Affective Responses to Increasing- and Decreasing-Intensity Resistance Training Protocols.

HUTCHINSON, Jasmin C., JONES, Leighton <http://orcid.org/0000-0002-7899-4119>, EKKEKAKIS, Panteleimon, CHEVAL, Boris, BRAND, Ralf, SALVATORE, Gabrielle M., ADLER, Samantha and LUO, Yan

Published version

HUTCHINSON, Jasmin C., JONES, Leighton, EKKEKAKIS, Panteleimon, CHEVAL, Boris, BRAND, Ralf, SALVATORE, Gabrielle M., ADLER, Samantha and LUO, Yan (2023). Affective Responses to Increasing- and Decreasing-Intensity Resistance Training Protocols. Journal of sport & exercise psychology, 1-17.

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Abstract

This study compared the effects of an increasing-intensity (UP) and a decreasing-intensity (DOWN) resistance training (RT) protocol on affective responses across six training sessions. Novice participants (M_{age} 43.5 ± 13.7 years) were randomly assigned to UP (n = 18) or DOWN (n = 17) RT groups. Linear mixed-effects models showed that the evolution of affective valence within each training session was significantly moderated by group (b = -0.45, p = <.001), with participants in the UP group reporting a decline in pleasure during each session (b = -0.82) and the DOWN group reporting an improvement (b = 0.97; ps <.001). Remembered pleasure was significantly higher in the DOWN group compared to the UP group (b = 0.57, p = .004). These findings indicate that a pattern of decreasing intensity throughout a resistance exercise session can elicit more positive affective responses and retrospective affective evaluations of RT.

Keywords: Affect, resistance exercise, opposing slopes, remembered pleasure

The benefits of regular physical activity and exercise are well established, yet most people in industrialized countries remain sedentary or inadequately active (Bull et al., 2020). Physical activity guidelines (Piercy et al. 2018) include recommended minimum thresholds for moderate or vigorous-intensity aerobic activity (150 or 75 min per week, respectively) and resistance exercise (two sessions per week). Most of the emphasis, however, is placed on the aerobic component, whereas the muscle-strengthening recommendations have been characterized as the “forgotten guidelines” (Strain et al., 2016, p. 10), prompting calls for further highlighting the importance of strength-based activities (Milton et al., 2018). Helping people to achieve these recommendations remains a key challenge for those working in physical activity promotion and the broader domain of public health.

Similar to physical activity recommendations, exercise prescription guidelines have traditionally been developed solely on the basis of physiological and medical considerations (e.g., optimizing overload while reducing injury potential). For example, in the case of cardiovascular exercise, despite evidence that aspects of the exercise dose (especially intensity) may be causally implicated in reduced adherence (e.g., Perri et al., 2002), the American College of Sports Medicine (ACSM) issues its guidelines for mode, frequency, duration, and intensity without referencing behavioral research. Likewise, in the case of resistance exercise, ACSM (2021) guidelines include recommendations for frequency, intensity, type, rest intervals, volume (sets), and progression but do not reference psychological (e.g., pleasure, enjoyment) or behavioral considerations (e.g., adherence, dropout). Therefore, it could be argued that these guidelines do not take advantage of advances in knowledge across different kinesiological subdisciplines (e.g., exercise psychology). This is problematic as suboptimal exercise intensity recommendations and prescriptions can undermine exercise motivation (Ladwig et al., 2017) and adherence (Williams et al., 2015).

Psychological Considerations

Resistance exercise can be performed across a range of intensities but there is a recognized need to incorporate higher-intensity efforts, given that higher-intensity work can yield additional benefits (Schoenfeld et al., 2016, 2017). According to a recent meta-analysis, high training loads > 60% of 1-repetition maximum (1-RM), elicit superior strength gains compared to low intensity loads ≤ 60% 1-RM (Refalo et al., 2021). For middle-aged to older adults, higher intensity (70-85% 1-RM) resistance training (RT) programs are recommended to counteract the age-related decline in muscle strength and bone mineral density that begins around 30 years of age (ACSM, 2009; Fragala et al., 2019; O'Bryan, 2022). However, higher-intensity exercise is often associated with reduced pleasure, and this might have negative implications for adherence (Ekkekakis & Brand, 2019). To help achieve a balance between maximizing fitness / health benefits and adherence to exercise, there is a need for integrative approaches accounting for physiological and psychological considerations.

As a case in point, individuals differ in the level of exercise intensity they prefer and can tolerate, leading researchers to propose the individual-difference constructs of intensity preference and tolerance (Ekkekakis et al., 2005). *Preference* for exercise intensity has been defined as the "predisposition to select a particular level of exercise intensity when given the opportunity" and *tolerance* as "a trait that influences one's ability to continue exercising at an imposed level of intensity beyond the point at which the activity becomes uncomfortable or unpleasant" (Ekkekakis et al., 2005, p. 354). In previous research, intensity preference and tolerance have been shown to be positively associated with muscular endurance (Hall et al., 2014), perseverance during exercise of increasing intensity (Ekkekakis et al., 2007), and affective responses to high-intensity exercise (Box & Petruzzello, 2020; Jones et al., 2018).

Dual-Process Models

Recent theoretical proposals in exercise psychology embrace dual-process models that acknowledge the importance of automatic, or non-reflective, processes in the determination of human behavior (Ekkekakis, 2017). The application of dual-process theories to exercise behavior represents a novel and potentially promising approach. Dual-process theories propose that human behavior is influenced by two distinguishable but constantly interacting classes of processes. First, reflective processes depend on rational and deliberative information processing. Intention to perform a behavior typically resides in this reflective system yet, despite the importance of reflective processes, clear gaps between intention and subsequent action have been identified (Rhodes & de Brujin, 2013; Sheeran & Webb, 2016). That is, strong behavioral intentions to exercise do not necessarily translate into actual exercise behavior. Second, automatic (non-reflective) processes operate quickly and spontaneously, do not require high cognitive reserves (i.e., high capacity for information processing or executive-control resources), and involve factors such as previously established automatic associations (Rebar et al., 2016).

The Affective-Reflective Theory (ART) of exercise and physical inactivity (Brand & Ekkekakis, 2018; Ekkekakis & Brand, 2021) is a dual-process theory that highlights the importance of core affective valence (i.e., feelings of pleasure-displeasure; Russell, 1980) in automatic processing. Repeated core affective reactions to exercise are theorized to result in an automatic affective valuation of the stimulus-concept of exercise; that is, a tacit assignment of a positive (association with pleasure) or negative (association with displeasure) value. This automatic affective valuation gives rise to an immediate action impulse (approach/avoidance). The automatic affective valuation and associated action impulse are theorized to represent the "default" mode of responding to stimuli, and form the basis for the subsequent controlled, reflective evaluation of exercise, deliberative decision making, and the development of conscious action plans. Thus, individuals with prior pleasant experiences of exercise, resulting in positive automatic affective valuation, will be more likely to engage in exercise when the opportunity arises (see Brand & Ekkekakis, 2021). Conversely, negative automatic associations with exercise act as a restraining force toward future exercise engagement (Brand & Cheval, 2019). In line with the ART, affective responses to episodes of physical activity have been found to predict concurrent and future physical activity behavior (e.g., Davis & Stenling, 2020; Williams et al., 2012).

Affective Responses to Exercise

Automatic affective valuations of exercise are theorized to be formed from repeated previous experiences with exercise (Brand & Ekkekakis, 2018; Ekkekakis & Brand, 2021). This includes experienced affective valence (how pleasant or unpleasant exercise feels while it is ongoing), as well as remembered pleasure (how pleasant or unpleasant exercise is remembered). Learned responses are also likely to affect forecasted pleasure (how pleasant or unpleasant one anticipates exercise to be). Remembered and forecasted pleasure are typically linked; how one recalls an exercise session is presumed to influence anticipated affective responses to subsequent exercise sessions (e.g., Davis & Stenling, 2020). Zenko et al. (2016) observed strong positive associations of remembered pleasure and subsequent forecasted pleasure assessed at 15 min (r = .84), 24 hours (r = .86), and 7 days (r = .88) following an exercise bout. The magnitude of observed associations between anticipated, experienced, and recalled affective states was reported to increase over the course of three 7-min cycling time trials (Davis & Stenling, 2020), suggesting a possible *carryover effect*. However, it is currently unknown whether this effect is observable across multiple exercise sessions held on different days.

