PREPRINT --NOT PEER REVIEWED

The effect of self-selecting the number of repetitions on motor performance and psychological outcomes

Submission Type: Original article

Authors: Aviv Emanuel^{a,b,c}, Itai Har-Nir^{b,c}, Isaac Isur Rozen Smukas^{b,c} and Israel Halperin^{b,c,*}

Affiliations:

^aSchool of Psychological Sciences, Tel-Aviv University, Tel-Aviv, Israel

^bSchool of Public Health, Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel

^cSylvan Adams Sports Institute, Tel Aviv University, Tel-Aviv, Israel

Address for Correspondence: Israel Halperin, School of Public Health, Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel.

Phone: +972-523-469-590

Email: ihalperin@tauex.tau.ac.il

Author agreement statement: We the authors agree to the sharing of this preprint on SportRxiv.

Running Head: A comparison between self-selected and predetermined approaches

Cite as: Emanuel A, Har-Nir I, Rozen Smukas II, Halperin I (2020). The effect of self-selecting the number of repetitions on motor performance and psychological outcomes. *Pre-print DOI:* [10.31236/osf.io/en3wx](https://doi.org/10.31236/osf.io/en3wx)

Word count: 3971

Abstract word count: 245

Abstract

In resistance-training, the number of repetitions can be either fixed and predetermined (e.g., 3 sets of 10 repetitions), or selected by the trainee during ongoing sets (e.g., 3 sets of 8-12 repetitions). The first approach is more goal-focused while the latter is more autonomy-focused. Here we compared between these two approaches on motor performance and psychological outcomes. Nineteen resistance-trained subjects (10-males) first completed one repetition-maximum (RM) tests in the barbell-squat and bench-press, and were familiarized with the isometric mid-thigh pull (IMTP). In the next two counterbalanced sessions, subjects completed two sets of the squat and bench-press using 70%1RM, and two sets of the IMTP. In the predetermined session, subjects completed 10 repetitions in all sets, and in the self-selected session, subjects chose how many repetitions to complete out of an 8-12 range. Bar-velocity was measured in the squat and bench-press, and force production in the IMTP. Enjoyment, perceived-autonomy, and approach-preferences were collected post-sessions. We observed comparable bar-velocity, force production, and enjoyment in both conditions (all $BF_{01} > 2.1$), and an even approach-preferences split. However, in the self-selected condition, subjects demonstrated considerable variability in the number of repetitions and reported greater perceived-autonomy. Given the similarities between approaches, both can be used with this cohort based on their personal-preference. Yet, we note that the self-selected approach has two distinct benefits: the variability in the number of repetitions completed suggests that subjects regulated their efforts, and the higher perceived autonomy could lead to long-term improvements in motor and psychological outcomes.

Keywords: Autonomy, Repetition-prescription, Resistance-training, Program-design.

Introduction

Prescribing the number of repetitions to complete per set and exercise is a key variable in designing resistance-training (RT) programs. Traditionally, the number of prescribed repetitions is predetermined and fixed. That is, the number of repetitions is decided upon before the session or set-initiation (e.g., 3 sets of 10 repetitions, or 5 sets of 5 repetitions) (DeLorme, 1945; Sands et al., 2012; Todd et al., 2012). Following this approach has a prominent psychological benefit – it provides one with a clear task endpoint. When people know exactly what to expect, they tend to apply greater efforts (Billaut et al., 2011; Halperin et al., 2014; Halperin et al., 2014; Hanson & Buckworth, 2015; Wingfield et al., 2018). For example, people run (Hanson & Buckworth, 2015) and cycle (Wingfield et al., 2018) faster when they know how long they need to run or cycle for, and apply greater forces when they know how many repetitions they need to complete, compared to unknown task endpoints (Halperin et al., 2014a; Halperin et al., 2014b).

The number of repetitions can also be prescribed out of a range (e.g., 3 sets of 8 to 12 repetitions, or 5 sets of 4 to 6 repetitions) (ACSM, 2013). Although the range approach is advocated in resistance-training guidelines (Fragala et al., 2019; ACSM, 2013; Nelson et al., 2007; Sands et al., 2012), it is not clear how it should be implemented. On the one hand, the number of repetitions can be determined prior to set- or session-initiation. For example, prescribing 12 repetitions in the first set and 8 in the third set (ACSM, 2013). This implementation strategy is in many ways similar to the fixed and predetermined approach, as it does not allow practitioners to evaluate their abilities during ongoing sets, and choose the number of repetitions accordingly. On the other hand, the range approach can be implemented by allowing trainees to choose how many

repetitions to complete during the set itself, based on various psychophysiological inputs (e.g., motivation, perception of effort, etc.). Here we refer to the latter prescription strategy as the self-selected approach.

