Psychology of Sport & Exercise 66 (2023) 102396

Contents lists available at ScienceDirect

Psychology of Sport & Exercise

journal homepage: www.elsevier.com/locate/psychsport

Rating of perceived effort but relative to what? A comparison between imposed and self-selected anchors

Tomer Malleron [a,b], Itai Har-Nir [a,b], Andrew D. Vigotsky [c,1], Israel Halperin [a,b,*,1]

[a] Department of Health Promotion, School of Public Health, Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel
[b] Sylvan Adams Sports Institute, Tel Aviv University, Tel-Aviv, Israel
[c] Departments of Biomedical Engineering and Statistics, Northwestern University, Evanston, USA

ARTICLE INFO

Keywords:
RPE
Anchoring procedures
Effort
Neuromuscular fatigue

ABSTRACT

Purpose: Collecting reliable and valid rating of perceived effort (RPE) data requires properly anchoring the scales' upper limits (*i.e.*, the meaning of 10 on a 0–10 scale). Yet, despite their importance, anchoring procedures remain understudied and theoretically underdeveloped. Here we propose a new task-based anchoring procedure that distinguishes between imposed and self-selected anchors. In the former, researchers impose on participants a specific task as the anchor; in the latter, participants choose the most effortful task experienced or imaginable as the anchor. We compared the impact of these conceptually different anchoring procedures on RPE.

Methods: Twenty-five resistance-trained participants (13 females) attended a familiarization and two randomized experimental sessions. In both experimental sessions, participants performed non-fatiguing and fatiguing isometric maximal voluntary contraction (MVC) protocols with the squat followed by the gripper or vice versa. After each MVC, participants reported their RPE on a 0–10 scale relative to an imposed anchor of the performed task (*e.g.*, gripper MVCs anchored to a gripper MVC) or to a self-selected anchor.

Results: In the non-fatiguing condition, imposed anchors yielded greater RPEs than self-selected anchors for both the squat [on average, 9.4 vs. 5.5; $\Delta(CI_{95\%}) = 3.9$ (3.2, 4.5)] and gripper [9.4 vs. 3.9; $\Delta = 5.5$ (4.7, 6.3)]. Similar results were observed in the fatiguing condition for both the squat [9.7 vs. 6.9; $\Delta = 2.8$ (2.1, 3.5)] and gripper [9.7 vs. 4.5; $\Delta = 5.2$ (4.3, 5.9)].

Conclusions: We found large differences in RPE between the two anchors, independent of exercises and fatigue state. These findings provide a basis for further development and refinement of anchoring procedures and highlight the importance of selecting, justifying, and consistently applying the chosen anchors.

1. Introduction

Rating of perceived effort (RPE) scales are some of the most commonly used tools in exercise science (Chen et al., 2002; Faulkner & Eston, 2008; Kasai et al., 2021; Lea et al., 2022). They are implemented via single-item scales that numerically quantify one's experience of investing effort in physical tasks (*e.g.*, 0–10 and 6–20 RPE scales) (Borg, 1998, pp. 44–52; Faulkner & Eston, 2008; Robertson & Noble, 1997). RPE scores are moderately to strongly correlated with a range of physiological states (Chen et al., 2002; Lea et al., 2022) and performance outcomes (Emanuel and SmukasHalperin, 2020; Helms et al., 2017). Accordingly, they are used to monitor and prescribe exercise intensity (Boxman-Zeevi et al., 2022; Buskard et al., 2019; Parfitt et al., 2012; Schwartz et al., 2021; Tiggemann et al., 2021). The advantages of RPE scales as monitoring and prescription tools persist across a wide variety of populations and exercise modalities (Buskard et al., 2019, van Waart et al., 2015; Yu et al., 2021).

Given the broad utility of RPE scales, numerous definitions, instructions, and scales have been developed over the years (Abbiss et al., 2015; Colado et al., 2020; Day et al., 2004; Gearhart et al., 2001; Zourdos et al., 2016). Although these developments have positive aspects, they can also lead to inconsistencies in how RPE is defined, explained, and collected. In turn, these inconsistencies may hinder communication between and within researchers and practitioners and undermine measurement validity (Halperin & Emanuel, 2020; Pageaux, 2016; Steele, 2020). One such example is the various ways in which the

* Corresponding author. Department of Health Promotion, School of Public Health, Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel.
E-mail address: ihalperin@tauex.tau.ac.il (I. Halperin).
[1] Equal senior authors.

https://doi.org/10.1016/j.psychsport.2023.102396
Received 20 October 2022; Received in revised form 18 January 2023; Accepted 20 January 2023
Available online 26 January 2023
1469-0292/

upper limit of RPE scales is anchored (*e.g.,* the meaning of 10 on a 0–10 RPE scale).

A common anchoring approach is to distinguish between "memory-based" and "exercise-based" anchors (Haile et al., 2015; Lagally & Costigan, 2004; Noble & Robertson, 1996, p. 78; Robertson, 2004, pp. 26–27). When using memory-based anchors, participants recall or imagine performing a particular task at maximal effort. When using exercise-based anchors, participants perform a maximal effort task, typically on a separate day before the experiment. In both approaches, participants are guided to assign their maximal perception of effort (memorized or practiced) to the upper limit of the scale. However, despite their procedural differences, memory and exercise-based anchors lead to negligible differences in RPE (Gearhart, 2008; Gearhart et al., 2004; Lagally & Costigan, 2004; Lamb et al., 2004). We speculate that these negligible differences stem from the fact that the anchored task is the same in both conditions (*e.g.,* recalling or actually performing a squat one-repetition maximum [1RM]). We further speculate that using different tasks as anchors (*e.g.,* squat 1RM vs. sprinting up a hill) will lead to different RPE values. We note that studies measuring RPE use a wide range of tasks as anchors, including those that are the same as (Zabala et al., 2011), similar to (Gearhart et al., 2001), or different (Hunter et al., 2005) from the tasks participants perform in the experiment. Yet, a task-based anchoring procedure has never been formalized nor directly studied.

We thus propose a new anchoring procedure that focuses on the task to which the upper limit is anchored. We distinguish between two types of task-based anchors: imposed and self-selected. Under the imposed anchor condition, the researchers anchor the scale's upper limit to a specific task (Gearhart et al., 2001; Pincivero et al., 1999, 2003; Robertson et al., 2000, 2004). For example, in resistance-based tasks, the upper limit can be anchored to a 1RM, a maximal voluntary contraction (MVC), or to reaching task failure (*i.e.*, the inability to complete another repetition). We use the term *imposed* because the specific task representing the upper limit is imposed upon the participants by the researchers or scale instructions. Under the self-selected anchor condition, the researchers anchor the scale's upper limit to the most strenuous, intense, or effortful task participants have ever experienced or can imagine ((Day et al., 2004), (Hollander et al., 2003; Hutchinson et al., 2021; Loenneke et al., 2011; Naclerio & Larumbe-Zabala, 2017; Simão et al., 2005; Zamunér et al., 2011)).[2] We use the term *self-selected* because participants themselves determine the task representing the upper limit (see Tables, Supplemental materials 1 and 2, for examples of studies using imposed and self-selected anchors).