Retrospective evaluation of a hedonic experience is most heavily influenced by the intense affective moment of the experience (i.e., the '*peak*') and the final few moments of an experience (i.e., the '*end*') rather than the experience as a whole (Fredrickson, 2000; Kahneman et al., 1993). Moreover, when evaluating an experience, individuals exhibit a strong preference for improving over declining experiences. That is, they prefer an unpleasant experience followed by a more pleasant experience (i.e., an improving pattern) than a pleasant experience followed by an unpleasant experience (i.e., a declining pattern); (Zauberman et al., 2006). The importance of affective peaks and endings for remembered pleasure have been previously demonstrated in exercise contexts (Hargreaves & Stych, 2013; Hutchinson et al., 2020). Likewise exercise studies have supported the positive effect of an improving affective trend on remembered and forecasted pleasure (Hutchinson et al., 2020; Zenko et al., 2016). These findings have important implications for behavior. In a series of experiments, Garbinsky et al. (2014) demonstrated that memory for the ending of a hedonic experience (in this case, a pleasant gustatory experience) determines how soon people desire to repeat that experience. In an exercise context, Brewer et al. (2000) reported that participants preferred to repeat an exercise bout with an added period of lower-intensity effort at the end, relative to a shorter exercise bout of matched intensity. This underscores the importance of maximizing pleasant affective endings during exercise.

Manipulating the Direction of Exercise Intensity: The Opposing-Slopes Model

As affective valuations are theorized to be a consequence of prior experiences (Brand & Ekkekakis, 2018; Ekkekakis & Brand, 2021) exercise prescriptions should be accompanied by recommendations on how to promote pleasant experiences, with particular emphasis on the ending of an experience. In turn, this improved affective ending experience should increase the likelihood of future engagement. An integrative approach to exercise prescription is exemplified by the *opposing-slopes* model (Ariely, 1998; Ariely & Carmon, 2000; Zauberman et al., 2006). This model combines physiological considerations (i.e., inclusion of high-intensity work that enhances physiological adaptations to exercise) and psychological considerations (i.e., promoting more positive affective responses). The opposing-slopes approach was developed based on evidence from behavioral economics and Solomon's (1980) "opponent process" theory of acquired motivation (see Hutchinson et al., 2020; Zenko et al., 2016).

The opposing-slopes model was first empirically tested in the context of exercise by Zenko et al. (2016), who randomly assigned participants to a 15-min bout of recumbent cycling of either increasing (UP) intensity (i.e., 0–120% of watts corresponding to each participant's ventilatory threshold) or decreasing (DOWN) intensity (i.e., 120–0%). The DOWN condition elicited a positive slope of pleasure during exercise, meaning that participants felt increasingly more pleasure as the exercise task progressed. This was associated with significantly higher ratings of post-exercise pleasure and enjoyment, remembered pleasure (24 h and 7 days later) and forecasted pleasure (i.e., expected affect associated with future exercise). In a follow-up study, Hutchinson et al. (2020) replicated and extended these findings to a resistance-training protocol. Participants completed a resistance-training circuit under two randomized and counterbalanced conditions. In the UP condition, the resistance load progressed over 3 sets, from 55% of 1RM, to 65% 1RM, and finally to 75% 1RM, while in the DOWN condition this order was reversed. The UP condition resulted in decreasing pleasure over time, whereas the DOWN condition resulted in increasing pleasure (i.e., participants felt the most pleasure at the end of the workout). The DOWN condition also resulted in significantly greater enjoyment of exercise, more positive post-exercise pleasure, and more positive remembered pleasure (24-hr post-exercise).

This recent line of research indicates that psychologically informed programming changes can successfully manipulate the experienced and remembered affect associated with a single bout of exercise while equating for volume. These studies provide important proof-of-concept evidence for the utility of ramp-down training protocols, however, the available evidence to date is based on single sessions of exercise. Given that repeated affective experiences with exercise are theorized to influence affective valuations and, consequently, subsequent exercise behavior (Ekkekakis & Brand, 2019), additional work is required to understand how this pattern might change over several exercise bouts. Such work would help better understand how to implement these approaches in practice and incorporate them into exercise prescription guidelines.

The Present Study

The present study sought to test the opposing-slopes model across multiple sessions of resistance training (RT). Specifically, we aimed to determine whether the main findings from previous studies (Hutchinson et al., 2020; Zenko et al., 2016) could be replicated, and whether the observed effect would be maintained over multiple training sessions. Thus, our primary aim was to examine the effect of manipulating the slope (direction) of intensity on affective responses to resistance exercise. We hypothesized that the evolution of affective valence within each session would be moderated by Group – specifically, that participants randomized to the UP group would show a negative change in affective valence during each session, whereas participants randomized to the DOWN group would exhibit a positive increase (*H1*). Moreover, in line with the opposing-slopes model, we expected that participants in the DOWN group would report greater remembered pleasure following exercise compared to those in the UP group (*H2*). We also tested whether the effect of Group (i.e., UP vs. DOWN) on remembered pleasure would vary across RT sessions. We did not expect that this would be the case as the mechanistic processes linking Group with remembered pleasure should be present from the first session; however, this was important to test in order to extend this line of research beyond a single exercise session. We assumed that individual differences in the preference for and tolerance of exercise intensity may influence affective responses during the RT sessions – specifically, we predicted that affective responses would be more positive in individuals with greater tolerance (*H3a*) and preference (*H3b*) for high exercise intensity. Therefore, we incorporated measures of intensity-preference and intensity-tolerance, namely the Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q; Ekkekakis et al., 2005) into our models as covariates.

The secondary aims of the study were: (a) to examine the carryover effect of remembered pleasure on forecasted pleasure at the next exercise session, and (b) to assess for an "end effect" (i.e., the end of the session being more influential) in remembered pleasure. We anticipated a positive carryover effect of remembered pleasure on subsequent forecasted pleasure (*H4*). We also expected that the affect reported at the end of the RT sessions would be more closely associated with remembered pleasure than the affect reported at the beginning of the sessions (*H5*). Finally, we conducted exploratory analyses to determine whether Group and RT session moderated the aforementioned effects.

Method

To estimate the sample size required for sufficient power (80%) with an alpha level of 5%, we focused on the linear mixed-effects models (MEM) used to test our primary hypotheses (*H1*). Sample size calculations for MEM are difficult and sensitive since they depend on the values of all (fixed and random) parameters. However, in a full-factorial model, estimations for repeated-measures analysis of variance (ANOVA) and MEM will be nearly identical (Miller et al., 2022). Therefore, we conducted a power analysis using G*Power 3.1.9.6 (Faul et al., 2009) for a repeated-measures, mixed factorial (within-between interaction) ANOVA, with two groups and two repeated measurements. Anticipating a medium effect size (Cohen's $f = .25$; based on Hutchinson et al., 2020) and correlated dependent measures ($r = .5$), with the nonsphericity correction (ε) set to 1, the power calculation indicated that 34 participants would be required to test the main hypothesis (i.e., the interactive effect of group on the evolution of the affective response during each exercise session). To account for an anticipated attrition rate of ~10% (Arikawa et al., 2011) the sample size was inflated to 38 participants.

Prior to the beginning of data collection, this study was approved by Institutional Review Board at the institution of the first author, and the project was preregistered (https://aspredicted.org/7LV_TQH). All participants provided written informed consent and the study was conducted in accordance with the Declaration of Helsinki.

Statement regarding the impact of COVID-19

Due to the COVID-19 pandemic, we were forced to make changes to our preregistered protocol. Fifteen participants who were enrolled in the study as of March 2020 were unable to complete the post-intervention measures when data collection was abruptly halted by the mandatory closure of all testing facilities. This reduced the number of complete datasets for the pre-post intervention data to 20, causing the sample to be underpowered for pre-registered aims 2, 3 and 4; consequently, these results are not reported in the main body of this paper. For completeness, we have included this information in a supplementary file, as the data may be considered exploratory and potentially useful for future, adequately powered, investigations.

Due to the uncertain nature of emerging COVID-19 variants and future shutdowns, the intervention protocol was shortened from 6 weeks (12 sessions) of supervised training to 3 weeks (6 sessions) of supervised training. Given the shortened intervention period, planned health-related outcomes (e.g., changes in strength and body composition) were not assessed at follow-up and the original power analysis, which was for a 2 (group) × 3 (time) design, was adjusted accordingly. These changes were reviewed and approved by the Institutional Review Board.