The self-selected approach has several benefits. First, it better accounts for between and within-subject variability in performance. For example, prescribing one with 10 repetitions using 70% of one repetition maximum (RM) in a given exercise can be easier to complete by one person and harder for another. Similarly, for the same person, performing 10 repetitions can be easier to complete on some days, and harder on others (Emanuel et al., 2019). By allowing one to choose the number of repetitions within a range, trainees can regulate their effort, which better accounts for between- and within-subject variability in performance. Second, choice provision within a training session is known to improve motor learning and performance among a range of populations and outcomes (Halperin et al., 2018; Sanli et al., 2013; Teixeira et al., 2012; Wulf & Lewthwaite, 2016). For example, Halperin et al. (2017) found that competitive boxers punched harder and faster when given a choice regarding the order of delivered punches in a combination, compared to a predetermined punching order. Finally, choice provision leads people to report greater levels of enjoyment following a training session, and increases the likelihood of adhering to the exercise program, compared to a no-choice group (Fortier et al., 2007; Silva et al., 2011). Indeed, granting people with the capacity to decide for themselves is a key component in prominent theories of motivation (Deci & Ryan, 2000, 2002; Wulf & Lewthwaite, 2016).

To date, no study has compared the effects of a fixed and self-selected approaches on performance and self-report measures in resistance-training setting. Such an investigation can hold high theoretical and practical value. Accordingly, in this study, resistance-trained subjects performed two resistance-training sessions composed of two sets of the bench-press and the squat

using 70% of their 1RM, followed by two sets with the isometric mid-thigh pull (IMTP). On one day subjects completed 10 repetitions across exercises and sets (fixed condition), and on the other day they chose how many repetitions to complete out of an 8-12 range during ongoing sets (self-selected condition). We compared the effects of both conditions on 1) performance measures, including bar-velocity and force output and; 2) psychological measures, including perceived autonomy, enjoyment levels, and preference of one approach over the other.

Methods

Subjects

The planned sample-size consisted of 25 resistance trained subjects. However, we were forced to terminate data collection prematurely due to the Coronavirus outbreak. The final sample consisted of 19 subjects who completed both experimental sessions (Table 1). Inclusion criteria included healthy subjects between the ages of 18 and 45 with at least six months of resistance-training experience. Subjects also had to be accustomed to performing the barbell-squat and bench-press using a variety of repetition ranges (e.g. 8-15 repetitions). Each subject signed an informed consent on the first day. This study was approved by the institutional review board.

Table 1. General Demographics.

	Females (n=9) Mean±SD (Range)	Males (n=10) Mean±SD (Range)
Age	29.2±3.4 (24-34)	31.6±5.8 (23-44)
Height (cm)	168±7.5 (153-170)	178.5±5.3 (171-186)
Weight (kg)	65.4±11.0 (49-82)	78.7±6.2 (70.9-89)
Experience in RT (yrs)	4.4±2.4 (1-4)	8.6±6.2 (3-19)
Mean workouts per week	3.4±1.1 (2-5)	3.3±1.0 (2-5)
1RM barbell bench press (kg)	45.5±10.3 (30-65)	92.7±10.4 (77.5-110)
1RM/ Bodyweight bench press	0.70±0.16 (0.36-0.91)	1.37±0.26 (0.95-1.16)
Average velocity 1RM barbell bench press ($\text{m}\cdot\text{s}^{-1}$)	0.16±0.09 (0.07-0.32)	0.16±0.02 (0.12-0.20)
1RM barbell squat (kg)	71.6±18.0 (50-110)	108.5±24.1 (75-160)
1RM/ Bodyweight squat	1.1±.23 (0.80-1.4)	1.3±.27 (0.96-1.86)
Average velocity 1RM barbell squat ($\text{m}\cdot\text{s}^{-1}$)	.21±.06 (0.09-0.31)	.27±.04 (0.19-0.34)
<i>1RM – one repetition maximum; RT – resistance training; SD – standard deviation</i>		

Measures

Performance measures

Average concentric velocity ($\text{m}\cdot\text{s}^{-1}$) of the barbell was measured using GymAware PowerTool (GymAware, Canberra, Australia) linear position transducer. The GymAware was synced with a tablet application that displayed the average concentric velocity of each repetition and exported

the data as an Excel file. The device was used according to the instructions of the manufacturers so that when it was attached to the barbell a perpendicular angle was achieved during all lifts.

