	1.88 ± 1.96	1.70 ± 1.65	*Δ* = −0.27; *d* = −0.15
	75% 1RM	0.94 ± 2.32	0.30 ± 2.76	0.55 ± 2.44	*Δ* = 0.64; *d* = 0.25
	90% 1RM	−0.88 ± 2.93	−1.12 ± 3.25	−0.79 ± 3.10	*Δ* = 0.24; *d* = 0.08
Squat	60% 1RM	1.46 ± 1.52	0.64 ± 1.83	0.76 ± 1.56	*Δ* = 0.82; *d* = 0.48
	75% 1RM	0.06 ± 2.08	−0.55 ± 2.40	−0.33 ± 2.19	*Δ* = 0.61; *d* = 0.27
	90% 1RM	−1.27 ± 2.82	−1.91 ± 3.50	−1.55 ± 3.45	*Δ* = 0.64; *d* = 0.20
Felt Arousal Scale (FAS)					
Bench-press	60% 1RM	3.18 ± 1.01	3.64 ± 0.99	3.52 ± 0.91	*Δ* = −0.46; *d* = −0.45
	75% 1RM	4.15 ± 0.87	4.67 ± 0.86	4.55 ± 0.79	*Δ* = −0.52; *d* = −0.60
	90% 1RM	4.85 ± 0.80	5.09 ± 1.31	5.12 ± 1.24	*Δ* = −0.24; *d* = −0.22
Squat	60% 1RM	3.70 ± 1.16	3.91 ± 1.23	3.94 ± 1.12	*Δ* = −0.21; *d* = −0.18
	75% 1RM	4.58 ± 1.00	4.88 ± 0.93	4.79 ± 0.93	*Δ* = −0.30; *d* = −0.31
	90% 1RM	5.12 ± 0.96	5.30 ± 1.05	5.33 ± 0.86	*Δ* = −0.18; *d* = −0.18

The results of the repeated-measures ANOVAs for the FS and FAS ratings are shown in Table 3 (also see Figure 1). For both dependent variables, all three main effects (exercise, %1RM, time) were significant but none of the two- and three-way interactions was significant.

For FS, examination of the marginal means showed (1) a lower rating associated with the squat (−0.300, 95% CI -0.972 to 0.373) than the bench press (0.465, 95% CI -0.227 to 1.156), with a mean difference of 0.764 ($p = 0.040$), (2) a progressive decline from 60% 1RM (1.338, 95% CI 0.905 to 1.772) to 75% (0.162, 95% CI -0.500 to 0.823), to 90% (−1.253, 95% CI -2.171 to −0.334), with significant declines from 60% to 75% ($p < 0.001$) and from 75% to 90% ($p < 0.001$), and (3) a V-shaped pattern in ratings over time, with a marginal mean of 0.318 intra-set (95% CI -0.191 to 0.827), −0.126 at end-of-set (95% CI -0.795 to 0.543), and 0.056 at 10-s post-set recall (95% CI -0.548 to 0.659). Although the 10-s post-set recall was in-between the two previous ratings and did not differ significantly from either one (mean difference of 0.262, $p = 0.217$, $d = 0.17$; and mean difference of −0.182, $p = 0.056$, $d = -0.10$, respectively), the overall average of intra-set ratings differed from the overall average of end-of-set ratings (mean difference of 0.444, $p = 0.028$, $d = 0.27$).

For FAS, examination of the marginal means showed (1) a higher rating associated with the squat (4.616, 95% CI 4.333 to 4.900) than the bench press (4.306, 95% CI 4.060 to 4.553), with a mean difference of 0.310 ($p = 0.027$), (2) a gradual increase across the levels of %1RM, from 60% (3.646, 95% CI 3.359 to 3.934), to 75% (4.601, 95% CI 4.376 to 4.827), to 90% (5.136, 95% CI 4.863 to 5.409), and (3) an inverted-V-shaped pattern in ratings over time, with a marginal mean of 4.263 intra-set (95% CI 4.039 to 4.486), 4.581 at end-of-set (95% CI 4.315 to 4.847), and 4.540 at the 10-s post-set recall (95% CI 4.297 to 4.784). The mean differences from the intra-set assessment to end-of-set (−0.318, p

Table 3
Results of main effects and interactions from the 2 (exercises: bench-press, squat) by 3 (%1RM: 60%, 75%, 90%) by 3 (time points: intra-set, end-of-set, post-set recall) repeated-measures analyses of variance (ANOVAs) for Feeling Scale (FS) and Felt Arousal Scale (FAS) ratings.