Participants

Potential participants were recruited from the institution of the first author (faculty, staff, and students) and from the surrounding community using print and electronic advertising. Potential participants (n = 85) were screened for eligibility using an online survey platform (Qualtrics, Provo, UT). Novice RT exercisers (i.e., untrained individuals with no RT experience or those who had not trained for two or more years; ACSM, 2021), aged 18–65 years, and reporting fewer than three days per week of moderate-to-vigorous aerobic exercise (i.e., inadequately active per ACSM guidelines) were eligible to participate. Exclusion criteria were pregnancy and signs or symptoms of and / or known cardiovascular, metabolic, or renal disease assessed using an ACSM health screening questionnaire (Riebe et al., 2015). After this initial screening, eligible participants (n = 38) were scheduled for testing. Two participants withdrew from the study during baseline testing and one dropped out during the intervention; therefore, 35 participants were retained (30 women; 5 men; 43.5 ± 13.7 years). See Figure 1. The self-reported racial distribution of participants was 83% White, 11% Black or African American, 3% Asian, and 3% other or mixed race. See Table 1 for additional participant characteristics.

Following baseline testing, participants were randomly assigned to one of two groups (UP or DOWN) using blocked randomization, to ensure equal group sizes. Participants in the

DOWN group were assigned an exercise program in which the intensity of resistance exercise decreased progressively across the sets of the exercise bout, whereas participants in the UP group were assigned an exercise program in which the intensity of resistance exercise increased during the exercise bout.

Measures

During-Session Measures

Core affective valence was measured using the Feeling Scale (FS; Hardy & Rejeski, 1989). The FS is a single-item bipolar rating scale that utilizes the stem “How do you feel right now, at this moment?” with possible responses ranging from −5 (*very bad*) to +5 (*very good*) and verbal anchors at zero ("neutral") and odd numbers. Forecasted and remembered pleasure were assessed using a visual analog scale (VAS) anchored with the descriptive phrases *very pleasant* to *very unpleasant* at the two extremes. In this case, participants were asked to respond to the question stem “How do you expect to feel during today’s workout?” (forecasted pleasure) and “Overall, how did the exercise session today make you feel?” (remembered pleasure). Respondents marked their response on the scales using a pencil. For the purposes of comparison with the FS, the VAS was scored from −5 to +5. This was achieved by dividing the 11-cm horizontal line into 11 equal intervals, with markings read to the closest integer (Flynn et al., 2010). In order to minimize common-method variance (Podsakoff et al., 2003; 2012), the VAS was oriented horizontally, whereas the FS had a vertical orientation, and each scale was printed on a separate, differently colored card.

Dispositional and Post-Intervention Measures

Participants completed the PRETIE-Q (Ekkekakis et al., 2005) to assess individual differences in preference for and tolerance of exercise intensity. The PRETIE-Q comprises 16 items with a response scale ranging from 1 (*I totally disagree*) to 5 (*I totally agree*). Items to assess preference include “When I exercise, I usually prefer a slow, steady pace” (low intensity preference) and “the faster and harder the workout, the more pleasant I feel” (high intensity preference). Items to measure tolerance include "Feeling tired during exercise is my signal to slow down or stop" (low tolerance) and "I always push through muscle soreness and fatigue when working out" (high tolerance). Items for low intensity preference and low tolerance are reversed-scored, thus higher PRETIE-Q scores indicate a preference for and tolerance of higher-intensity exercise. In the present study, Cronbach's alpha of .83 for the preference scale and .71 for the tolerance scale indicated satisfactory internal consistency.

As a control measure to assess for non-specific treatment effects, the perceived credibility and friendliness of the personal trainer were rated using a 5-point Likert scale. Participants rated their level of agreement with two statements: "my personal trainer was knowledgeable about the exercises" and "my personal trainer was friendly," using a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). This questionnaire was administered electronically by the first author (i.e., not by the personal trainers) at the end of the study. Ratings indicated high satisfaction and no difference between groups (mean = 5.0, *SD* = 0 for both groups).

Procedure

Baseline Testing and Familiarization

During the first study visit, participants completed the PRETIE-Q. In addition, demographic and anthropometric data were collected. Body mass (in kilograms) and height (in centimeters) were measured using a medical scale and stadiometer, respectively (Detecto 437; Detecto, Webb City, MO). Body composition was estimated via bioelectrical impedance using a segmental body composition analyzer (Tanita BC-418, Tokyo, Japan). Muscular strength was assessed in order to set the workload for the subsequent training sessions.

The three-repetition maximum (3-RM) for each exercise in the resistance training protocol (Table 2) was determined by measuring the maximum weight that could be lifted for three repetitions. After receiving instruction and an interactive demonstration of safe and correct lifting technique, participants warmed up using a light load on each exercise for 8–10 repetitions. Additional weight was then added successively until a participant could not complete three repetitions with good form. All participants reached their 3-RM in no more than five attempts and were given 2 min of rest between each attempt. A 3-RM test is more appropriate for untrained participants than a 1-RM test, which carries a higher risk of injury (Brzycki, 1993). 1-RM was estimated from 3-RM using an established prediction equation (Epley, 1985), and the load for each exercise was then calculated as a percentage of 1-RM.

Three-to-five days following baseline testing, participants completed a familiarization session using the assigned percentages of 1-RM; these percentages were based upon pilot testing and prior research (Hutchinson et al., 2020). At the higher percentage, the prescribed loads were determined to be appropriate if the participant was able to complete at least 8, but no more than 12, repetitions. If any participant was outside of this range, the load was adjusted to ensure that all participants were within the target repetition range for the higher-intensity set. During this session, participants were provided with standardized instructions on the use of the affect-rating scales and practiced providing ratings during the familiarization exercises.

Training Program

The supervised RT program consisted of two sets of six exercises per session (see Table 2). The exercises were chosen to target the major muscle groups and the repetition range was consistent with recommendations for novice lifters (ACSM, 2009). Participants completed one set of each exercise in the order listed before moving on to the next, with 30-s rest between sets and 3-min rest between each circuit. For reasons of safety and to ensure compliance with the RT protocols, all sessions were supervised by a certified personal trainer.

Participants in the UP group completed the exercises by beginning with one set at a lighter load and ending with one set at a heavier load. In contrast, participants in the DOWN group began with one set at a higher load and ended with one set at a lighter load. The UP and DOWN protocols were matched for total volume, so that only the increasing or decreasing slope of exercise intensity differed between the two groups. Participants were instructed to refrain from performing any additional resistance-type or high-intensity exercise for the duration of the study, and this was verbally confirmed prior to each session.

Training for both groups consisted of two RT sessions per week on non-consecutive days. The lower-intensity set was performed for 10 repetitions and the higher-intensity set was carried out to the point of momentary concentric muscular failure (i.e., the inability to perform another concentric repetition while maintaining proper form; Fisher et al., 2011). The number of heavy-set reps to failure were recorded and mean values were equivalent between groups (UP = 11.41 reps, DOWN = 11.69 reps). Repetitions were performed in controlled fashion, with a moderate 2:1:2 tempo (Schoenfeld et al., 2015). Participants completed one set of each exercise in the order listed in Table 2 before moving on to the next set of each exercise.

Training Protocol

The RT sessions were conducted at a 48,000 sq. ft. college wellness and recreation complex. Each session began with a warm-up consisting of a 5-min brisk walk on a treadmill and a series of dynamic stretches. Prior to each RT session, participants provided a rating of forecasted pleasure for the training session that day. During the training sessions, the personal trainer recorded repetitions to fatigue for each exercise, and obtained the ratings of in-task affective valence and remembered pleasure. All personal training staff were trained in the administration of the psychometric instruments used and were instructed on the study protocol using standardized training materials. Specifically, the personal trainers were instructed on how to conduct themselves in a uniform manner across the two groups, in order to avoid nonspecific treatment effects. To confirm this, participants completed a brief questionnaire at the end of the study assessing trainer credibility and friendliness. Further, while it was not possible to blind the personal trainers to group allocation, the trainers were unaware of the purpose and directional hypotheses of the study. To minimize cross-contamination between groups, all training sessions were conducted individually (i.e., without other study participants present). At the end of the study, a funnel debriefing procedure (Bargh & Chartrand, 2014) was used to assess, through increasingly specific questions, whether participants were aware of the purpose of the study. All participants reported no awareness of any other training protocol being used in the study.