Peak force (N) production in the IMTP was collected by AMTI AccuPower portable force plate (AMTI, Massachusetts, USA). The force plate synchronized with a Dell laptop and analyzed with a LabView (v2017, National Instruments, TX, USA). Force data were sampled at 500 Hz via an analogue to digital converter (16-Bit, 250 kS/s National Instruments, Austin, TX, United States). The repetitions were automatically recognized by a code, which set to include force data higher than 1.5 of one's body weight, detected as the peak force measured when the subject first stood on the force plate. Next, the code omitted 500ms from the beginning and ending of each repetition to reduce noise.

Self-report measures

Perception of autonomy was measured using a modified version of the Basic Psychological Needs in Exercise questionnaire (Vlachopoulos et al., 2010). Subjects rated three items on a Likert scale which ranged from 1 ("I don't agree at all") to 5 ("I totally agree"). The items were presented and explained to the subjects using an A4 sheet: "1. The way I exercised today is aligned with my choices and preference", "2. I feel the way I exercised today is the way I want to exercise", and "3. I feel like I could make decisions regarding how I exercised today".

In order to rate session enjoyment, subjects were presented the following question after the fixed session: "How much did you enjoy today's session? In your answer, please focus on the fact that the number of repetitions you performed was fixed and predetermined to be 10" and the following question after the range sessions: "How much did you enjoy today's session? In your

answer, please focus on the fact that the number of repetitions you performed was selected out of an 8-12 range". Subjects indicated their answer using a VAS scale, ranging from "0" ("not at all") to "100" ("extremely enjoyable"), which included vertical lines on each 10 units (see Online Resource).

In order to rate subjects' preference between the two approaches, subjects were presented with the following question immediately after the last session and 24h afterwards: "Out of the two training sessions you performed, which approach do you prefer performing and to what extent?". Subjects indicated their answer using a VAS scale, ranging from "-100" ("absolute preference for the fixed approach") to "100" ("absolute preference for the range approach"), that includes vertical lines on each 20 units (see Online Resource).

Procedures

The study consisted of three testing sessions with a minimum of three and a maximum of ten days between sessions. The first session consisted of 1RM tests for the barbell-back-squat followed by the barbell-bench-press exercise, and a familiarization with the IMTP exercise, questionnaires, and experimental procedure. In the next two sessions, subjects performed two sets of each exercise: squat, bench-press (using 70% of 1RM), and IMTP. On the fixed session, subjects performed 10 repetitions in all exercises and sets. On the range session, subjects chose to perform any number of repetitions between 8 to 12 in all exercises and sets. We employed this range as it can be found in numerous guidelines (Nelson et al., 2007; Sands et al., 2012). We asked subjects to decide how many repetitions to complete within this range during the set rather than before initiating it. Subjects were explained that when making this decision, they should account to how they feel, as they would do in their regular day-to-day training. On days that they feel refreshed and motivated,

they may push themselves harder, and in this study, they may wish to complete more repetitions out of the given range (e.g., complete 11 or 12 repetitions). Conversely, on days that they feel fatigued and demotivated, they may hold themselves back, and in this study, they may wish to complete fewer repetitions out of the given range (e.g., complete 8 or 9 repetitions). At the end of each session, subjects rated their perception of autonomy and enjoyment levels. Following the last session and 24h afterwards, subjects reported which of the two training routines they prefer following.