To illustrate why we predict meaningful differences in RPE between the imposed and self-selected anchoring procedures, consider a task in which participants are requested to open a jar of honey and to provide an RPE value after a single attempt. The tighter the lid is screwed on, the more effort one will need to invest to open the jar. If participants are instructed to anchor the upper limit to the specified task (*i.e.*, applying maximal effort at attempting to open the jar), and if participants apply maximal effort, then their RPE is expected to be maximal. Conversely, if participants are instructed to anchor the upper limit of the scale to a self-selected task, they will be free to select one of their own (*i.e.*, the most effortful task they have ever performed). Compared to such tasks, the effort required to open the jar may be perceived as low, leading to relatively low RPE values. However, this prediction remains to be determined.

Recently, Halperin and Emanuel defined perceived effort as *"The process of investing a given amount of one's perceived physical or mental resources out of the perceived maximum to perform a specific task"* (Halperin & Emanuel, 2020).[3] Since a "specific task" can be anchored in imposed and self-selected ways, this definition can serve as a basis to inspect if and to what extent these anchoring procedures impact RPE values. Accordingly, we compared RPE values anchored to imposed and self-selected tasks when performing both multi- and single-joint isometric tasks (squat and gripper) under non-fatiguing and fatiguing conditions. In line with our honey jar example, we hypothesized that (Faulkner & Eston, 2008) under the imposed anchor condition, RPE values will be maximal, or close to maximal, independent of exercises and fatiguing conditions, and (Chen et al., 2002) under the self-selected anchor condition, RPE ratings will be consistently lower compared to the imposed anchor across exercises and fatiguing conditions.

2. Methods

2.1. Participants

We recruited a convenience sample of 25 resistance-trained men and women aged 18–45 (Table 1) via advertisement posts on various social media channels. Inclusion criteria included healthy participants between the ages of 18 and 45 with at least one year of resistance-training experience. Participants also had to be accustomed to performing the back squat and sets composed of 8–15 repetitions to task-failure to ensure sufficient experience with applying maximal effort in resistance-based exercises. Participants signed the informed consent before beginning the first session. The study was approved by the Ethics Committee of Tel-Aviv University (approval number: 0002205–1).

2.2. Experimental approach

We implemented a randomized, within-subject, cross-over design. All participants attended three laboratory sessions: a familiarization session and two experimental sessions, carried out at least three and a maximum of eight days apart. Participants completed a modified (familiarization session) and a full (experimental sessions) protocol composed of repeated isometric 5-s MVCs with the squat and the gripper (Fig. 1A). The full protocol included three repetitions (three MVCs) with 60 s of rest between repetitions (*i.e.*, non-fatiguing), followed by 12 repetitions (12 MVCs), with 20 s of rest between repetitions (*i.e.*, fatiguing). The protocol was completed once with each task and included 10 min of rest between each protocol. After every repetition, participants reported their RPE anchored to either an imposed or a self-selected task. The order of the experimental sessions and of the per-

Table 1
Participants characteristics (mean ± SD).

	Male (n = 13)	Female (n = 12)
Age (years)	29 ± 4	32 ± 6
Height (cm)	177 ± 8	163 ± 7
Body mass (kg)	75 ± 8	61 ± 8
Training experience (years)	6 ± 3	4 ± 2

[2] Here we classify the anchoring approach of studies who cite Borg (1998) as self-selected anchors unless the authors explicitly state that a specific task was used as an anchor. This is because in the 6–20 Borg scale, 20 is anchored as "maximal effort" and 19 as "… extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced" (p. 47). Additionally, for the Borg CR10, 10 is anchored as "… extremely strenuous exercise level. For most people this is an exercise as strenuous as they have ever experienced before in their lives" (p. 51).

[3] We note that a reviewer pointed out that the term "process" in the implemented perceived effort definition can be confusing (i.e., unclear what perception of a process is) and partly redundant (i.e., investment is a process). We agree with this perspective and suggest the following modified perceived effort definition as an alternative: "The perceived investment of one's physical or mental resources to perform a specific task out of a perceived maximum."

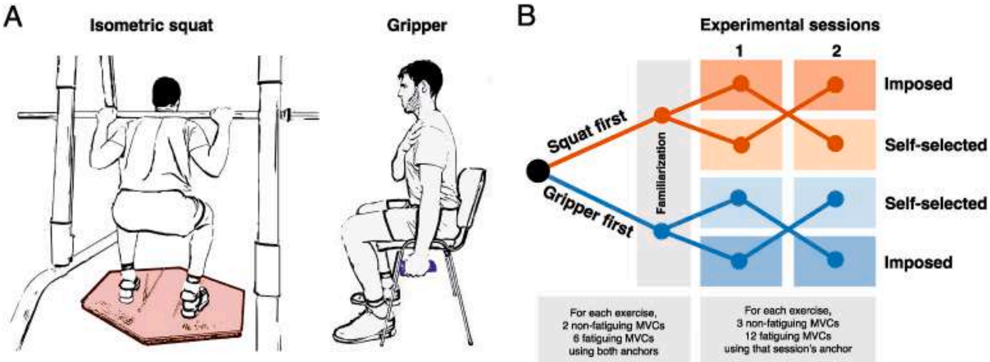

Fig. 1. Experimental setup and timelines. (A) Illustrates the isometric squat (left) and gripper setup. (B) Illustrates the study timeline. Note that each of the four rows indicates a possible order of days to which participants were randomized.

formed exercises within sessions was counterbalanced and then randomized. Yet, to prevent information overload, once participants were randomized to a particular exercise order, it remained constant throughout all sessions. Hence, we randomized each participant to one of four order possibilities (https://www.random.org/lists) (see four rows in Fig. 1B).