Affective valence was assessed twice during each training session, once during each of the two sets (i.e., high vs. low load). Ratings were obtained *during* RT (i.e., while muscles were loaded) after ~7 complete repetitions (while participants were in the process of executing the eighth repetition). The seventh repetition was chosen as it “represents a point in the repetition scheme where fatigue is beginning to accumulate and the lifter may be near, but not at, momentary muscular failure” (Cavarretta et al., 2019, p. 2). Pilot testing indicated that obtaining ratings at this point was feasible and safe. Approximately five min after each training session, just before exiting the facility, participants provided a rating of remembered pleasure for the preceding session. A visual overview of the study protocol is shown in Figure 2.

Statistical Analyses

Primary Analyses: Affective Valence and Remembered Pleasure

Affective valence and remembered pleasure were estimated using linear mixed-effects models (MEM). MEM allow for correct parameter estimation by accounting for the nested structure of the data (in this case, multiple observations within single participants), and thereby provide accurate parameter estimates with acceptable Type I error rates (Boisgontier & Cheval, 2016). To examine the effect of the independent variables on change in affective valence during each session (i.e., *H1*), the MEM included the effect of group (i.e., UP vs DOWN), the effect of time (i.e., first and second set of exercises), as well as the interaction between these terms. A significant interaction would indicate that the evolution of affective valence during each session was moderated by group. Participants were specified as a random factor and the models also included a random slope for the effect of time at the level of participants. This last random effect allows each participant to have their own evolution of affective valence during the session. The model was adjusted for age, sex, body composition, and preference for and tolerance of exercise intensity. All these variables were centered, to facilitate the interpretation of the model intercept.

To test the effect of group on remembered pleasure (i.e., *H2*), we built a model that included group as fixed effect and participants as a random factor, along with the aforementioned covariates (i.e., age, sex, body composition, and preference for and tolerance of exercise intensity). To examine whether the effect of group on remembered pleasure was consistent across the exercise sessions, we built a second model that included the linear and quadratic effects (see below) of exercise session, as well as the effect of the interaction between exercise session and group, as fixed factors. The interactive effect allows the examination of whether the effect of group on remembered pleasure depends on the exercise session. The linear effect tests whether the effect of group on remembered pleasure strengthens linearly across the exercise sessions (i.e., a linear dose-response pattern). The quadratic effect indicates whether the effect of group on remembered pleasure is not constant across the exercise sessions (i.e., has non-linear effects). For example, this parameter accounts for the possibility that the effect of group on remembered pleasure may appear only after a certain number of sessions, or alternatively, if the effect of group is observed as soon as the first session and then reaches a plateau. If the quadratic effect was significant, simple slopes, region of significance, and confidence bands were examined using computational tools for probing interactions in mixed models (Preacher et al., 2006).

Estimates of the effect size were reported using the conditional and marginal pseudo R^2 from the MuMin package (Barton, 2018). Statistical assumptions associated with MEM (i.e., normality of the residuals, homogeneity of variance, linearity, multicollinearity, and undue influence) were checked and met for all models. The analyses were conducted in R with the lme4 and lmerTest packages (Bates et al., 2014; Kuznetsova et al., 2015; R Core Team, 2017).

Secondary Analyses

The carryover effects of previous remembered pleasure on forecasted pleasure at the next RT session (*H4*) were also assessed using MEM. Specifically, the model included the effect of the previous remembered pleasure (i.e., remembered pleasure at the prior exercise session), the time interval between the measures of previous remembered pleasure and forecasted pleasure (i.e., the number of days between RT sessions), as well as an interaction between these terms. The time interval (and its interaction with the previous remembered pleasure) allowed us to account for possible unequal spacing of time between the measure of remembered pleasure and the measure of forecasted pleasure (for example, if a participant trained twice a week on Tuesday and Thursday, the time intervals were not equal between all six sessions). This model was adjusted for the aforementioned covariates.

Additionally, we conducted an exploratory analysis to investigate whether the association between previous remembered pleasure and forecasted pleasure was moderated by group and/or the number of sessions; two-way interactions of remembered pleasure with group and session, as well as a three-way interaction between remembered pleasure, group and session, were included in the second model. In these models, participants were specified as a random factor. The models also included a random slope for the effect of remembered pleasure at the level of participants.

To assess for an “end effect” (i.e., the end of the episode being more influential for how the episode registers in memory; *H5*) on remembered pleasure, we used MEM to test whether the strength of the association between remembered pleasure and affective valence is moderated by the time of measurement (i.e., the first vs. second set of exercises). Specifically, this model included the effect of remembered pleasure and time, as well as the interaction between these terms, as fixed factors. A statistically significant interaction would indicate that the strength of the association between remembered pleasure and affective valence was different across the time of measurement (i.e., the first vs. second set). Participants were specified as a random factor and the models also included a random slope for the effect of time and of remembered pleasure at the level of participants. Like the previous analyses, this model was also adjusted for group, age, sex, body composition, and preference for and tolerance of exercise intensity.

Results

Change in Affective Valence During RT Sessions

Results of the MEM (Table 3) showed no significant main effects of group (*b* = 0.25, 95 % CI [-0.06, 0.56], *p* =.153) and time (*b* = -0.04, 95% CI [-0.17, 0.10], *p* =.577), however the Group × Time interaction was significant (*b* = -0.45, 95% CI [-0.58, -0.31], *p* < .001). Simple-effect tests showed that participants in the DOWN group exhibited an improvement in affective valence during the exercise session (*b* = 0.97, 95% CI [0.58, 1.36], *p* < .001), whereas participants in the UP group exhibited a decline (*b* = -0.82, 95% CI [-1.20, -0.44], *p* < .001) (Figure 3). This means that, as hypothesized, the traditional ramp-up protocol resulted in a negative change in affective valence (i.e., a declining slope) during each session, whereas the ramp-down protocol resulted in a positive change (i.e., improving valence). Regarding the covariates, age (*b* = 0.81, 95% CI [0.50, 1.13], *p* < .001), body composition (*b* = -0.47, 95% CI [-0.80, -0.14], *p* = .015), and tolerance for high exercise intensity (*b* = 0.33, 95% CI [-0.01, 0.66], *p* = .049) were significantly related to the change in affective valence.

Remembered Pleasure

Results of the MEM (Table 4, Model 1) showed a significant main effect of group (*b* = 0.57, 95% CI [0.24, 0.90], *p* =.004), with participants in the DOWN group reporting a higher remembered pleasure (2.47, SE=1.10) than participants in the UP group (1.34, SE=0.99). Age (*b* = 0.67, 95% CI [0.32, 1.02], *p* =.002), body composition (*b* = -0.43, 95% CI [-0.79, -0.06], *p* =.044), and PRETIE-Q Tolerance (*b* = 0.46, 95% CI [0.15, 0.78], *p* =.014) were significantly related to remembered pleasure.

Results (Table 4, Model 2) showed that, as hypothesized, the effect of group on remembered pleasure was not significantly moderated by exercise session (*b* = 0.03, 95% CI [-0.03, 0.09], *p* =.291 for the linear interaction; *b* = -0.01, 95% CI [-0.03, 0.03], *p* =.854 for the quadratic interaction). However, we observed significant linear (*b* = 0.09, 95% CI [0.04, 0.15], *p* =.002) and quadratic effects (*b* = -0.05, 95% CI [-0.08, -0.01], *p* =.009) of exercise session. As illustrated in Figure 4, these results suggested an initial increase in remembered pleasure across the exercise sessions that slowed down until it became non-significant.

Secondary Analyses

Carryover Effects

Results of the MEM (Table 5, Model 1) showed that greater remembered pleasure at the previous exercise session was associated with higher forecasted pleasure at the next session (b = 0.60, 95% CI [0.29, 0.97], p =.001). Neither time interval (p = .584) nor the interaction between time interval and previous remembered pleasure (p = .267) were significantly associated with forecasted pleasure. In other words, the association between remembered pleasure and forecasted pleasure was not moderated by the amount of time that intervened between these measures. Age (b = 0.51, 95% CI [0.10, 0.89], p =.022) and, though not statistically significant, preference for high exercise intensity (b = 0.39, 95% CI [0.04, 0.76], p =.051) were also associated with forecasted pleasure. Finally, tests of the potential moderating role of Group and Session on the effect of remembered pleasure on forecasted pleasure (Table 5, Model 2) did not reveal significant effects (*ps* > .133).