1RM tests and familiarization (session 1)

In the beginning of the session, subjects were weighed, indicated their height, age and experience in strength training, and were briefed on the study's aims. All subjects then performed a squat to an approximate fixed knee angle using a box, which height was adjusted individually in the beginning of the session (Mean knee angle=118.31, SD=4.76). During the bench-press, subjects' preferred grip and body position were recorded and maintained throughout the study. In each repetition the bar must have lightly touched subjects' chest prior to the concentric portion of the lift in order to be counted. Subjects then performed a structured warmup protocol consisting of dynamic stretching and calisthenic exercises, and a five-minute individualized warmup. This warmup protocol was identical in all sessions. Upon completion of the warmup, subjects performed the barbell-squat 1RM protocol followed by the barbell-bench 1RM protocol. Briefly, the 1RM protocol consisted of a gradual load-progression towards an estimated 1RM weight indicated by the subjects. The increase in weight towards the actual 1RM was decided by the subjects and investigators with 3-5 minutes of rest between 1RM attempts. After performing the 1RM squat and bench-press, IMTP measurements took place. Bar height was adjusted and secured

using Ratchet Straps, to achieve a knee and hip angle of 125-145° and 140-150°, respectively, as subjects stood on the middle of the force plate (Comfort et al., 2019). Given the repetitive nature of this task, all subjects were requested to use the same hand wraps to reduce muscular fatigue of the wrist flexors.

Experimental sessions (sessions 2-3)

In the beginning of each session, subjects were reminded of the four self-report measures and performed the general warmup protocol. Subjects then performed a specific warmup procedure prior to performing two sets in the squat, two sets in the bench press and two sets of the IMTP. In the squat and bench-press exercises, subjects lifted 70% of 1RM and were asked to complete the concentric phase of each repetition as fast as possible as bar-velocity was measured. In the IMTP subjects were asked to apply as much force as they possibly can in each repetition against the force plate. Two minutes of rest were provided between sets and exercises. Bar-velocity was recorded during the performance of the squat and bench-press exercises, and force production was recorded during the performance of the IMTP. All sessions were performed in the same facilities, ran by the same two experimenters at approximately the same hour of the day (± 2 h). No verbal encouragement was provided throughout the sessions. Subjects were asked to refrain from an intense training session 24h prior to testing days that may lead to performance decrements and muscle soreness. Subjects were also asked to avoid a heavy meal and caffeinated drinks or supplements at least 3h before testing sessions.

Statistical analysis

Performance measures. We compared the bar-velocity and force outcomes between conditions using two approaches. First, we analyzed the extent by which bar-velocity or force decreased during each set, and whether this trend differs between conditions, in which all repetitions were included in the analysis, despite not necessarily being the same in both conditions. We tested linear, and quadratic mixed models for each exercise with bar-velocity as the dependent variable and repetition number as the predictor, nested within subjects. We examined the best-fitted trend by comparing the linear and quadratic models for the best goodness-of-fit, as indicated by the deviance statistic. We then examined whether this trend differs between conditions by testing if the condition variable (dummy coded as fixed condition=0) increases model fit compared to the previous best-fitted model. We added random slopes as recommended by Bliese and Ployhart (2002) as long as their addition did not result in a convergence error. We followed the same approach when analyzing the IMTP exercise, with force serving as the dependent variable instead of bar-velocity. Conditional R^2 for mixed regression models was calculated to quantify the explained variance of each model.

Second, we analyzed the mean difference in bar-velocity and mean force of each condition by equalizing the number of repetitions. This was done by removing excess repetitions from the analysis. For example, if a subject performed 8 repetitions in the choice condition and 10 in the fixed condition, then the two last repetitions from the fixed condition were removed. We then calculated the mean velocity or force value for each subject in each condition and compared these between the two conditions for each exercise via three separate paired-sample t-tests.

Variability in self-selected repetitions. First, we calculated the mean and SD of the repetitions performed in each exercise. Second, to examine the extent by which subjects utilized the provided

repetition range (i.e., 8-12), we calculated the percent of each number of repetitions completed per set for each exercise. Finally, to assess the extent by which subjects changed the number of repetitions between sets, we calculated whether the number of repetitions was either equal (0) or different (1) between sets for each set in each exercise. We then calculated these proportions for each exercise.

Self-report measures. Because the three items of the perceived autonomy scale revealed high reliability (Cronbach's $\alpha=.72$ and $.69$ in the choice and fixed conditions, respectively) we calculated the mean of the three items for each subject in each condition, and compared the outcome between the two conditions via a paired-sample t-test. We compared the enjoyment ratings between the two conditions via a paired-sample t-test. We coded subjects' responses on the preference scale as "self-selected condition" for positive values, "fixed condition" for negative values, and "no preference" for zero, and calculated the proportion of each. We then compared the proportion of subjects preferring either the self-selected or fixed condition, using a binomial test.