	ε	df_1	df_2	F	p	η_p^2
Feeling Scale (FS)						
Main effect of exercise	1.000	1.000	32.000	4.592	**0.040**	0.125
Main effect of %1RM	0.620	1.240	39.673	29.775	< **.001**	0.482
Main effect of time	0.663	1.326	42.433	5.846	**0.013**	0.154
Exercise by %1RM	0.659	1.318	42.169	0.116	0.803	0.004
Exercise by time	0.618	1.237	39.573	3.509	0.060	0.099
%1RM by time	0.452	1.806	57.797	0.900	0.403	0.027
Exercise by %1RM by time	0.801	3.203	102.502	2.386	0.069	0.069
Felt Arousal Scale (FAS)						
Main effect of exercise	1.000	1.000	32.000	5.387	**0.027**	0.144
Main effect of %1RM	0.671	1.342	42.947	90.731	< **.001**	0.739
Main effect of time	0.648	1.295	41.448	10.495	**0.001**	0.247
Exercise by %1RM	0.778	1.555	49.767	0.431	0.602	0.013
Exercise by time	0.713	1.426	45.616	1.241	0.288	0.037
%1RM by time	0.573	2.291	73.297	0.588	0.580	0.018
Exercise by %1RM by time	0.459	1.836	58.737	0.183	0.815	0.006

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

$= 0.007$, $d = -0.46$) and 10-s post-set recall (-0.278, $p = 0.004$, $d = -0.42$) were both significant. On the other hand, the mean difference from end-of-set to the 10-s post-set recall was not (0.041, $p = 1.000$, $d = 0.06$).

4. Discussion

The aim of the present study was to evaluate the role of obtaining ratings of affective valence (FS) and perceived activation (FAS) at different time points during a resistance exercise protocol at intensities ranging from moderate to near maximal in both upper- and lower-body movements in a sample of male health-club exercisers. We had hypothesized that we would find no significant differences between the intra-set and the immediate end-of-set assessments of affect. The rationale for this hypothesis was that we predicted an attenuated or absent "affective rebound" phenomenon in the context of resistance exercise, unlike the robust affective rebound commonly found in studies investigating cardiovascular exercise. Indeed, we found no evidence of an affective rebound in 5 of the 6 conditions we tested (two exercises, each performed at three levels of %1RM). The only exception was a small (mean difference of -0.27 units, $d = -0.15$) change toward a more positive FS rating (from 1.61 ± 1.54 intra-set to 1.88 ± 1.96 at end-of-set) in the bench press at 60% 1RM.

On the other hand, contrary to our prediction that we would find no significant differences between the intra-set and the immediate end-of-set assessments of affect, we did find significant main effects of time and significant mean differences for both the FS and FAS between the intra-set and the end-of-set assessments. Moreover, the changes were not in the direction of an affective rebound but rather in the direction of a worsening of affect, evidenced by a decline in affective valence (overall mean of FS ratings: 0.318 intra-set to -0.126 at end-of-set) and an increase in perceived activation (overall mean of FAS ratings: 4.263 intra-set to 4.581 at end-of-set). This phenomenon, namely the worsening affect from intra-set to the end-of-set assessments, did not vary significantly by type of exercise or %1RM since time exhibited no interactions with these independent variables.

The absence of an affective rebound stands in contrast to voluminous previous findings from cardiovascular exercise (Ekkekakis et al., 2011), as well as a limited body of evidence that has emerged from resistance exercise (Cavarretta et al., 2019a; Emanuel et al., 2020; Evmenenko & Teixeira, 2020; Portugal et al., 2015). It is important to underscore that, in the present study, the end-of-set measurement was taken immediately after load removal. It is, therefore, possible that one reason for the discrepant findings might be the exact sampling time, since the passage of additional time since load removal (perhaps even only a few additional seconds) might have resulted in the emergence of a detectable