End Effects

Results of the MEM (Table 6) showed that the time of measurement significantly moderated the strength of the association between remembered pleasure and affective valence (b = -0.16, 95% CI [-0.32, -0.02], p =.046). Simple-effect tests showed that the association between remembered pleasure and affective valence was significantly stronger for affective valence measured during the second set of exercises (b = 0.91, 95% CI [0.64, 1.25], p <.001) relative to the first set (b = 0.60, 95% CI [0.34, 0.87], p <.001), which demonstrates the expected ‘end-effect’. Age (b = 0.47, 95% CI [0.23, 0.69], p =.001) was the only significant covariate for this analysis.

Discussion

It is uncontroversial that, as long as injuries are avoided, higher intensity (load) can amplify the benefits of exercise training (e.g., Refalo et al., 2021). However, higher intensity is experienced as more unpleasant during both aerobic (Ekkekakis et al., 2011) and resistance exercise (Greene & Petruzzello, 2015; Hutchinson et al., 2020), leading to negative implications for adherence. Here, we use psychological theory and previous evidence to show that a psychologically informed training protocol can improve the affective experience of RT without compromising the training effect.

The primary aim of this study was to compare the effect of an increasing-intensity (UP) or decreasing-intensity (DOWN) RT protocol on experienced and remembered pleasure across six training sessions. As hypothesized (*H1*), participants in the UP group reported a decline in affective valence during each session (i.e., from the first to the second set), whereas those in the DOWN group reported an improvement in valence. Moreover, across all training sessions, remembered pleasure was significantly higher in the DOWN group compared to the UP group, which was consistent with our second hypothesis (*H2*). These findings replicate and extend previous results (Hutchinson et al., 2020; Zenko et al., 2016), demonstrating that these effects are not limited to a single bout of exercise, but remain consistent over multiple training sessions. To date, the role of psychology in exercise programming has largely been neglected. Our findings demonstrate that an RT protocol of decreasing intensity can elicit increasing pleasure within an RT session, leading to more positive retrospective affective evaluations of RT, without sacrificing training load. This holds important implications for exercise behavior, as positive affective experiences associated with exercise are important predictors of subsequent engagement (Rhodes & Kates, 2015).

A possible mechanistic explanation for the pattern of affective responses to ramp-up and ramp-down training protocols is offered by the opponent-process theory of acquired motivation (Solomon, 1980). Solomon suggested that affective responses to stimuli may be the result of an "affect summator," which constantly computes the algebraic sum of two underlying processes, namely a primary process and an “opponent process,” with opposing valence. The onset of a stimulus activates the primary response, which is termed the a-process (displeasure in the case of heavy exercise). If the a-process reaches a critical threshold (e.g., if the exercise becomes stressful and unpleasant), a b-process is triggered, which functions to oppose and suppress the departure from the state of affective neutrality generated by the a-process (Solomon, 1980). Because the b-process is an opponent process, its affective or hedonic quality is always opposite to that of the a-process (i.e., pleasure in the case of heavy exercise). When the precipitating stimulus (e.g., heavy exercise) ceases, the a-process is terminated almost instantly. However, the b-process, which had a slow rise time, also has a slow decay and can thus persist for a period of time after the cessation of the precipitating stimulus. This theorized temporal pattern of affective responding matches the rebound phenomenon that is well documented in the case of aerobic exercise (Ekkekakis et al., 2011), evidenced by a positive affective state following exercise. The ramp-down training protocol uniquely allows for the affective rebound (i.e., opponent process) to be initiated early *during* the exercise session and to be extended over the remainder of the session. Opponent processes are strengthened by use (Solomon & Corbit, 1978). With multiple stimulus presentations, the b-process becomes stronger, more efficient, and demonstrates increased persistence (i.e., is sustained well beyond the quieting of the a-process; Solomon, 1980). This highlights the importance of the effects observed in the present study occurring consistently across multiple training sessions.

Both the opponent-process theory and the ART highlight the importance of associative learning. Positive feelings elicited by the b-process in response to an aversive stimulus eventually become associated with that stimulus via a relief-conditioning paradigm (Andreatta et al., 2012), which can lead to more positive associations with the stimulus. The ART emphasizes the importance of automatic positive and negative associations for exercise engagement or avoidance. According to the ART, momentary automatic associations are based on learned (repeated) pairings of exercise with pleasure or displeasure, resulting in the felt automatic positive or negative affective valuation of exercise. Both the activated automatic associations and the related affective valuation leave traces in memory, and become the updated basis of new momentary states of experience. Our data can be interpreted in light of this theorized learning cycle (Brand & Ekkekakis, 2021). By experiencing increasingly pleasant affective states over the course of RT sessions, participants in the DOWN group possibly learned to associate RT with pleasure and, therefore, to remember RT as pleasant. However, our results also suggest that this learning effect may diminish over a series of sessions (see Figure 4). This phenomenon may reflect a process whereby the exercise-pleasure association that had already been experienced several times, was no longer new for the participants and, therefore, had diminishing influence on their subsequent recollections of exercise.

Participants in the present study demonstrated a stronger association between remembered pleasure and affective valence measured during the second set of exercises, compared to the first set. Thus, the anticipated ‘end-effect’, wherein the end of the episode is most influential for how the episode registers in memory (*H5*), was supported. This finding is consistent with research from the field of behavioral economics, according to which the recollection of affective experiences is influenced by a number of cognitive biases. Rather than forming affective memories based on the totality of the pleasure or displeasure experienced over an episode, recollections are disproportionately influenced by highly salient moments or "snapshots," such as the moment of the most intense pleasure or displeasure, and whether an episode was pleasant or unpleasant at the end (Kahneman et al., 1993). Endings have been found to be particularly important for determining subsequent behavior (Garbinsky et al., 2014; Kahneman et al., 1997). Both the end-point and the direction of change especially during the latter half of the experience, are important in this regard, particularly for aversive experiences (Ariely, 1998). The ramp-down training protocol leverages this heuristic by assuring a more positive ending to exercise experiences.

The importance of facilitating pleasant affective endings of exercise sessions is further highlighted by the observed carryover effect, whereby previous remembered pleasure positively predicted forecasted pleasure at the next exercise session. This finding was in line with our hypothesis (*H4*) and corroborates previously reported associations of remembered pleasure following an exercise bout and subsequent forecasted pleasure (Zenko et al., 2016). Retrospective evaluations have an adaptive function in that they determine whether a situation experienced in the past should now be approached or avoided (Kahneman et al., 1997). Such predictions draw heavily upon the anticipated hedonic consequences of future events; simply put, if people expect exercise to be more pleasant, they are more likely to engage in this behavior. This underscores the importance of targeting remembered pleasure to promote exercise behavior (Ekkekakis et al., 2021).

Regarding the carryover effect, it is important to note that while participants in the DOWN group finished with a low load, they started the next session with a high load. Although participants were blinded to the purpose of the study, it is possible that after a couple of sessions they became familiar with the structure (i.e., increasing or decreasing load) and were able to anticipate that they would start the next session with a high load. If this were the case, we might expect to see findings in the opposite direction to those observed (i.e., the DOWN group would report lower forecasted pleasure). For example, Ruby et al. (2011) found that exercisers' anticipated enjoyment was greater when the preferred component of a workout was placed at the beginning rather than the end, leading the authors to suggest that, "just as endings disproportionately influence retrospective evaluations, … beginnings disproportionately influence prospective evaluations" (p. 68). In the present study we did not find this to be the case, perhaps because the warm-up at the start of each session ensured that both groups would start the next session with the same intensity. However, this is an important consideration for future investigations of the opposing slopes approach to exercise prescription.

We had predicted that affective responses would be more positive in individuals with a greater dispositional tolerance (*H3a*) and preference (*H3b*) for high exercise intensity. Exercise tolerance, but not preference, was positively related to the slope of affective valence and remembered pleasure, meaning that this hypothesis was partially supported. Exercise tolerance reflects the ability to continue exercising at an imposed level of intensity even when the activity has become unpleasant or uncomfortable (Ekkekakis et al., 2005). Thus, we can infer that the training loads were likely experienced as challenging, and those with greater dispositional tolerance were able to maintain more positive affective valence in response to exercise. This finding is in line with prior investigations (e.g., Box & Petruzzello, 2020; Jones et al., 2018), and reiterates the need to take individual differences into account when designing exercise programs, since they appear to significantly modulate affective experiences.