Participants completed the same general and exercise-specific warm-up in all sessions before the MVC protocols. The general warm-up included two rounds of high knees, heel flicks and jumping jacks, 10 s each, followed by three sets of eight body weight squats and four push-ups, and 5 min of self-selected dynamic stretching. The exercise-specific warm-up included five, 5-s repetitions with gradual increases in force production. The forces increased by units of 10% and corresponded to 50–90% of the normative values of the average MVCs in the two exercises (Brady et al., 2020; Günther et al., 2008; Leyk et al., 2007) (familiarization session), or of each participant's familiarization session's highest MVC values (two experimental sessions). During the warmup participants viewed their force traces on a computer screen in real-time to guide them and ensure they were applying the required forces. In contrast, during the MVC protocols we provided no visual or verbal feedback. We asked participants to refrain from intense training 24 h prior to testing days and avoid heavy meals and caffeinated drinks at least 4 h before all three sessions.

2.3. Familiarization session

To reduce the likelihood of different response biases, we told participants that the main goals of the study were to examine the test-retest reliability of the performance and heart rate outcomes and the secondary goal was to compare two different RPE measurement techniques. We then measured participants' weight and height (mBCA 515, SECA, Hamburg, Germany) and explained how to perform the exercises and how to rate RPE under the two conditions (see detailed description below). Following the warmup, we familiarized participants with the protocol and RPE by having them go through a partial protocol composed of eight MVCs per task and per RPE condition. That is, they performed two non-fatiguing MVCs and six fatiguing MVCs in the same task. After each MVC, participants reported the RPE anchored to either the imposed or self-selected tasks. They then repeated the same protocol with the same task, but this time using the alternative anchor. Participants then repeated this procedure with the other task (*i.e.*, eight MVCs per each of the RPE conditions).

2.4. Experimental sessions

We reviewed how to rate RPE with the participants and then had them perform the warmup. They then completed the full MVC protocol (three non-fatiguing followed by 12 fatiguing MVCs) with one of the exercises. After each MVC, participants provided their RPE in accordance with the condition they were randomized to for that session. Following 10 min of rest, they repeated the full protocol with the other task and the same RPE anchoring approach. Participants performed the same protocol in the next experimental session but followed the other RPE anchoring approach. Heart rate was measured in both sessions using a heart rate strap (Polar Electro Oy, Kempele, Finland).

2.5. Measures

We recorded all force data using the Kforce Pro app (Kinvent, Orsay, France) and used the mean force values of both the squat and gripper for the analyses.

Isometric squat. Participants stood on a force plate (Deltas, Kinvent, Orsay, France) which recorded ground reaction forces at a sampling frequency of 500 Hz. For each MVC, we asked participants to apply maximal forces into the ground by pushing the barbell secured by ratchet straps to a Smith machine (Insight Fitness, DR030B). The barbell height was set to mid-scapula, and the knee angle was set to 90° as measured with a goniometer at the familiarization session (Fig. 1A). The bar height was documented and repeated in the following sessions.

Gripper. Participants sat on a stable chair without arm support. They held the gripper (Kinvent, Orsay, France) with their dominant arm extended next to their body, their non-dominant hand placed across their chest, and their feet firmly on the ground. We asked participants to squeeze the gripper as hard as they possibly could in each MVC (Fig. 1A).

RPE. In the familiarization session, we covered what RPE is in the following manner: We explained that effort is the process of investing a given amount of one's physical or mental resources out of the maximum to perform a specific task, and that RPE is the perceived investment of one's physical or mental resources out of the perceived maximum to perform a specific task. We then explained that they will rate their invested effort using a number ranging from 0 to 10, in which 0 represents investing no effort at all, and 10 represents investing all available resources at the performed task. We introduced them to the 0–10 perceived effort scale that was placed on the wall in front of them (420 × 594 mm) to assist them in their ratings. Note that the RPE scale had numbers appearing vertically in ascending order, with the main title of '*Rating of Perceived Effort Scale*' and a subtitle of '*Rate your perceived effort for the repetition you have just completed*' in Hebrew. To avoid possible biases, we did not include any text next to the numbers (*e.g.,* "hard").

Finally, we explained that they will rate their perceived effort in two ways: relative to an imposed or self-selected anchor. To illustrate the differences between the two ways, we asked participants to imagine that they are trying to unscrew the lid off a jar of honey, and despite trying as hard as possible, they cannot do so. Under the imposed anchor condition, the upper anchor (*i.e.*, 10) represents the investment of all resources in an attempt to complete the task at hand (*i.e.*, unscrew the lid off the jar). Under the self-selected anchor condition, 10 represents the greatest effort they have ever invested in a task they have performed in the past or one they can imagine. To ensure an adequate understanding of the ratings, we repeated the explanations as needed throughout the familiarization and experimental sessions.

Before completing the modified MVC protocol, we provided the same instructions but exchanged the honey jar example with force production in the squat and gripper, and had participants report RPE anchored to either the imposed or self-selected task. We provided the respective RPE condition instructions prior to the full MVC protocols in the experimental sessions. At the end of the self-selected anchor session, we asked participants what task they imagined or remembered. We recorded and later transcribed their responses.

2.6. Statistical analysis

Our principal research question was how different anchoring procedures would affect RPE. To answer this, we fit a linear mixed-effects model (Bates et al., 2015) in which RPE was the dependent variable, and fatiguing condition (fatiguing vs. non-fatiguing), anchoring condition (imposed vs. self-selected), exercise (squat vs. gripper), and repetition number (1–3 for non-fatiguing and 1–12 for fatiguing, centered and treated continuously) were independent variables. We included all four independent variables up to and including their quadruple interaction as fixed effects. In contrast, just intercepts, anchoring condition, exercise, fatigue condition, and anchor-by-fatigue were permitted to vary across participants (random effects); higher-order random effects caused model convergence issues. The model residuals were unstructured and homoscedastic but deviated from normality; thus, we bootstrapped the fixed effects estimates by resampling participants for 5000 replicates. We used the bootstrap distributions to estimate the fixed effects' variance-covariance matrix (for SEs and plotting) and calculate 95% compatibility intervals (CI) using the bias-corrected and accelerated bootstrap. Nakagawa's marginal (fixed effects only) and conditional (fixed and random effects) R^2's were calculated (Nakagawa et al., 2017; Nakagawa & Schielzeth, 2013), and their variances were used in permutation tests (999 permutations) to evaluate the influences of gender, a quadratic term for repetition, and exercise order.

As secondary analyses, we quantified the extent to which force and heart rate data systematically differed across anchoring sessions. These analyses were specified identically to the ones for RPE, but the dependent variables (force and heart rate) were logged to stabilize their variances (*i.e.*, for homoscedasticity), and because these variables generally seem to behave multiplicatively. For consistency, we used the same bootstrap procedures as for the primary analyses. All statistical analyses were conducted using R (version 4.2.1, R Core Team, Vienna, Austria) and marginal effects were calculated using emmeans (Searle et al., 1980) (see CSV sheet, Supplemental material 3, for raw data).