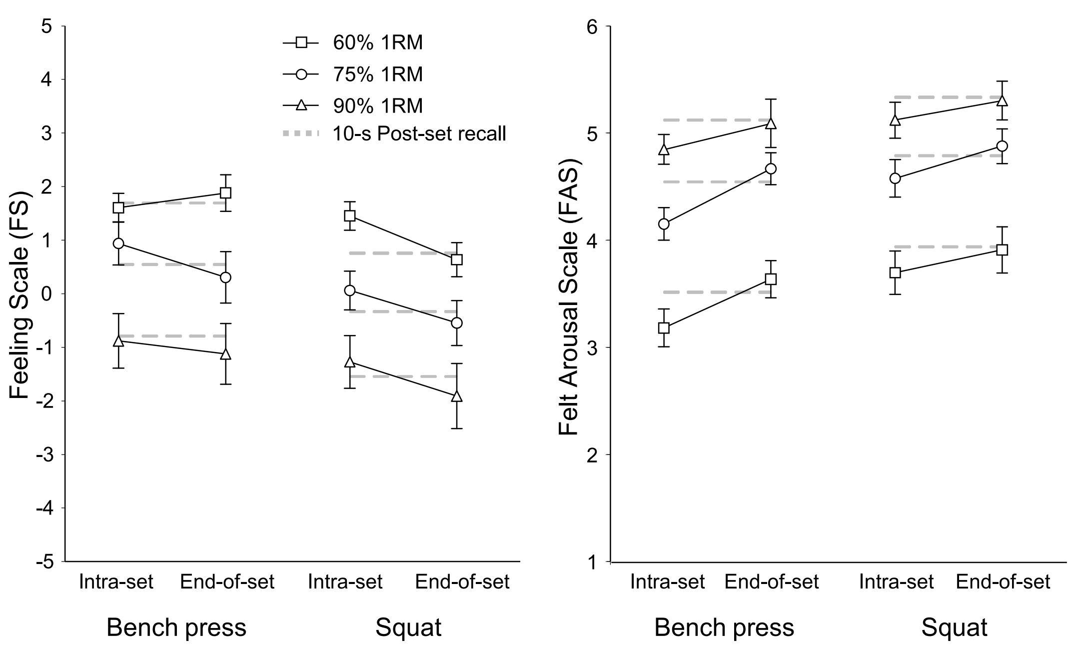

Fig. 1. Mean (± standard errors) ratings on the Feeling Scale (FS; left panel) and Felt Arousal Scale (FAS; right panel) obtained intra-set and end-of-set across the six experimental conditions (two exercises: bench press, squat; three levels of resistance: 60%, 75%, 90% 1RM). The grey dashed lines indicate the mean of 10-s post-set recalls obtained in response to the question "how did you feel during this last set?"

affective rebound. For example, the study by Cavarretta et al. (2019a) included administrations of the FS during the set (with muscles under tension), "after" the completion of the final repetition (but without specifying the exact timing), and 5 min post-set. The study by Emanuel et al. (2020) included administrations of the FS after each repetition and 10 s after the last repetition. It is, therefore, possible that the presence or absence of evidence for an affective rebound depends on the number of seconds that elapse from the cessation of a set until the administration of the FS and FAS.

In general, it seems clear from previous studies (e.g., Bellezza et al., 2009; Cavarretta et al., 2018) that ratings of affect tend to become more positive after the end of an activity that induced affective decline, and that this effect tends to become more pronounced over time (e.g., 5 min vs. 30 min post-exercise). However, in order to assess core affective valence and perceived activation (i.e., feeling pleasure or displeasure with relatively low contribution from reflective thought and relevant cognitive appraisals), measurements should be taken in as close temporal proximity to the end of the activity as is technically feasible, in order to preserve the contribution of interoceptive signals and homeostatic perturbations to the affective state (Ekkekakis et al., 2011, 2019). In contrast, it is assumed that, when post-exercise assessments are taken several minutes after the completion of exercise, ratings of affective state will reflect the strong influence of reflective cognition and, in particular, the interpretation of the preceding exercise performance for the self-evaluation and sense of self-worth of the individual (e.g., "I think I did well, so I am feeling good"). Conceivably, the post-exercise cognitive interpretation of the situation may even lead to affect ratings after an exercise bout that are antithetical to affective experiences that occurred while the exercise was ongoing (e.g., "this set was really hard, I struggled to finish, so I am now satisfied that I challenged myself to get stronger"; see Ekkekakis et al., 2011; Ekkekakis, 2013).

The present results suggest that, at least for loads of 75% 1RM or higher, an end-of-set assessment of affect taken immediately after load removal, in conjunction with a baseline assessment, might be sufficient to represent the changes that take place during a set. It appears that, at least above a certain critical threshold or resistance, affect deteriorates (valence declines and perceives activation increases) in progressive fashion during a set. Assuming that the trend is indeed linear, researchers and practitioners could capture it with an assessment of affect taken immediately after the final repetition.