Several covariates were included in our analyses, which, while not associated with an explicit a priori hypothesis, yielded some noteworthy insights. In the present study, body composition was negatively related to both the slope of affective valence and remembered pleasure. To our knowledge, no prior research has assessed the influence of body composition on affective responses to resistance exercise, although there is evidence that women with obesity report lower ratings of affective valence during exercise than overweight and normal-weight women during aerobic exercise (Ekkekakis et al., 2010). Several obesity-related factors are thought to increase the range and intensity of aversive somatic sensations experienced during exercise, which results in a less pleasant (or more unpleasant) exercise experience for individuals with obesity relative to their normal-weight and overweight counterparts (Ekkekakis et al., 2016). Somewhat surprisingly, age was positively related to the change in affective valence, remembered pleasure, and forecasted pleasure. Few studies have examined age differences in affective response to exercise. Among those that have, most have found no age-related differences in affective valence during moderate aerobic exercise (DaSilva et al., 2010; Focht et al., 2007). However, while not assessing valence specifically, Barnett (2012) reported that older women showed higher positive engagement (e.g., enthusiastic, happy, upbeat) than younger women, during 20 min of stationary cycling at 60% VO_2 max. It is possible that in the present study, the older participants benefitted more from the interaction with a personal trainer. Personal trainers can be important facilitators of perceived competence and self-efficacy (Wayment & McDonald, 2017) and offer opportunity for social interaction. This study was not designed to explore the influence of demographic characteristics on affective response to RT, but our covariate results suggest the need for further exploration of these considerations. It is important to highlight that the effect of ramp-up vs. ramp-down RT protocols remains significant after adjusting for these variables.

Strengths, Limitations, and Future Directions

In evaluating the results of this study, readers should be aware of its strengths and limitations. One potential limitation pertains to the timing and frequency of the measurement of remembered pleasure. In order to reduce participant burden, we took only one assessment of remembered pleasure, shortly after the cessation of exercise at each session. However, fluctuations in the recall of affective experience of experience over a 24-hour period have been noted (Slawinska & Davis, 2020) and should be considered. In prior investigations of ramped-intensity training, group differences in remembered pleasure were sustained at 24-hr post-exercise (Hutchinson et al., 2020; Zenko et al., 2016), which is of particular importance given the potential implications of remembered pleasure at the time of the decision to reengage (or not) in exercise for adherence.

Participants in the current study were novice resistance exercisers and predominantly (85%) women, which limits the generalizability of our findings. However, it should be noted that women are historically underrepresented in sport and exercise science research (Costello et al., 2014; Cowley et al., 2021) and particularly in RT research. We also note that our main findings are in line with those of Andrade et al. (2022) who observed a progressive decline in affective valence with increasing RT load among a sample of resistance-trained men.

Nonetheless, the results of the present investigation should be replicated with different samples (e.g., with a sample with a more equal representation of men and women).

A strength of the current study was that affective valence was measured twice during each RT session over three weeks of training. While it is possible that more frequent assessments might have captured subtle fluctuations in affective valence, excessive assessments can be intrusive, burdensome, and may even influence the ratings themselves (Meir et al., 2015). Recent methodological papers present evidence that affective valence across six resistance exercises can be adequately assessed with a single measurement (Andrade et al. 2022; Bastos et al., 2022). A potential problem with assessing valence during the last exercise within a set is that ratings may be overly weighed upon a participant’s affective response to that particular exercise (in this case, the lateral pull-down and assisted pull-up). However, our results mirror those of Hutchinson et al. (2020), who obtained ratings of affective valence for each individual exercise within a set, during ramped-intensity RT, which helps to allay this concern.

Changing the direction of exercise intensity from low–high to high–low is an easily implementable strategy that can be immediately adopted by individuals and exercise prescription professionals. The scalability of this strategy is a strength and offers a point of difference from other strategies developed to promote more pleasant exercise experiences (e.g., music and video). In the present study, disruptions encountered during the onset of the COVID-19 pandemic resulted in a shorter intervention than originally planned and limited our ability to collect outcome measures. As such, the need to establish the long-term behavioral impact of interventions designed to optimize exercise-related affect remains a pressing issue. Investigating the impact of ramped-intensity training on exercise adherence remains an important goal for future studies.

Conclusion

The results of this study show that an RT protocol of decreasing intensity can elicit increasing pleasure within an RT session, leading to more positive recollections of the affective experience of RT. These findings replicate and extend the results of previous studies that were limited to single bouts of exercise (Hutchinson et al., 2020; Zenko et al., 2016) by demonstrating the consistency of these effects over multiple training sessions. Moreover, these effects were significant after accounting for covariates that could influence affective response to exercise. This extension of prior findings should encourage practitioners to incorporate psychological considerations into their exercise prescriptions.

Dedication

This article is dedicated to the memory of Daniel J. Cavarretta of Boxford, MA, whose pioneering research on the timing of affective responses to resistance exercise is cited herein.

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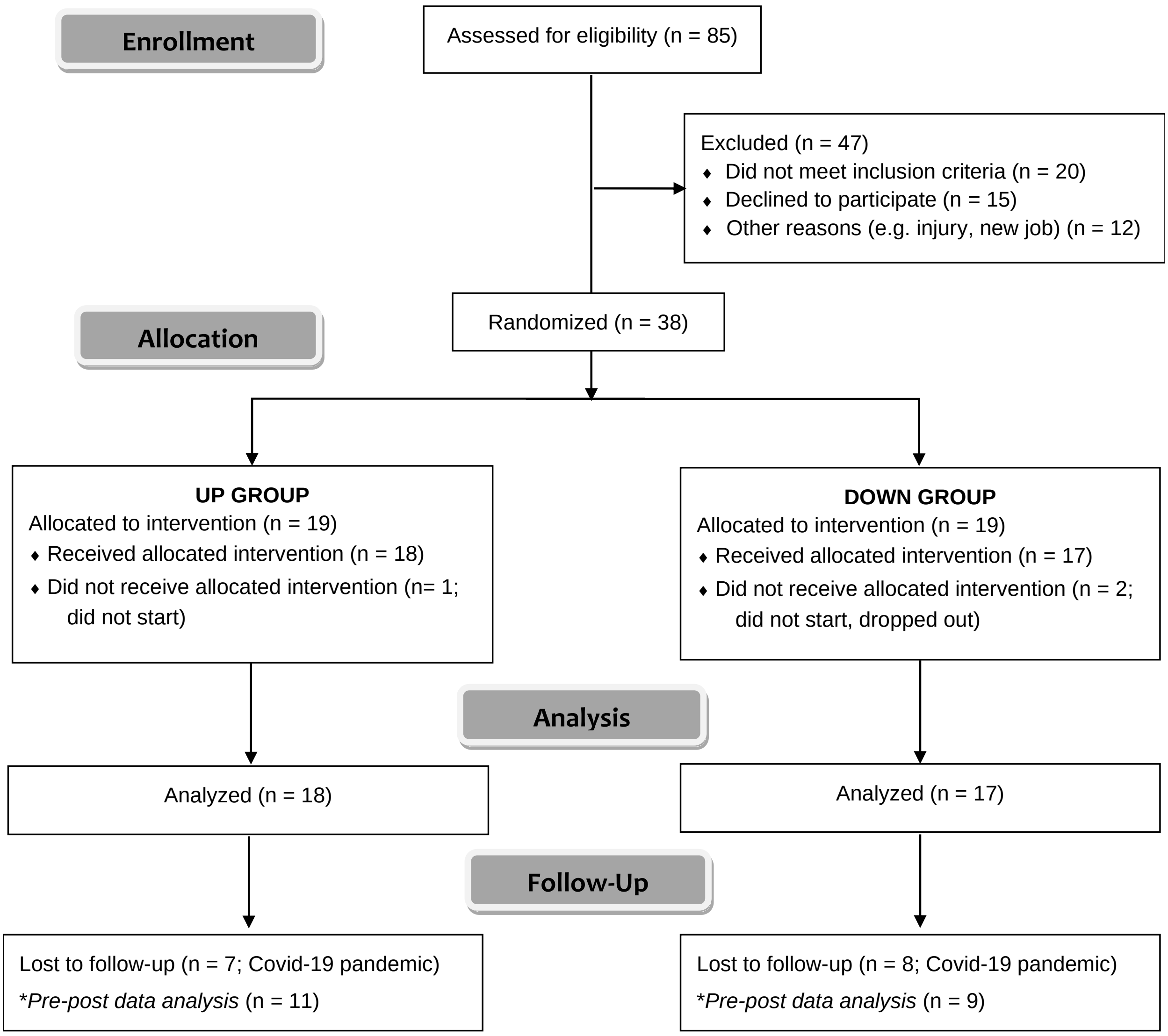
Figure 1.