3. Results

Descriptive statistics (mean ± SD) of RPEs in the two conditions, fatigue states, and tasks, are presented in Table 2.

3.1. Primary outcome: RPE

Our primary mixed effects model fit the data well ($R^2_{marginal} = 0.628$; $R^2_{conditional} = 0.944$); the fixed effects (See Table, Supplemental material 4) and random effects (See Table, Supplemental material 5) can be found in the supplement. Including gender ($\Delta R^2_{marginal} = 0.019$, $P_{marginal} = 0.178$), a quadratic term for repetition ($\Delta R^2_{marginal} < 0.001, P_{marginal} = 0.493$; $\Delta R^2_{conditional} < 0.001, P_{conditional} = 0.697$), and order ($\Delta R^2_{marginal} = 0.011, P_{marginal} = 0.25$) did not appreciably improve the model fit.

Table 2
Descriptive statistics (mean ± SD) of RPEs.

		Non-fatiguing	Fatiguing
Squat	Imposed	9.4 ± 0.8	9.7 ± 0.7
	Self-selected	5.5 ± 2.1	6.9 ± 2.2
Grip	Imposed	9.4 ± 0.8	9.7 ± 0.5
	Self-selected	3.9 ± 2.4	4.5 ± 2.6

Non-fatiguing condition: When using imposed anchors, RPEs were 9.4 ± 0.1 for both the squat and gripper (estimate ± SE) after the 2nd repetition (i.e., the model's intercept). In contrast, RPEs reported with the self-selected anchors were much lower: squat RPEs were 5.5 ± 0.3 and gripper RPEs were 3.9 ± 0.4. Thus, imposed anchors increased squat RPE by 3.9 ± 0.3 and gripper RPE by 5.5 ± 0.4 relative to self-selected anchors. All model parameters, including repetition effects, can be seen in Table 3 and Fig. 2A.

Fatiguing condition: When using imposed anchors, RPEs were 9.7 ± 0.1 for both the squat and gripper (estimate ±SE) after the "6.5th repetition" (i.e., the model's intercept). In contrast, RPEs reported with the self-selected anchors were much lower: squat RPEs were 6.9 ± 0.3 and gripper RPEs were 4.5 ± 0.4. Thus, imposed anchors increased squat RPE by 2.8 ± 0.3 and gripper RPE by 5.2 ± 0.4 relative to self-selected anchors. Estimated marginal effects and their contrasts can be seen in Table 3 and Fig. 2B.

3.2. Secondary outcome: force

Forces were similar across anchoring conditions (Fig. 3A and B). In the non-fatiguing condition, there was a ≤2% difference in average force between the imposed and self-selected anchoring procedures (estimate ± SE of the contrast on the log scale = 0.01 ± 0.01 for the squat; 0.02 ± 0.02 for the gripper). In addition, forces changed similarly with additional repetitions (0.02 ± 0.01 for the squat; 0.01 ± 0.01 for the

Table 3
RPE intercepts and slopes across exercises and anchoring conditions.

			Non-fatiguing		Fatiguing	
			Estimate ± SE	Δ ($CI_{95\%}$)	Estimate ± SE	Δ ($CI_{95\%}$)
Intercept	Squat	Imposed	9.4 ± 0.1	3.9 (3.2, 4.5)	9.7 ± 0.1	5.2 (4.3, 5.9)
		Self-selected	5.5 ± 0.3		6.9 ± 0.3	
	Grip	Imposed	9.4 ± 0.1	5.5 (4.7, 6.3)	9.7 ± 0.1	2.8 (2.1, 3.5)
		Self-selected	3.9 ± 0.4		4.5 ± 0.4	
Slope (RPE/rep)	Squat	Imposed	0.5 ± 0.1	0.12 (−0.06, 0.30)	0.02 ± 0.01	−0.15 (−0.20, −0.11)
		Self-selected	0.4 ± 0.1		0.18 ± 0.02	
	Grip	Imposed	0.3 ± 0.1	−0.02 (−0.34, 0.19)	0.03 ± 0.01	−0.07 (−0.11, −0.04)
		Self-selected	0.3 ± 0.1		0.10 ± 0.02	

As depicted in Fig. 2, our observations can be conceptualized as eight linear models: imposed and self-selected anchoring for both the isometric squat and gripper exercises, under non-fatiguing and fatiguing conditions (2 × 2 × 2 = 8). Here, we present the intercept and slope of each of those lines (Estimate ±SE columns), along with contrasts to investigate the effect of anchoring within each exercise and fatigue condition (Δ ($CI_{95\%}$) columns). Since repetition was mean-centered, the intercepts represent the estimated RPE halfway through each set (after the 2nd repetition for non-fatiguing and after the "6.5th repetition" for fatiguing). In addition, the slopes represent the expected change in RPE for each additional repetition. SEs were calculated using 5000 bootstrap replicates, and 95% CIs of the contrasts were calculated using the bias-corrected and accelerated bootstrap.

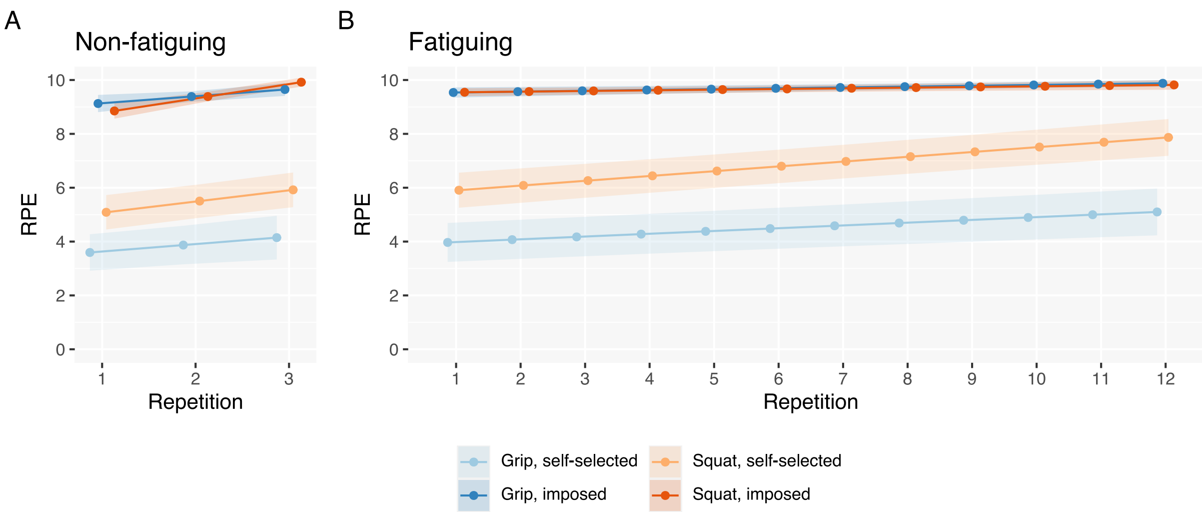

Fig. 2. Effects of anchoring procedures, exercise, and repetitions on RPE. In both the non-fatiguing (A) and fatiguing (B) conditions, the imposed anchors led to higher RPE relative to self-selected anchors for the gripper and squat tasks. Error ribbons indicate 95% CIs.

