4-2017

Impact of Direction of Unloading Influence on Template Rate of Perceived Exertion

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Recommended Citation

Greer, B.K., Young, P.R., Thompson, B., Rickert, B.J. & Moran, M.F. (2017). *Journal of Strength and Conditioning Research, 31*. doi:10.1519/JSC.0000000000001846

Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000001846

TITLE: Impact of Direction of Unloading Influence on Template Rate of Perceived Exertion

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ABSTRACT

It is suggested that exercisers engage in a process of teleoanticipation and create an exercise template based upon previous experience with the exercise task which guides their perceptions of the amount of effort required for task completion. The present study examined how altering workload intensity during a positive-pressure treadmill task may impact ratings of perceived exertion (RPE). In a counter-balanced design, 15 collegiate cross country runners (7 males, 8 females) performed two 25-min runs at a constant velocity while bodyweight (BW) was either increased from 60% to 100% (INC) or decreased from 100% to 60% (DEC) in 5 min increments. Oxygen consumption (VO_2), heart rate (HR), and respiratory exchange ratio (RER) were collected. RPE was recorded at the end of each stage, and energy expenditure (EE) was calculated with VO_2 and RER data. There were no significant differences between direction of loading conditions for VO_2, EE, HR, and RER ($p > 0.05$). Between-trial differences in RPE at 100%, 90%, 80% BW were statistically significant ($p < 0.001$) with higher RPEs observed during the INC trial. Differences in RPE observed between conditions cannot be explained by physiological mechanisms. These findings suggest that RPE is a multifaceted construct which can be impacted by subjectively based anticipatory factors such as exercise intensity.

Key Words: aerobic fitness, psychology, performance

INTRODUCTION

Regulation of exercise intensity, both in practice and competition, is integral to reach peak performance within exercise and sport. Accordingly, concerted effort has been placed on investigating factors that influence exercise intensity selection; one factor that appears to be directly related to exercise intensity is effort perception (25). The most commonly used measure of effort perception is Borg's Rating of Perceived Exertion (RPE) scale (11). This scale is a valid, subjective measure of effort, stress, or discomfort experienced while engaged in physical activity (4, 5, 11). Previous research suggests that an exerciser's RPE is linearly related to exercise intensity (17) and is directly associated with various physiological variables (e.g., heart rate, ventilation, and oxygen consumption).

While the relationship between RPE and such physiological variables is well supported, research has shown that RPE can be impacted by psychological, sociological, and situational variables (26). In support, the relationship between physiological factors and RPE is not always direct, and RPE can vary even when metabolic demand is held constant (12, 21, 22, 28). Such findings provide strong evidence that RPE is highly impacted by non-physiological factors. Thus, current conceptualizations of RPE suggest that it is guided by a number of factors including past expectations, current physiological demands (e.g., effort, strain, pain), and time to completion (1). The present study was designed to potentially provide evidence for non-physiological influences on RPE, and if such evidence exists, to provide practitioners strategies to manipulate exercise prescriptions to maximize time at higher exercise intensities within a fixed-duration workout.

Recent research has emphasized the relationship between RPE and duration of exercise or time to completion (20). In fact, Noakes (2011) suggested that RPE be explained primarily as a measure of relative exercise duration (20). It has been shown that RPE demonstrates a scalar linear relationship with duration of exercise (6, 8, 19). This relationship has been consistently demonstrated across a wide variety of modalities, intensities, environments, and lengths of exercise (29). The fact that RPE increases in a scalar linear manner suggests that an anticipated end point is taken into consideration when setting RPE at the initiation of exercise (8). Research has suggested that a process of teleoanticipation, which refers to the ability to anticipate the necessary requirements for the successful completion of a task (31) occurs when making determinations of RPE.

In order to determine the intensity required to complete a task, Patterson and Marino (2004) have suggested that exercisers often create an “exertion template” (also referred to as template RPE) (23). The theoretical template is guided by the duration of the exercise as well as previous experience with similar exercise trials (8, 13). During exercise, physiological feedback and external performance cues are compared to the template RPE and the remaining task duration to produce a “conscious” RPE. For a typical exercise bout, template RPE is set in such a way that “conscious” RPE increases linearly at a constant rate throughout the task so that maximal RPE is reached just prior to the end of the task (30). A large number of the studies that have examined the influence of exercise duration on RPE have focused on a pattern of exercise in which the highest intensity stimuli are experienced in the latter portion of the task. However, at present there is limited research on the impact of varied intensity patterns (i.e., low to high versus high to low) on RPE (14).