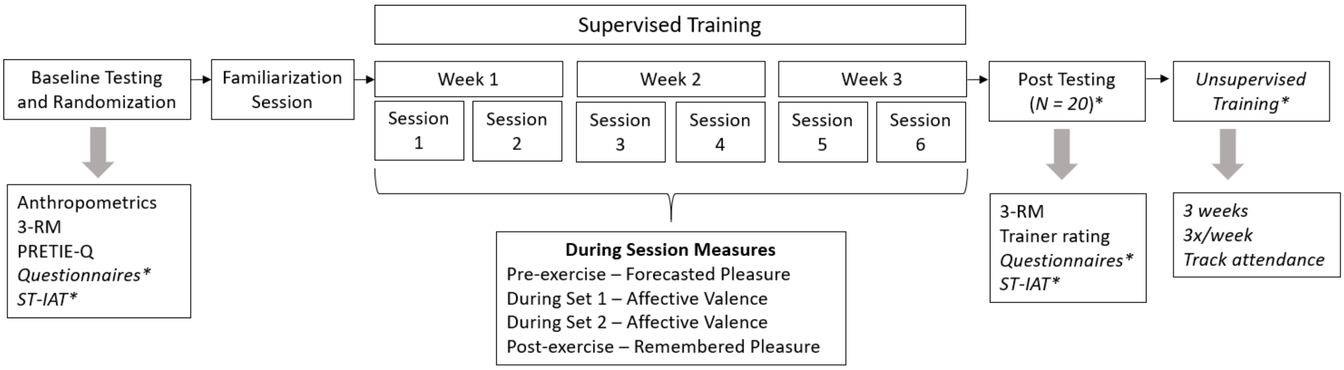
Consort Flow Diagram



Note: *Pre-post analyses are presented in a supplementary file

Figure 2.

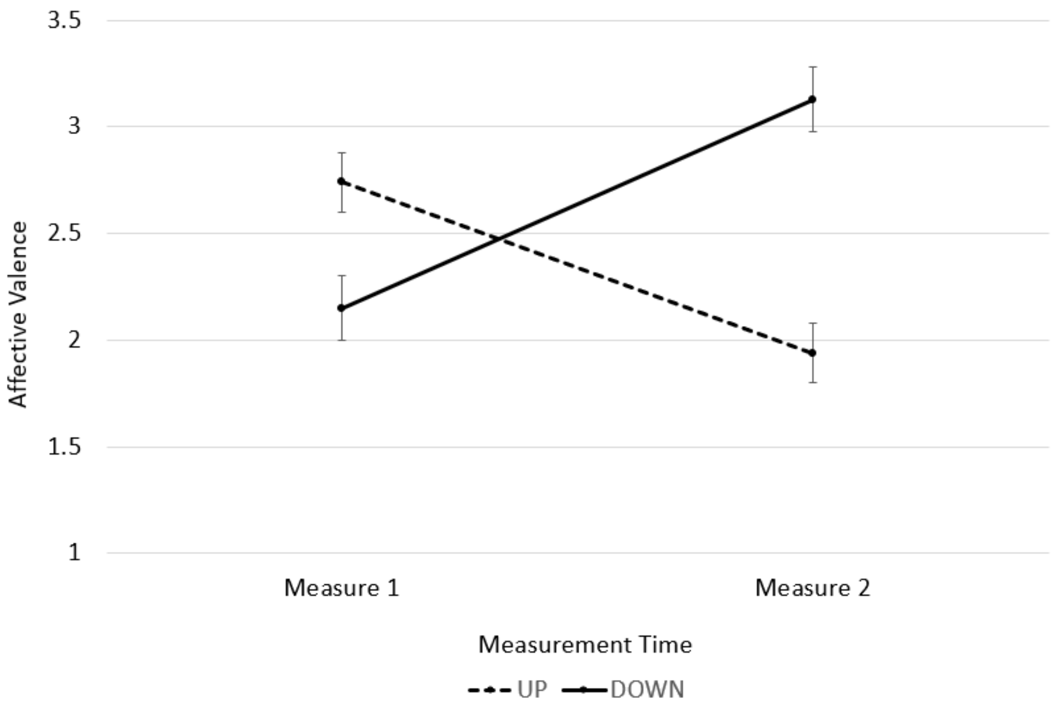
Overview of the Study Protocol with the Associated Measures at each Time Point.



Note: *Details of the measures in italics and pre-post data analysis for these variables (N=20) are presented in a supplementary file.

Figure 3.

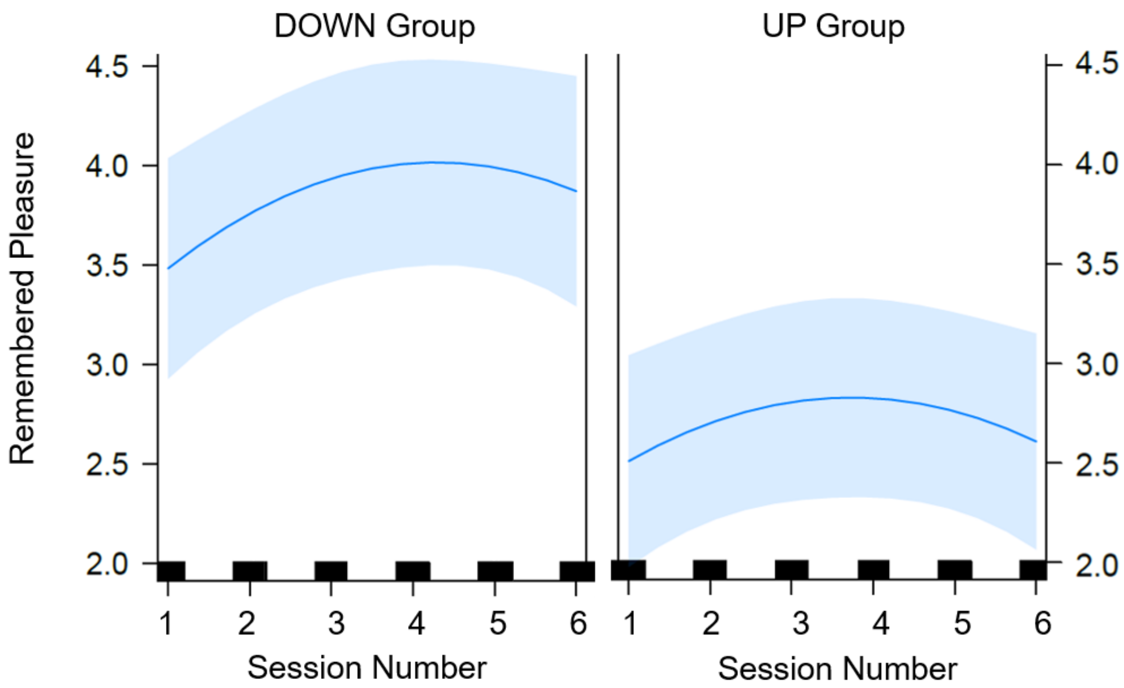
Results of the Mixed Models Predicting Affective Valence as a Function of Group.



Note. UP = increasing intensity; DOWN = decreasing intensity; measure 1 = set 1; measure 2 = set 2. Error bars represent standard errors.

Figure 4.

Evolution of Remembered Pleasure across Exercise Sessions as a Function of Group.



Note. Evolution of remembered pleasure was plotted as a function of the quadratic effect of exercise sessions. DOWN = decreasing load; UP = increasing load. Shaded area represents the 95% confidence interval.

Table 1.