gripper). In the fatiguing condition, there was a $\leq$2% difference in average force between the imposed and self-selected anchoring procedures (estimate $\pm$ SE of the contrast on the log scale = 0.02 $\pm$ 0.01 for the squat; 0.01 $\pm$ 0.02 for the gripper). In addition, forces changed similarly with additional repetitions ($-$0.001 $\pm$ 0.001 for the squat; $-$0.004 $\pm$ 0.002 for the gripper).

3.3. Secondary outcome: heart rate

Heart rates were also similar across anchoring conditions (Fig. 3C and D). In the non-fatiguing condition, there was a $\leq$2% difference in average force between the imposed and self-selected anchoring procedures (estimate $\pm$ SE of the contrast on the log scale = 0.01 $\pm$ 0.02 for the squat; 0.02 $\pm$ 0.02 for the gripper). In addition, heart rate changed similarly with additional repetitions (0.002 $\pm$ 0.008 for the squat; 0.01 $\pm$ 0.01 for the gripper). In the fatiguing condition, there was a $\leq$1% difference in heart rate between the imposed and self-selected anchoring procedures (estimate $\pm$ SE of the contrast on the log scale = 0.01 $\pm$ 0.01 for the squat; 0.01 $\pm$ 0.02 for the gripper). In addition, heart rate changed similarly with additional repetitions ($-$0.001 $\pm$ 0.001 for the squat; 0 $\pm$ 0.001 for the gripper).

4. Discussion

We compared the imposed and self-selected anchoring approaches on RPE when performing both multi- and single-joint maximal-intensity isometric tasks under non-fatiguing and fatiguing conditions. As hypothesized, we observed large differences in RPE between the two anchoring approaches, independent of the task and fatigue state. Under the imposed anchor condition, the RPE values were mostly maximal. Conversely, under the self-selected anchor condition, the RPE values in both exercises and fatiguing conditions gradually increased throughout the protocol but tended to be submaximal. Additionally, ratings in the squat began at higher values and progressed more steeply compared to the gripper. The negligible differences in force production and heart rate between the two experimental sessions reinforce the assumption that the anchoring procedures' effects on ratings were not mediated by physiological or performance measures. Below we discuss the implications of these results.

We expected negligible differences in RPE between tasks and fatiguing conditions within the imposed anchor condition for two main reasons. First, the task and the anchor were the same for each task (*i.e.*, squat as the task and squat as the anchor). Second, the definition of perceived effort we used focuses on the investment of resources required for the task (Halperin & Emanuel, 2020), rendering both type of tasks and level of fatigue irrelevant. Simply put, if the upper limit is anchored to an MVC, and participants perform MVCs with the same task as the anchor, one invests all perceived resources out of the perceived maximum to complete the task. Assuming the MVCs were performed with maximal effort, neither the muscle mass involved nor the fatigue state should impact the ratings.

It can be argued that using the same task (*e.g.*, gripper) and task mode (*e.g.*, MVC) in the task and anchor, as was done in the imposed anchor session, is not a representative practice when compared to the body of RPE literature. In most studies measuring RPE, the task is commonly performed with submaximal effort and with a different task mode relative to the anchor (Gearhart et al., 2001; Lagally et al., 2002; Pincivero & Gear, 2000). For example, lifting 30% of a 1RM load anchored to the 1RM of the same task (Gearhart et al., 2001). Our decision to use this approach was based on several reasons. First, some studies that have measured RPE use maximal effort tasks (*i.e.*, a maximal effort task anchored to a maximal effort task) (Hureau et al., 2016; Wittekind et al., 2011; Zabala et al., 2011), as was done in the present study. Hence, this approach is still within the boundaries of the literature. Second, we presume that similar trends, albeit smaller, will be found when using submaximal effort tasks (*e.g.*, 70% of MVC rather than an MVC). Third, since no study to date has compared these task-based anchors, we sought to understand and reconcile their differences and highlight the ramifications of the task-based anchoring procedures. Future studies could inspect if different imposed anchors lead to different ratings while keeping the task the same and when using submaximal effort tasks.

When interpreting the results of the self-selected session, it is important to consider that, in contrast to the imposed anchor session, participants selected anchors that 1) were different from the completed tasks and 2) were the same across exercises (*i.e.*, RPE of squat and gripper provided relative to the same selected anchor). Since the squat involves more muscle mass than the gripper, it requires a greater investment of resources to complete MVCs relative to the same anchor, which can explain the higher RPEs in the squat. Additionally, performing successive MVCs coupled with short rest durations can result in neuromuscular fatigue (*e.g.*, accumulation of metabolic by-products in the muscles). We expect that performing MVCs under fatiguing conditions requires more resources than in non-fatiguing conditions, which can explain the gradual increases in RPE in both exercises.

We speculate that the large differences in RPE between the two conditions stemmed from the different anchors rather than participants' going through different experiences of effort. This speculation is based