If this finding is replicated, it could have interesting implications for research and practice. From a research-methodological perspective, this means that additional, potentially intrusive, intra-set assessments (e.g., asking participants to report their affective state during the final muscular contraction) may not be necessary. In turn, this would increase the generalizability and ecological validity of studies investigating affective responses to resistance exercise. For exercise practitioners, this means that a valid record of the affective experiences of participants can be obtained with minimal disruption. In turn, such assessments can be used to tailor resistance-exercise intensity prescriptions to individuals and to track longitudinal changes in affective experiences (e.g., in response to overload).

It should also be noted that, as can be seen in Table 2 and Figure 1, the 10-s post-set recalls of affect (obtained with the instruction "how did you feel during this last set?") similarly did not exhibit evidence of an affective rebound. In most cases, the 10-s recall was a reasonably close representation of the average of the intra-set and end-of-set assessments. For FS, the average discrepancy between the 10-s post-set recall and the average of the intra-set and end-of-set assessments was -0.04 ± 0.15, with the largest discrepancy for the 60% 1RM of the squat (-0.29) due to an apparent recency effect (i.e., the post-set assessment being close to the end-of-set assessment but farther away from the intra-set assessment). For FAS, the average discrepancy between the 10-s post-set recall and the average of the intra-set and end-of-set assessments was 0.12 ± 0.03, with no individual discrepancy exceeding 0.15 FAS units. These small discrepancies suggest that even 10-s post-set recall assessments could be useful indicators of affective responses to resistance training for exercise practitioners.

Another noteworthy observation from the present study was an apparent stepwise increase in the interindividual variability of affective valence ratings in response to increasing level of resistance. Specifically, as can be seen in Table 2, in the bench press, compared to the variance in FS ratings at 60% 1RM, the variance (S^2) doubled (x 2.11) at 75% 1RM and tripled (x 3.21) at 90% 1RM. Likewise, in the squat, variance doubled (x 1.83) at 75% 1RM and quadrupled (x 3.95) at 90% 1RM. Remarkably, no such phenomenon emerged for FAS ratings, where the variance exhibited no pattern of systematic escalation. Considering that resistance was individualized (i.e., set as a percentage of the individually determined 1RM for each exercise), the observation of progressively escalating variance in ratings of affective valence is likely an indication of individual differences in the modulation of interoceptive afferents, as theorized by Ekkekakis et al. (2005). Specifically, Ekkekakis et al. (2005) introduced the constructs of exercise intensity preference, defined as the predisposition to choose a particular level of exercise intensity when given the opportunity, and exercise intensity tolerance, defined as the ability to tolerate an imposed level of intensity that is unpleasant or uncomfortable. These individual-difference dispositions, assessed by the Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q), have been found to account for significant portions of the variance in affective valence responses to exercise (e.g., Box & Petruzzello, 2020; Jones et al., 2018), and may have implications for the affect-adherence relationship (Faria et al., 2021; Teixeira et al., 2022). Given the present finding of escalating variance in affective valence responses to increasing levels of resistance, it is reasonable to suggest that further investigations of the relation of affective valence ratings with intensity-preference and, especially, intensity-tolerance are warranted.

In evaluating the results of the present investigation, critical readers should consider the following limitations. First, it should be clear that the present results are limited by the fact that the participants were all male health-club exercisers who were experienced in resistance training, and the experimental protocol consisted of only two exercises (bench press, squat) and three levels of resistance (60%, 75%, 90% 1RM). Therefore, any extrapolations should take these limitations into account.