Participant Characteristics (*N* or *M* ± *SD*)

	UP Group (n = 18)	DOWN Group (n = 17)	p
Sex	4 male, 14 female	1 male, 16 female	.167
Age (years)	44.28 ± 12.50	42.59 ± 15.24	.722
Body Mass Index (kg/m^2)	29.42 ± 6.70	28.61 ± 4.41	.680
Body composition (% fat)	35.06 ± 7.95	36.53 ± 7.68	.581
PRETIE-Q Preference (8-40)	24.94 ± 2.04	24.23 ± 2.56	.370
PRETIE-Q Tolerance (8-40)	23.27 ± 2.25	23.00 ±1.84	.692

Note. *p* values are based on analysis of variance and chi-square tests for continuous and categorical variables, respectively, testing the effect of Group on these variables. The two groups did not differ with respect to the assessed demographic, anthropometric, and psychological characteristics.

Table 2.

Resistance Training Protocol

Exercises		**Training intensity (% 1-RM)**	
Session 1	Session 2	UP group	DOWN group
1. Hex-bar deadlift	1. Leg press	Week 1: 55→60%	Week 1: 60→55%
2. Leg extension	2. Leg curl	Week 2: 60→65%	Week 2: 65→60%
3. Chest press	3. Chest press		
4. Seated row	4. Long-pull cable row	Week 3: 65→70%	Week 3: 70→65%
5. Half-kneel, single-arm dumbbell press	5. Overhead shoulder press		
6. Lat pull down	6. Assisted pull up		

Table 3.

Results of the Mixed Models Predicting Affective Valence as a Function of Group.

Affective response	*b* (95% CI)	*p*
Fixed effects		
Intercept	1.46 (-0.21, 3.13)	.126
Group	0.25 (-0.06, 0.56)	.153
Time (ref. one)	-0.04 (-0.17, 0.10)	.577
Group × Time	-0.45 (-0.58, -0.31)	<.001
Covariates		
Age	0.81 (0.50, 1.13)	<.001
Sex	0.54 (-0.35, 1.44)	.279
Body composition	-0.47 (-0.80, -0.14)	.015
PRETIE-Q Preference	0.12 (-0.17, 0.41)	.467
PRETIE-Q Tolerance	0.33 (-0.01, 0.66)	.049
Random effects		
Participants		
Intercept	0.78	
Time	0.07	
Corr. (Intercept, Time)	-0.42	
Residuals	1.15	
R^2	Marginal = 0.31	
	Conditional = 0.60	

Note. *b* = unstandardized regression coefficient; 95% CI= 95% confidence interval.

Table 4.

Results of the Mixed Models Predicting Remembered Pleasure as a Function of Group and Exercise Session.

	Model 1		Model 2	
Remembered pleasure	*b* [95% CI]	*p*	*b* [95% CI]	*p*
Fixed effects				
Intercept	1.91 [0.05, 3.76]	.075	2.00 [0.15, 3.85]	.062
Group	0.57 [0.24, 0.90]	.004	0.56 [0.22, 0.90]	.005
Session (1 to 6)				
Linear			0.09 [0.04, 0.15]	.002
Quadratic			-0.05 [-0.08, -0.01]	.009
Group × Session				
Linear			0.03 [-0.03, 0.09]	.291
Quadratic			-0.01 [-0.03, 0.03]	.854
Covariates				
Age	0.67 [0.32, 1.02]	.002	0.66 [0.32, 1.01]	.002
Sex	0.74 [-0.26, 1.74]	.192	0.75 [-0.25, 1.74]	.188
Body composition	-0.43 [-0.79, -0.06]	.044	-0.42 [-0.79, -0.06]	.045
PRETIE-Q Preference	0.02 [-0.30, 0.34]	.897	0.02 [-0.29, 0.35]	.887
PRETIE-Q Tolerance	0.46 [0.15, 0.78]	.014	0.46 [0.15, 0.78]	.014
Random effects				
Participants				
Intercept	0.95		0.95	
Residuals	0.76		0.74	
R^2	Marginal = 0.34		Marginal = 0.35	
	Conditional = 0.71		Conditional = 0.72	

Note. *b* = unstandardized regression coefficient; 95% CI= 95% confidence interval. Session was centered on session number 3. Note that we included a random effect of session at the level of the participant, to account for potential individual differences in the evolution of remembered pleasure across the exercise sessions. Yet, this model estimates a correlation between participants and session equal to -1.00, suggesting redundancy in the parameters. This random effect was, therefore, not included. Note, however, that the results of the fixed effect remained unchanged with or without this random effect.

Table 5.

Results of the Mixed Models Predicting Forecasted Pleasure as a Function of Previous Remembered Pleasure.

	Model 1		Model 2	
Forecasted pleasure	*b* [95% CI]	*p*	*b* [95% CI]	*p*
Fixed effects				
Intercept	2.21 [1.30, 3.13]	<.001	1.94 [0.97, 2.96]	.002
Remembered pleasure	0.60 [0.29, 0.97]	.001	0.38 [-0.01, 0.88]	.089
Time interval	-0.05 [-0.24, 0.15]	.584	-0.06 [-0.24, 0.13]	.538
Remembered pleasure × Time interval	-0.13 [-0.39, 0.09]	.267	-0.12 [-0.24, 0.13]	.327
Group			-0.40 [-1.23, 0.40]	.386
Session (1 to 6)				
Linear			0.07 [-0.28, 0.41]	.703
Quadratic			-0.02 [-0.17, 0.13]	.760
Remembered pleasure × Group			0.40 [-0.33, 1.06]	.282
Remembered pleasure × Session				
Linear			-0.13 [-0.48, 0.23]	.541
Quadratic			0.02 [-0.14, 0.18]	.815
Group × Session				
Linear			0.07 [-0.43, 0.55]	.790
Quadratic			0.10 [-0.12, 0.33]	.398
Remembered pleasure × Group × Session				
Linear			0.42 [-0.08, 0.99]	.133
Quadratic			-0.11 [-0.38, 0.13]	.400
Covariates				
Age	0.51 [0.10, 0.89]	.022	0.48 [0.07, 0.89]	.048
Sex	0.22 [-0.83, 1.24]	.708	0.50 [-0.61, 1.58]	.435
Body composition	-0.27 [-0.67, 0.12]	.221	-0.31 [-0.71, 0.10]	.196
PRETIE-Q Preference	0.39 [0.04, 0.76]	.051	0.43 [0.08, 0.77]	.043
PRETIE-Q Tolerance	0.05 [-0.29, 0.09]	.779	0.13 [-0.24, 0.48]	.541
Random effects				
Participants				
Intercept	0.76		0.96	
Remembered pleasure	0.12			
Corr. (Intercept, remembered pleasure)	-0.17			
Residuals	1.36		1.29	
R^2	Marginal = 0.30 Conditional = 0.57		Marginal = 0.33 Conditional = 0.62	

Note. *b* = unstandardized regression coefficient; 95% CI= 95% confidence interval; time interval = time (days) between sessions. In Model 2, the correlation between intercept and remembered pleasure was equal to -1.00, suggesting redundancy. Accordingly, the random effect of remembered pleasure was not included.

Table 6.

Results of the Mixed Models Testing the Strength of the Association between Remembered Pleasure and Affective Valence as a Function of the Time of Measurement

Affective valence	*b* [95% CI]	*p*
Fixed effects		
Intercept	2.24 [1.22, 3.34]	.001
Remembered pleasure	0.75 [0.55, 1.00]	<.001
Time	-0.03 [-0.20, 0.15]	.748
Remembered pleasure × Time	-0.16 [-0.32, -0.02]	.046
Covariates		
Group	0.05 [-0.20, 0.33]	.689
Age	0.47 [0.23, 0.69]	.001
Sex	0.10 [-0.48, 0.66]	.763
Body composition	-0.24 [-0.46, -0.01]	.071
PRETIE-Q Preference	0.08 [-0.12, 0.27]	.495
PRETIE-Q Tolerance	0.21 [0.02, 0.41]	.062
Random effects		
Participants		
Intercept	0.30	
Time	0.20	
Remembered pleasure	0.20	
Remembered pleasure × Time	0.02	
Corr. (Intercept, Remembered pleasure)	0.39	
Corr. (Intercept, Time)	0.32	
Corr. (Intercept, Remembered pleasure × Time)	-0.50	
Corr. (Remembered pleasure, Time)	-0.32	
Corr. (Remembered pleasure, Remembered pleasure × Time)	-0.69	
Corr. (Time, Remembered pleasure × Time)	-0.45	
Residuals	0.97	
R^2	Marginal = 0.40 Conditional = 0.65	

Note. b = unstandardized regression coefficient; 95% CI= 95% confidence interval.