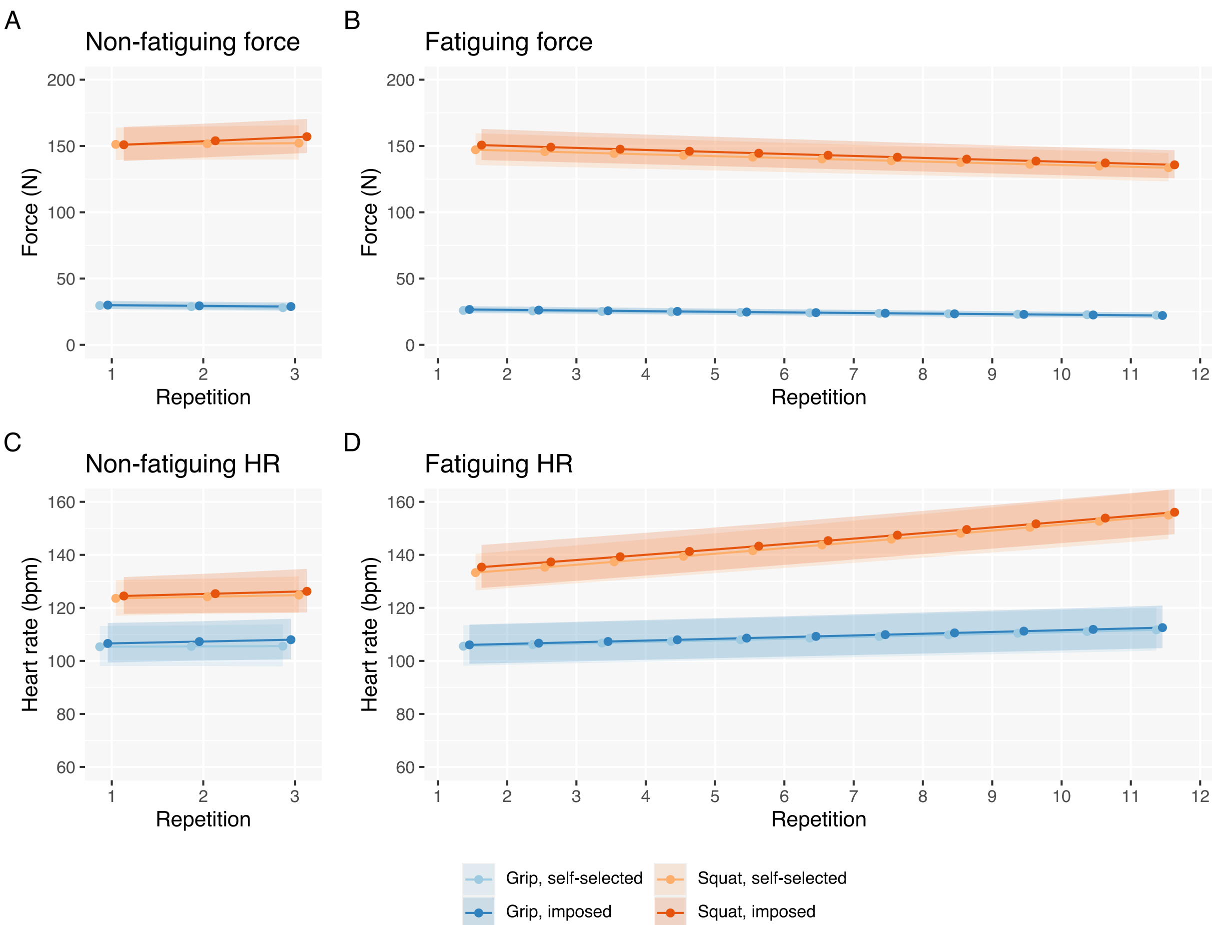

Fig. 3. Force and heart in both anchoring sessions. Under the non-fatiguing (A and C) and fatiguing (B and D) conditions, the anchors had negligible effects on force and heart rate in both the isometric squat and gripper. Error ribbons indicate 95% CIs.

on three reasons. First, the highly similar forces and heart rates across conditions suggest similar actual effort and thus experienced effort. Second, the ratings were provided retrospectively, a second or two after the completion of each MVC. If the two conditions led to dissimilar experiences of effort, then it implies that the anchors changed experiences that have already occurred, violating temporal precedence. A more likely explanation is that the anchors influenced the ratings due to changes in the reference points. Finally, comparison-based theories of judgment highlight the impact of anchors on self-report outcomes (Morina, 2021; Stewart et al., 2006; Vlaev et al., 2011). These theories posit that persons cannot generate a numeric evaluation in isolation; rather, they directly compare one variable to another to evaluate the variable of interest (Morina, 2021; Stewart et al., 2006; Vlaev et al., 2011). Thus, depending on the anchor, participants may provide different ratings for a specific question. For example, when individuals were asked to numerically report their well-being using an 11-point scale, their reports changed as a function of the provided anchors (*e.g.*, current well-being compared to previous-self, future-self, different person, etc.) (Morina et al., 2022). Since it is unlikely that one's well-being changes so rapidly, the different anchors seem to account for the different reports. We note that comparison-based theories of judgment can provide a sound theoretical basis for future RPE-related work and other experiences measured by exercise scientists, such as enjoyment and fatigue.

Given the anchors' central role in the rating process, we had participants report the anchors they selected in the self-selected anchor session. The anchors included a range of memorized and imagined tasks. Examples include giving birth, loaded marches during military service,[4] running races ranging from 1500 to 40,000 m, and lifting various objects, including barbells, a motorbike, and a car (see Table, Supplemental material 6, containing the full list of participants' responses). While insightful, the implications of these results are not straightforward. Future studies can inspect whether between-subject variability in ratings reflects the variability in the selected anchors.

Several methodological aspects of this study are worthy of discussion. First, the task (repeated MVCs) was always performed with maximal effort under both conditions. Future studies could compare the two anchoring procedures while implementing tasks performed with submaximal effort. Second, we used a relatively new definition of RPE and an RPE scale that did not include any accompanying text next to the numbers. It is unclear if the observed results will persist when using other, more common RPE definitions and traditional RPE scales (Borg, 1998, pp. 44–52; Robertson & Noble, 1997). Third, we used isometric tasks as they fit this study's aims, but dynamic tasks may offer additional insights. Forth, the sample included resistance-trained participants. It remains to be determined if the observed effects generalize to untrained participants. Fifth, we placed a strong emphasis on resistance-based exercises in this study as well as in the literature we cited. It remains

[4] It is of interest to note that nine participants reported that the tasks they anchored took place during their military service, which is mandatory in Israel.

to be determined if similar effects will be observed in other activities. Yet, despite not being generalizable to the aforementioned conditions, by quantifying the impact of task-based anchoring procedures on RPE, our results represent an important proof of principle that should be further explored.

In conclusion, we found a large and consistent difference in ratings between the two anchoring approaches independent of exercise type and fatigue state. In addition to the development and refinement of anchoring procedures, these results have several practical implications. First, it is essential to consistently use the same anchor within and between participants in studies and in applied settings. Researchers and practitioners should thus be fully aligned with which anchor to use. Second, comparing studies using imposed and self-selected anchors may not lead to valid conclusions (*e.g.*, meta-analysis). Third, researchers and practitioners should consider which anchor is better suited to answer their questions. It can be argued that the imposed anchor should lead to more interpretable ratings since it is provided in reference to a stable task across participants. However, depending on the research question, the self-selected anchor may be preferred (*e.g.*, qualitative designs). We recommend explicitly reporting and justifying the selected anchoring approach in manuscripts regardless of the chosen method.