Significance was set at $p<.05$. When testing for the same hypothesis (e.g., mean bar-velocity and force output), t-tests were Holm corrected for multiple comparisons. Hedge's g effect size for t-tests was calculated based on the mean standard-deviations (Hedge's g_{av}). If a t-test yielded a non-significant result, we conducted a Bayesian t-test ($r_{prior} = .707$) (Morey et al., 2015) to assess the extent by which the data was likely under the null hypothesis, compared to a non-zero difference (i.e., a Bayes factor; BF_{01}) (Jarosz & Wiley, 2014). When relevant, 95% confidence intervals (CIs) are reported. Statistical analyses and figures were carried out with R (version 3.6.1) using the following packages: lme4, lmeTest, piecewiseSEM, BayesFactor, and ggplot2. R syntax for all analyses and data are available at <https://bit.ly/2WSeNli>.

Results

Bar-velocity over repetitions. In the bench-press, a linear model with a random slope for repetitions yielded the best model-fit (Conditional $R^2=.86$). The addition of the condition variable increased model-fit ($p=.046$, Conditional $R^2=.87$), yet no difference was found in the linear slopes between conditions ($b=.001$, $SE=.0006$, $p=.085$, 95% CI $[-.0001, .002]$). In the squat, a linear model with a random slope for repetitions yielded the best model-fit (Conditional $R^2=.90$). The addition of the condition variable increased model fit ($p<.001$, Conditional $R^2=.91$), yet no difference was found in the linear slopes between conditions ($b=-.001$, $SE=.0007$, $p=.146$, 95% CI $[-.002, .0003]$) (see Figure 1).

Force production over repetitions. Across conditions, a linear model with a random slope for repetitions yielded the best model-fit ($b=-7.00$, $SE=2.73$, $p=.018$, 95% CI $[-12.24, -1.36]$, Conditional $R^2=.99$). The addition of the condition variable did not increase model-fit ($p=.202$, Conditional $R^2=.99$)

Figure 1. Distribution of bar-velocity and force over the set in each exercise and condition. The gray lines represent the values of individual subjects, fitted using the locally estimated scatterplot smoothing (LOESS) method, and the fitted regression model in a black line. Panels A, B, and C, D depict bar-velocity in the bench-press and squat in each condition, respectively. Panels E and F depict force-output in the IMTP in each condition.

Variability in self-selected repetitions. The mean and SD of the number of repetitions completed in the bench-press, squat and IMTP exercises were 10.2 ± 1.6 , 9.6 ± 1.4 and 10.6 ± 1.6 , respectively. The proportion of selected number of repetitions in each exercise is presented in Figure 2. Out of the two consecutive sets performed per exercise in the choice condition, in 50%, 59% and 50% of the cases the number of repetitions were the same in the bench-press, squat, and IMTP exercises,

respectively.

Table 2. Mean $\pm$ SD (minimum and maximum) values of performance and self-report measures of each experimental condition. Mean differences, 95% confidence intervals (CI), p-values, Hedge's g effect sizes, and Bayes factors of the condition-differences are also reported.

	Fixed condition	Self-selected condition	Mean difference (95%CI)	<i>p-value</i>	<i>g'</i>	<i>BF₀₁</i>
Squat: Mean bar-velocity (m/s)	0.52 $\pm$ 0.08 (0.34, 0.62)	0.54 $\pm$ 0.07 (0.36, 0.63)	-0.02 (-.061, .008)	0.37	0.31	2.12
Bench-press: Mean bar-velocity (m/s)	0.43 $\pm$ 0.06 (0.28, 0.55)	0.44 $\pm$ 0.06 (0.27, 0.56)	-0.006 (-.03, .01)	1.00	0.09	3.00
IMTP: Mean force (N)	1967 $\pm$ 500 (1180, 3139)	1969 $\pm$ 538 (1154, 3470)	-1.77 (-66.97, 63.43)	1.00	0.003	3.17
Enjoyment	77.88 $\pm$ 19.60 (35, 100)	70.83 $\pm$ 29.86 (20, 100)	7.05 (-10.21, 24.32)	0.40	0.26	2.96
Perceived autonomy	2.19 $\pm$.733 (1, 3.75)	3.05 $\pm$.757 (1.25, 4)	1.05 (.605, 1.50)	<.001	1.48	-
Preference N(%)	7 (36.84%)	10 (52.63%)	-	0.63	-	-

Figure 2. Distribution of the self-determined repetitions. Panels A-C depict the percent of sets in which each number of repetition was performed from 8-12, in the bench-press, squat and IMTP, respectively.