Moreover, the experimental protocol had to balance two competing considerations. On the one hand, it was necessary for the purpose of our study to assess affect during the set, in order to obtain an indication of the trend of affective change as the set unfolds. On the other hand, it was also important to preserve the ecological validity of the study as much as possible, so that any conclusions would be relevant to how resistance exercise is practiced in realistic settings. These two needs cannot be met simultaneously, so a compromise had to be sought. Resistance exercise is performed in a series of repetitions, during which afferent information changes continuously in a cyclical manner (i.e., through a series of concentric and eccentric contractions). Since core affect is theorized to respond dynamically to the changing physiological condition of the body, presumably affect would show a similar oscillatory pattern. In addition, affect may show longer-term trends, from the first to the last contraction within a set, and from the first to the last set, as a result of accumulating fatigue (e.g., incomplete local clearance of metabolites in the working muscles). Obtaining a faithful representation of this complex pattern would necessitate numerous repeated assessments of affect, in close temporal proximity. However, such an assessment protocol would be overly intrusive and logistically challenging, fundamentally altering the nature of the affective experience. In addition, asking the same questions repeatedly is known to elicit various artifacts (e.g., reactivity to testing, variance carry-over effects). Therefore, in the present study, as a reasonable compromise, we opted to acquire one "intra-set" and one "end-of-set" assessment per experimental condition. These two time points enabled us to obtain an estimate of linear trends but precluded a more fine-grained depiction of changes from repetition to repetition and from set to set. In the future, researchers should seek to devise novel methodologies that would address this limitation, allowing more frequent assessment of affect while preserving ecological validity (Ekkekakis et al., 2019).

In addition, taking the intra-set assessments near the mid-point of the volume of weight lifted at each %1RM introduced an inconsistency in terms of the position of these assessments within a set. Specifically, (a) for 60% 1RM, the measurement was taken near the end of a set (14th-15th repetition out of 15–17 repetitions in the first set), (b) for 75% 1RM, the measurement was taken near the middle of a set (4th-5th repetition out of 8–10 repetitions in the second set), and (c) for the 90% 1RM, the measurement was taken near the end of a set (4th-5th repetition out of 5–6 repetitions in the second set). It is conceivable that knowledge of the proximity to the end of the set might have influenced the intra-set reports of affect.

Finally, readers should keep in mind that this was a study with a primarily methodological focus, whose purpose was to evaluate whether assessments of affect taken immediately upon the conclusion of a set would differ from assessments taken during a set of resistance exercise. We addressed this question under several different experimental conditions (two exercises, each performed at three levels of %1RM) in order to evaluate the robustness of the observed results. To reduce intragroup variance and, therefore, preserve statistical power, we did not counterbalance or randomize the order of presentation of the six combinations of experimental conditions. Instead, these were presented in fixed order (as noted in the Methods, the bench press was performed first and the squat second, and, for each exercise, the %1RM conditions were performed from lowest to highest, namely 60%, 75%, 90%). Because of the fixed order of presentation of the experimental conditions, readers are cautioned to not interpret the results as representing valid comparisons of affective responses to upper-body (bench press) and lower-body (squat) exercises or between low (60% 1RM), middle (75% 1RM), and high (90% 1RM) levels of resistance. For example, as reported in the Results, we did find declines in affective valence (FS) and increases in perceived activation (FAS) from the bench press to the squat and from the lightest to the heaviest level of %1RM. However, given the experimental protocol employed in the present study, it is not possible to decipher whether, or to what extent, the reported patterns were the result of order effects.

In conclusion, in the present study, comparisons between intra-set and immediate end-of-set assessments of affect across six resistance-exercise experimental conditions (two exercises and three levels of % 1RM) produced no evidence of an “affective rebound”. These findings suggest that, given proper familiarization of the participants with the FS and FAS, administration of these scales immediately upon the cessation of a set of resistance exercise may suffice to provide a meaningful representation of the affective changes that occur during resistance exercise. If confirmed, this finding may simplify assessments of affective responses to resistance exercise, reducing the need for intrusive intra-set assessments. For exercise practitioners, this suggests that they may be able to use the FS and FAS in monitoring the affective experiences of participants and tailoring resistance-exercise prescriptions to individuals, with the goal of optimizing affect and, by extension, encouraging long-term adherence in accordance with hedonic models of motivation.

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Authors’ contributions

AA, DT, AE and DM developed the design, collect and analysed the data. DT, AA and PE wrote the manuscript. FR, LC and AE reviewed and critiqued the manuscript. All authors approved the final version of the manuscript.

CRediT authorship contribution statement

A.J. Andrade: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **P. Ekkekakis:** Writing – original draft, Validation, Supervision. **A. Evmenenko:** Conceptualization, Visualization, Writing – review & editing. **D. Monteiro:** Methodology, Formal analysis. **F. Rodrigues:** Visualization, Writing – review & editing. **L. Cid:** Writing – review & editing. **D.S. Teixeira:** Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Supervision, Project administration.

Declaration of interest

The authors have no conflicts of interest.

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