Funding information

This study was supported by grants from the Israeli Science Foundation (1249/20). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Declaration of competing interest

The authors declare that the results presented are clear and honest, without fabrication, falsification or inappropriate manipulation. As well, the authors declare that they have no competing interests.

Data availability

I have shared my data as a CSV file at the attached file step.

Appendix ASupplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2023.102396.

References

Abbiss, C. R., Peiffer, J. J., Meeusen, R., & Skorski, S. (2015). Role of ratings of perceived exertion during self-paced exercise: What are we actually measuring? *Sports Medicine, 45*(9), 1235–1243.
Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48.
Borg, G. (1998). *Borg's perceived exertion and pain scales*. Champaign: Human Kinetics.
Boxman-Zeevi, Y., Schwartz, H., Har-Nir, I., Bordo, N., & Halperin, I. (2022). Prescribing intensity in resistance training using rating of perceived effort: A randomized controlled trial. *Frontiers in Physiology, 13*, Article 891385.
Brady, C. J., Harrison, A. J., & Comyns, T. M. (2020). A review of the reliability of biomechanical variables produced during the isometric mid-thigh pull and isometric squat and the reporting of normative data. *Sports Biomechanics, 19*(1), 1–25.
Buskard, A. N. L., Jacobs, K. A., Eltoukhy, M. M., Strand, K. L., Villanueva, L., Desai, P. P., et al. (2019). Optimal approach to load progressions during strength training in older adults. *Medicine & Science in Sports & Exercise, 51*(11), 2224–2233.
Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: A meta-analysis. *Journal of Sports Science, 20*(11), 873–899.
Colado, J. C., Furtado, G. E., Teixeira, A. M., Flandez, J., & Naclerio, F. (2020). Concurrent and construct validation of a new scale for rating perceived exertion during elastic resistance training in the elderly. *Journal of Sports Science and Medicine, 19*(1), 175–186.
Day, M. L., McGuigan, M. R., Brice, G., & Foster, C. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. *The Journal of Strength & Conditioning Research, 18*(2), 353–358.
Emanuel, A., Smukas, R., II, & Halperin, I. (2020). The effects of lifting lighter and heavier loads on subjective measures. *International Journal of Sports Physiology and Performance, 16*(2), 176–183.
Faulkner, J., & Eston, R. (2008). Perceived exertion research in the 21st century: Developments, reflections and questions for the future. *Journal of Exercise Science & Fitness, 6*(1), 1–14.
Gearhart, R. F. (2008). Ratings of perceived exertion and oxygen consumption during maximal, graded, treadmill exercise following different anchoring procedures. *European Journal of Sport Science, 8*(1), 35–40.
Gearhart, R. F., Becque, M. D., Hutchins, M. D., & Palm, C. M. (2004). Comparison of memory and combined exercise and memory-anchoring procedures on ratings of perceived exertion during short duration, near-peak-intensity cycle ergometer exercise. *Perceptual & Motor Skills, 99*(3 Pt 1), 775–784.
Gearhart, R. E., Goss, F. L., Lagally, K. M., Jakicic, J. M., Gallagher, J., & Robertson, R. J. (2001). Standardized scaling procedures for rating perceived exertion during resistance exercise. *The Journal of Strength & Conditioning Research, 15*(3), 320–325.
Günther, C. M., Bürger, A., Rickert, M., Crispin, A., & Schulz, C. U. (2008). Grip strength in healthy caucasian adults: Reference values. *The Journal of Hand Surgery, 33*(4), 558–565.
Haile, L., Gallagher, M., & Robertson R, J. (2015). Perceived exertion scaling procedures. In *Perceived exertion laboratory manual: From standard practice to contemporary application* (pp. 43–54). New York, NY: Springer New York.
Halperin, I., & Emanuel, A. (2020). Rating of perceived effort: Methodological concerns and future directions. *Sports Medicine, 50*(4), 679–687.
Helms, E. R., Storey, A., Cross, M. R., Brown, S. R., Lenetsky, S., Ramsay, H., et al. (2017). RPE and velocity relationships for the back squat, bench press, and deadlift in powerlifters. *The Journal of Strength & Conditioning Research, 31*(2), 292–297.
Hollander, D. B., Durand, R. J., Trynicki, J. L., Larock, D., Castracane, V. D., Hebert, E. P., et al. (2003). RPE, pain, and physiological adjustment to concentric and eccentric contractions. *Medicine & Science in Sports & Exercise, 35*(6), 1017–1025.
Hunter, S. K., Rochette, L., Critchlow, A., & Enoka, R. M. (2005). Time to task failure differs with load type when old adults perform a submaximal fatiguing contraction. *Muscle & Nerve, 31*(6), 730–740.
Hureau, T. J., Ducrocq, G. P., & Blain, G. M. (2016). Peripheral and central fatigue development during all-out repeated cycling sprints. *Medicine & Science in Sports & Exercise, 48*(3), 391–401.
Hutchinson, M. J., Kouwijzer, I., de Groot, S., & Goosey-Tolfrey, V. L. (2021). Comparison of two Borg exertion scales for monitoring exercise intensity in able-bodied participants, and those with paraplegia and tetraplegia. *Spinal Cord, 59*(11), 1162–1169.
Kasai, D., Parfitt, G., Tarca, B., Eston, R., & Tsiros, M. D. (2021). The use of ratings of perceived exertion in children and adolescents: A scoping review. *Sports Medicine, 51*(1), 33–50.
Lagally, K. M., & Costigan, E. M. (2004). Anchoring procedures in reliability of ratings of perceived exertion during resistance exercise. *Perceptual & Motor Skills, 98*(3 Pt 2), 1285–1295.
Lagally, K. M., Robertson, R. J., Gallagher, K. I., Gearhart, R., & Goss, F. L. (2002). Ratings of perceived exertion during low- and high-intensity resistance exercise by young adults. *Perceptual & Motor Skills, 94*(3 Pt 1), 723–731.
Lamb, K. L., Eaves, S. J., & Hartshorn, J. E. O. (2004). The effect of experiential anchoring on the reproducibility of exercise regulation in adolescent children. *Journal of Sports Science, 22*(2), 159–165.
Lea, J. W. D., O'Driscoll, J. M., Hulbert, S., Scales, J., & Wiles, J. D. (2022). Convergent validity of ratings of perceived exertion during resistance exercise in healthy participants: A systematic review and meta-analysis. *Sports Medicine - Open, 8*(1), 2.
Leyk, D., Gorges, W., Ridder, D., Wunderlich, M., Rüther, T., Sievert, A., et al. (2007). Hand-grip strength of young men, women and highly trained female athletes. *European Journal of Applied Physiology, 99*(4), 415–421.
Loenneke, J. P., Balapur, A., Thrower, A. D., Barnes, J. T., & Pujol, T. J. (2011). The perceptual responses to occluded exercise. *Int J Sports Med, 32*(3), 181–184.
Morina, N. (2021). Comparisons inform me who I Am: A general comparative-processing model of self-perception. *Perspectives on Psychological Science, 16*(6), 1281–1299.
Morina, N., Meyer, T., & Sickinghe, M. (2022). How do I know how I am doing? Use of different types of comparison in judgment of well-being in patients seeking psychological treatment and healthy controls. *Appl Psychol Health Well Being, 14*(4), 1369–1388.
Naclerio, F., & Larumbe-Zabala, E. (2017). Loading intensity prediction by velocity and the OMNI-RES 0-10 scale in bench press. *The Journal of Strength & Conditioning Research, 31*(2), 323–329.
Nakagawa, S., Johnson, P. C. D., & Schielzeth, H. (2017). The coefficient of determination R2 and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded. *Journal of The Royal Society Interface, 14*(134).
Nakagawa, S., & Schielzeth, H. (2013). A general and simple method for obtaining R 2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution, 4*(2), 133–142.
Noble, B. J., & Robertson, R. J. (1996). *Perceived exertion, human kinetics*. Illinois: Champaign.
Pageaux, B. (2016). Perception of effort in exercise science: Definition, measurement and perspectives. *European Journal of Sport Science, 16*(8), 885–894.
Parfitt, G., Evans, H., & Eston, R. (2012). Perceptually regulated training at RPE13 is pleasant and improves physical health. *Medicine & Science in Sports & Exercise, 44*(8), 1613–1618.
Pincivero, D. M., Coelho, A. J., & Campy, R. M. (2003). Perceived exertion and maximal quadriceps femoris muscle strength during dynamic knee extension exercise in