A recent study by Kilpatrick and colleagues (2012) explored this relationship by investigating the impact of varying intensity patterns on RPE during an aerobic task (14). Specifically, the impact of an easy finish (increased intensity at beginning and gradually decreasing) or hard finish (low intensity at beginning and gradually inclining) on RPE was examined. The findings indicate that during the most intense portions of the exercise, RPEs were lower in the easy finish condition compared to the hard finish condition even though the overall workload (WL) was the same in both conditions. The authors contend that experiencing the highest intensity stimuli early within an exercise task, when the participant is “fresh”, allows for lower exertion ratings. These results provide evidence that the timing of exposure to high intensity stimuli during an exercise task can affect RPE.

As noted, empirical support on the impact of the specific timing of exercise intensities on RPE during exercise is scarce. Thus, the present study sought to extend upon the research of Kilpatrick et al. (2012) by applying the use of a positive-pressure treadmill within an exercise task (14). Within recent years, research interest in lower body positive-pressure treadmills for rehabilitative purposes has increased dramatically (24). Positive-pressure treadmills have the capacity to unload variable proportions of bodyweight (BW) with less interference to gait patterns than harness-based unloading techniques (10, 24). The strategy of the present study was to examine the effect of varying intensity patterns on RPE by manipulating the direction of BW unloading. A previous investigation in our laboratory (unpublished work) suggests that RPE determinations on positive-pressure treadmills differ for equivalent WL depending on the direction of unloading. Consequently, the primary hypothesis of the present study was that RPE would be affected by the direction of unloading (with higher RPEs observed as WL was progressively increasing as opposed to decreasing). Furthermore, it was hypothesized that these differences would be explained psychologically as opposed to via alterations in metabolic demand. The information gained from such an investigation could allow athletes to complete more metabolically demanding tasks with less perception of the physical exhaustion that typically accompany it.

METHODS

Experimental Approach to the Problem

The current study implemented a repeated measures crossover experimental design. The sole independent variable for between-trial comparisons was the direction of unloading. The unloading either progressed incrementally from a low-to-high 60% BW condition up to 100% BW (INC), or progressed in a high-to-low 100% BW to 60% BW (DEC) fashion. Although subjects were not informed of study's hypotheses, they were informed of the condition prior to exercise; thus, they had time to construct a template for anticipated exertion. The primary dependent variables consisted of RPE and running economy (RE). A counterbalance design was applied in order to minimize the potential for an order effect. After completing the initial condition, subjects were then exposed to the remaining condition on the following day.

Subjects

Sixteen male (n = 8) and female (n = 8) subjects were recruited from a collegiate cross-country team; participant number required to achieve an acceptable degree of predicted power (i.e., ≥ 0.8) was determined *a priori* from a previous unpublished investigation. Both male and female subjects were recruited as there is no effect of gender observed with RPE scale usage (4). Data collection occurred during the competition season (3 weeks prior to intended peak race performance), and the mean self-reported running mileage was 78.9 ± 25.7 km per wk. All subjects were provided informed consent and all procedures were approved by the primary author's University's Institutional Review Board. Subject characteristics can be seen in Table 1.

**** Table 1 near here ****

Measures

Subjects' RPE was assessed via Borg's (1998) RPES while engaged in a treadmill task (2). The scale includes a 15-point ordinal ranking which ranges from 6 (*No exertion at all*) to 20 (*Maximal exertion*). The RPES is a reliable and valid scale, which is commonly used to assess subjective perceptions of effort or exercise intensity (5), and has been demonstrated to be unaffected by such demographic variables as gender, age, or physical activity level (11).

The TrueOne® 2400 (Sandy, UT) is a portable metabolic measurement system and is commonly used to administer cardiopulmonary stress testing, as well as to assess O_2 consumption during various aerobically oriented tasks. Within the current study, the TrueOne® system was used to collect oxygen consumption (VO_2), respiratory exchange ratio (RER), and heart rate (HR) data with the additional use of a Polar Wearlink® Heart Rate Transmitter (Kempele, Finland).