Mean bar-velocity, mean force, enjoyment, perceived autonomy and preferences.

Comparisons between conditions in mean bar-velocity, mean force, enjoyment, perceived autonomy, and preferences are presented in Table 2. Individual ratings of approach preferences are presented in Figure 3.

Figure 3. Extent of preference ratings of each subject for either the fixed approach (-100) or the self-determined approach (100). Note that subjects 8 and 9 rated 0 which indicates they had no preference.

Discussion

To our knowledge, this is the first study to directly compare between two repetitions-prescription approaches: a fixed and predetermined number of repetitions and a self-selected number out of a given range. In both conditions, subjects completed two sets of the bench-press and squat using 70% of their 1RM, and two sets of the IMTP. In the fixed condition subjects performed 10 repetitions across sets and exercises, whereas in the self-selected condition they selected how many repetitions to perform out of the 8 to 12 range. Subjects reported their perceived autonomy, and enjoyment after each session, and rated their preference for each approach immediately after the last session, and 24h afterwards. We found no differences between the two approaches in bar-velocity and force, but observed that subjects changed the number of self-selected repetitions in approximately 50% of the time between sets, and that subjects utilized most of the repetition range.

Subjects reported similar enjoyment levels in both conditions, and mixed responses concerning the approach they preferred following. However, perceived autonomy was considerably higher in the self-selected condition.

Several reasons might explain the similar performance outcomes observed in both conditions. First, the repetitions-range in the self-selected condition was at most 2 repetitions away from the 10 repetitions performed in the fixed condition. The similarities between conditions have likely induced similar neuromuscular fatiguing effects leading to the comparable performance outcomes. Second, it is possible that the measurement tools used in the present study lacked the required sensitivity to capture small differences in performance that may exist. While no differences were observed in performance metrics, the number of selected repetitions differed considerably between sets and exercises in the self-selected condition. This indicates that subjects took advantage of the option to adjust the number of repetitions within the session, and employed an exercise-regulation strategy (Halperin et al., 2014). This finding is practically useful as it suggests that letting trainees select the repetitions-number out of a range allows for ongoing intensity-adjustments in RT sessions in view of one's motivation, fatigue, etc. By accounting for this variability, the self-selected approach may optimize RT related adaptations over time. However, this speculation remains to be examined in a longitudinal study.

From a psychological perspective, the two approaches seemed to have emphasized different motivational components. The fixed approach provided one with a clear task-endpoint but did so at the expense of acting autonomously. Conversely, the self-selected approach provided less clarity about the task-endpoint but allowed subjects to act autonomously. Both clear task-endpoints and acting autonomously are factors known to positively influence motivation (Deci &

Ryan, 2000; Locke & Latham, 1990) and motor performance (Halperin et al., 2014; Wulf & Lewthwaite, 2016). As such, it may be that some subjects were influenced to a greater extent by one of these components. As noted by one subject who preferred the self-determined approach: *"...by using this approach I can manage my effort with respect to my capacity and goals"*. Conversely, another subject who preferred the fixed approach noted that: *"I find it easier to achieve predetermined objectives than making decisions as I go"*. This possibility can partly explain the similar enjoyment levels, and the mixed preferences of approaches.

Perception of autonomy was higher in the self-selected condition, indicating that the choice manipulation was effective. Yet, in contrast to other studies (Halperin et al., 2017, 2018; Wulf & Lewthwaite, 2016), we observed no performance-enhancing effects in the self-selected condition. This finding does not necessarily indicate that the autonomy in the self-selected condition did not affect performance, but that the psychological and performance enhancing effects of the fixed approach associated with the clear task-endpoint, may have equalized the effects. We note that despite not observing acute performance and psychological effects, the higher ratings of perceived autonomy can be viewed as a possible advantage of the self-selected approach. This is due to the large body of evidence indicating several positive long-term associations between high autonomy and motor learning (Wulf & Lewthwaite, 2016), exercise adherences (Fortier et al., 2007; Silva et al., 2011), and positive affect (Deci & Ryan, 2000). The evidence in support of the null hypothesis in most psychological measures suggest both approaches are viable strategies for implementation in the field. However, it remains to be established if similar effects persist over time.