young adult males and females. *European Journal of Applied Physiology, 89*(2), 150–156.

Pincivero, D. M., & Gear, W. S. (2000). Quadriceps activation and perceived exertion during a high intensity, steady state contraction to failure. *Muscle & Nerve, 23*(4), 514–520.

Pincivero, D. M., Lephart, S. M., Moyna, N. M., Karunakara, R. G., & Robertson, R. J. (1999). Neuromuscular activation and RPE in the quadriceps at low and high isometric intensities. *Electromyography & Clinical Neurophysiology, 39*(1), 43–48.

Robertson, R. (2004). *Perceived exertion for practitioners: Rating effort with the OMNI picture system* (1st ed.). Champaign, IL: Human Kinetics.

Robertson, R. J., Goss, F. L., Boer, N. F., Peoples, J. A., Foreman, A. J., Dabayebeh, I. M., et al. (2000). Children's OMNI scale of perceived exertion: Mixed gender and race validation. *Medicine & Science in Sports & Exercise, 32*(2), 452–458.

Robertson, R. J., Goss, F. L., Dube, J., Rutkowski, J., Dupain, M., Brennan, C., et al. (2004). Validation of the adult OMNI scale of perceived exertion for cycle ergometer exercise. *Medicine & Science in Sports & Exercise, 36*(1), 102–108.

Robertson, R. J., & Noble, B. N. (1997). Perception of physical exertion: Methods, mediators, and applications. In *Exercise and sport sciences review, 25* pp. 407–452). Baltimore: Williams & Williams, 1.

Schwartz, H., Har-Nir, I., Wenhoda, T., & Halperin, I. (2021). Staying physically active during the COVID-19 quarantine: Exploring the feasibility of live, online, group training sessions among older adults. *Transl Behav Med, 11*(2), 314–322.

Searle, S. R., Speed, F. M., & Milliken, G. A. (1980). Population marginal means in the linear model: An alternative to least squares means. *The American Statistician, 34*(4), 216–221.

Simão, R., Farinatti, P. de TV., Polito, M. D., Maior, A. S., & Fleck, S. J. (2005). Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercises. *The Journal of Strength & Conditioning Research, 19*(1), 152–156.

Steele, J. (2020). *What is (perception of) effort? Objective and subjective effort during task performance*. PsyArXiv.

Stewart, N., Chater, N., & Brown, G. D. A. (2006). Decision by sampling. *Cognitive Psychology, 53*(1), 1–26.

Tiggemann, C. L., Pietta-Dias, C., Schoenell, M. C. W., Noll, M., Alberton, C. L., Pinto, R. S., et al. (2021). Rating of perceived exertion as a method to determine training loads in strength training in elderly women: A randomized controlled study. *International Journal of Environmental Research and Public Health, 18*(15).

Vlaev, I., Chater, N., Stewart, N., & Brown, G. D. A. (2011). Does the brain calculate value? *Trends in Cognitive Sciences, 15*(11), 546–554.

van Waart, H., Stuiver, M. M., van Harten, W. H., Geleijn, E., Kieffer, J. M., Buffart, L. M., et al. (2015). Effect of low-intensity physical activity and moderate- to high-intensity physical exercise during adjuvant chemotherapy on physical fitness, fatigue, and chemotherapy completion rates: Results of the PACES randomized clinical trial. *Journal of Clinical Oncology, 33*(17), 1918–1927.

Wittekind, A. L., Micklewright, D., & Beneke, R. (2011). Teleoanticipation in all-out short-duration cycling. *British Journal of Sports Medicine, 45*(2), 114–119.

Yu, H., Sun, C., Sun, B., Chen, X., & Tan, Z. (2021). Systematic review and meta-analysis of the relationship between actual exercise intensity and rating of perceived exertion in the overweight and obese population. *International Journal of Environmental Research and Public Health*, (24), 18.

Zabala, M., Peinado, A. B., Calderón, F. J., Sampedro, J., Castillo, M. J., & Benito, P. J. (2011). Bicarbonate ingestion has no ergogenic effect on consecutive all out sprint tests in BMX elite cyclists. *European Journal of Applied Physiology, 111*(12), 3127–3134.

Zamunér, A. R., Moreno, M. A., Camargo, T. M., Graetz, J. P., Rebelo, A. C. S., Tamburús, N. Y., et al. (2011). Assessment of subjective perceived exertion at the anaerobic threshold with the Borg CR-10 scale. *Journal of Sports Science and Medicine, 10*(1), 130–136.

Zourdos, M. C., Klemp, A., Dolan, C., Quiles, J. M., Schau, K. A., Jo, E., et al. (2016). Novel resistance training-specific rating of perceived exertion scale measuring repetitions in reserve. *The Journal of Strength & Conditioning Research, 30*(1), 267–275.