This study has several limitations. First, the uneven number of repetitions completed in both conditions may have led to some confounding effects. We attempted to bypass this limitation by using a narrow repetition range in the self-selected condition, turning both conditions similar to one another in terms of the number of repetitions completed, and by using two different analyses of repetitions. Moreover, the consistent null effects observed in most outcomes suggest that such confounders were less likely to occur. Second, the study consisted of a smaller sample than originally planned. This did not seem to affect the results, as the findings in almost all measures indicate the same trend. Third, we only compared the short-term effects of the two approaches. It is possible that the long-term effects of following one approach or the other will lead to different performance and psychological outcomes. Finally, it is unclear whether the observed effects can be generalized to untrained populations. For example, it may be that for untrained populations, a fixed prescription approach might prove superior due to its inherent task-endpoint clarity. Alternatively, in the self-selected approach, untrained populations might choose to perform the lowest number of repetitions out of a range due to a fear of exerting high effort, or the highest possible number due to a lack of experience in exercise-regulation. Further research is required to answer these questions.

Conclusions

To our knowledge, this is the first study to directly compare performance and self-report outcomes between the fixed and self-selected repetitions-prescription approaches, both advocated by leading RT guidelines. The mostly equivalent outcomes in both conditions indicate both approaches are comparable, at least in the short-term. However, the finding that subjects adjusted the number of repetitions between sets and exercises in the self-selected condition demonstrates effort-regulation.

Hence, the self-selected approach seems to be more adaptable and flexible as it accounts for day-to-day fluctuations in performance. The higher perceived autonomy may also hold long-term performance and psychological benefits. Overall, these findings are practically useful as they suggest that coaches and trainees can follow either one of the approaches based on preferences or certain training goals.

Declarations

Authors' Contributions

IH, AE, and IHN, designed the study, IHN and IIRS collected and coded the data, AE analyzed the data, IH and AE interpreted the data, and wrote the manuscript. All authors have read and approved the final version of the manuscript.

Ethical Standards

The manuscript does not contain clinical studies or patient data. All subjects read and signed an informed consent form prior to their participation in this study. The authors declare that they have no competing interests.

Ethics approval

This study was approved by the Tel-Aviv University Institutional Review Board 2019-0325.

Data and code availability

R syntax and data for all analyses and data are available at <https://bit.ly/2WSeNli>.

References

- Billaut, F., Bishop, D. J., Schaerz, S., & Noakes, T. D. (2011). Influence of knowledge of sprint number on pacing during repeated-sprint exercise. *Medicine & Science in Sports & Exercise*, 43(4), 665–672.
- Bliese, P. D., & Ployhart, R. E. (2002). Growth Modeling Using Random Coefficient Models: Model Building, Testing, and Illustrations. *Organizational Research Methods*, 5(4), 362–387. <https://doi.org/10.1177/109442802237116>
- Comfort, P., Dos'Santos, T., Beckham, G. K., Stone, M. H., Guppy, S. N., & Haff, G. G. (2019). Standardization and Methodological Considerations for the Isometric Midthigh Pull: *Strength and Conditioning Journal*, 41(2), 57–79. <https://doi.org/10.1519/SSC.0000000000000433>
- Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11(4), 227–268.
- Deci, E. L., & Ryan, R. M. (2002). Overview of self-determination theory: An organismic dialectical perspective. *Handbook of Self-Determination Research*, 3–33.
- DeLorme, T. L. (1945). Restoration of muscle power by heavy-resistance exercises. *JBJS*, 27(4), 645–667.
- Emanuel, A., Smukas, I. R., & Halperin, I. (2019). *How one feels during resistance exercises: A repetition by repetition analysis across exercises and loads* [Preprint]. SportRxiv. <https://doi.org/10.31236/osf.io/4qbgj>
- Fortier, M. S., Sweet, S. N., O'Sullivan, T. L., & Williams, G. C. (2007). A self-determination process model of physical activity adoption in the context of a randomized controlled trial. *Psychology of Sport and Exercise*, 8(5), 741–757.

- Fragala, M. S., Cadore, E. L., Dorgo, S., Izquierdo, M., Kraemer, W. J., Peterson, M. D., & Ryan, E. D. (2019). Resistance training for older adults: position statement from the National strength and conditioning association. *The Journal of Strength & Conditioning Research*, 33(8).
- Halperin, I., Aboodarda, S. J., Basset, F. A., Byrne, J. M., & Behm, D. G. (2014). Pacing strategies during repeated maximal voluntary contractions. *European Journal of Applied Physiology*, 114(7), 1413–1420. <https://doi.org/10.1007/s00421-014-2872-3>
- Halperin, Israel, Aboodarda, S. J., Basset, F. A., & Behm, D. G. (2014). Knowledge of repetitions range affects force production in trained females. *Journal of Sports Science & Medicine*, 13(4), 736.
- Halperin, Israel, Chapman, D. W., Martin, D. T., Lewthwaite, R., & Wulf, G. (2017). Choices enhance punching performance of competitive kickboxers. *Psychological Research*, 81(5), 1051–1058.
- Halperin, Israel, Wulf, G., Vigotsky, A. D., Schoenfeld, B. J., & Behm, D. G. (2018). Autonomy: a missing ingredient of a successful program? *Strength & Conditioning Journal*, 40(4), 18–25.
- Hanson, N. J., & Buckworth, J. (2015). The effect of endpoint knowledge on perceived exertion, affect, and attentional focus during self-paced running. *The Journal of Strength & Conditioning Research*, 29(4), 934–941.
- Jarosz, A. F., & Wiley, J. (2014). What are the odds? A practical guide to computing and reporting Bayes factors. *The Journal of Problem Solving*, 7(1), 2.
- Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting & task performance*. Prentice-Hall, Inc.

- American College of Sports Medicine. (2013). *ACSM's guidelines for exercise testing and prescription*. Lippincott Williams & Wilkins.
- Morey, R. D., Rouder, J. N., & Jamil, T. (2015). BayesFactor: Computation of Bayes factors for common designs. *R Package Version 0.9*, 9, 2014.
- Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A., & Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine & Science in Sports & Exercise*, 39(8), 1435–1445.
- Sands, W. A., Wurth, J. J., & Hewitt, J. K. (2012). The National Strength and Conditioning Association's (NSCA) Basics of Strength and Conditioning Manual. *NSCA, Editor: NSCA*.
- Sanli, E. A., Patterson, J. T., Bray, S. R., & Lee, T. D. (2013). Understanding self-controlled motor learning protocols through the self-determination theory. *Frontiers in Psychology*, 3, 611.
- Silva, M. N., Markland, D., Carraca, E. V., Vieira, P. N., Coutinho, S. R., Minderico, C. S., Matos, M. G., Sardinha, L. B., & Teixeira, P. J. (2011). Exercise autonomous motivation predicts 3-yr weight loss in women. *Medicine & Science in Sports & Exercise*, 43(4), 728–737.
- Teixeira, P. J., Carraça, E. V., Markland, D., Silva, M. N., & Ryan, R. M. (2012). Exercise, physical activity, and self-determination theory: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 9(1), 78.

- Todd, J. S., Shurley, J. P., & Todd, T. C. (2012). Thomas L. DeLorme and the Science of Progressive Resistance Exercise: *Journal of Strength and Conditioning Research*, 26(11), 2913–2923. <https://doi.org/10.1519/JSC.0b013e31825adcb4>
- Vlachopoulos, S. P., Ntoumanis, N., & Smith, A. L. (2010). The basic psychological needs in exercise scale: Translation and evidence for cross-cultural validity. *International Journal of Sport and Exercise Psychology*, 8(4), 394–412. <https://doi.org/10.1080/1612197X.2010.9671960>
- Wingfield, G., Marino, F., & Skein, M. (2018). The influence of knowledge of performance endpoint on pacing strategies, perception of effort, and neural activity during 30-km cycling time trials. *Physiological Reports*, 6(21), e13892.
- Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychonomic Bulletin & Review*, 23(5), 1382–1414.