Recently, the accuracy of using oxygen consumption (VO_2 expressed relatively as ml/kg/min) as the sole determinant of RE has been called into question (27); consequently energy expenditure (EE) was also calculated for RE analysis using the RER (16). Our laboratory's mean coefficients of variation for running VO_2 and EE measurements are 0.67% and 1.62%, respectively, which compare favorably to other laboratories (3).

A MI/F32 model AlterG® anti-gravity lower body positive (Fremont, CA) pressure system was used. The AlterG® provides either a lifting or lowering force by enclosing an individual within a pressurized bag. The AlterG® is traditionally used by individuals during recovery and rehabilitation from injury as it minimizes the degree of stress on the individual's body. Within the current study, it was used to either progressively increase or decrease subjects' BW load during the treadmill task. It also provided a unique and less familiar style of exercise intensity alteration, as opposed to simply increasing speed or grade.

Procedure

Upon the initial visit to the laboratory and following a 10 min self-paced warm-up, subjects performed a continuous, graded exercise test to volitional exhaustion (18) on the AlterG® treadmill to determine VO_2 peak.

Following a minimum of 48 hr post-VO_2 peak assessment, subjects returned to the laboratory for two consecutive days of experimental testing. For both testing days subjects ran at a pace corresponding to 70% VO_2 peak for five continuous segments of unloading (60% BW, 70% BW, 80% BW, 90% BW, 100% BW/no unload). Each of the five unloading segments was 5 min in duration, the last two of which were used for RE analysis (i.e., continuous metabolic sampling averaged over the 2 min period). Given that the sample population was aerobically trained, it was presumed that steady state aerobic metabolism would be achieved within 3 min at the prescribed intensity, regardless of unloading condition. Within the last 15 sec of each stage, RPE and HR data were collected. Subjects were aware via informed consent document that their exertion level may be affected by unloading in either direction of unloading, however no indication of our hypothesis was provided. Subjects were informed of the loading condition immediately prior to the first stage of each exercise session.

Subjects abstained from exercise for 48 hr prior to the first experimental trial. The following day, the alternative protocol was performed with identical measurements made within an hour of the previous days' time. Subjects were not permitted to exercise or perform any strenuous activity between the two trials. Based on data from a comparable participant pool (7), it is unlikely that fatigue or muscular damage from the first trial would have any influence on variable (e.g., RE, RPE) response to the second trial performed 23.5 hr later. Subjects were required to fast for 4 hours prior to all data collection in order to minimize any acute dietary effects on RER. General dietary data was not collected since a crossover design was utilized with data collection taking place on back-to-back days, greatly minimizing any influence that general macronutrient intake variance would have on results.

Statistical Analysis

VO_2, EE, HR, and RER were analyzed parametrically via repeated measures ANOVA, and a Tukey HSD test was used for post-hoc analysis. Partial eta squared values (η_p^2) were calculated for effect sizes as repeated measures were used. As RPE operates on an ordinal scale, a Friedman's test with a Wilcoxon post-hoc analysis was used to compare those data. Significance level was set at $p < 0.05$ *a priori*. Data were processed using SPSS V23.0 (IBM; Armonk, NY).

RESULTS

Fifteen of the 16 subjects completed all testing procedures (7 M, 8 F) and were thus included in the final statistical analyses. Significant between-trial differences [X^2 (9) = 78.94, $p < 0.001$] were present for RPE at 80%, 90%, and 100% BW conditions. These data, as well as within-trial differences, are presented in Figure 1.

There were no significant between-trial differences [$F(2, 32) = 0.86$, $p > 0.05$, $\eta_p^2 = 0.06$] for VO_2 or for EE [$F(2, 30) = 1.76$, $p > 0.05$, $\eta_p^2 = 0.11$]. Each stage of unloading showed a within-trial difference [$F(2, 20) = 125.98$, $p < 0.001$, $\eta_p^2 = 0.90$] from its preceding or following stage for both VO_2 and EE data [$F(1, 18) = 87.46$, $p < 0.001$, $\eta_p^2 = 0.86$]. There were significant between-trial differences [$F(2, 34) = 15.77$, $p < 0.001$, $\eta_p^2 = 0.53$] in RER at the 60% BW condition as well as significant within-trial differences [$F(2, 35) = 15.46$, $p < 0.001$, $\eta_p^2 = 0.53$] between 60% and 70% BW conditions in the INC trial and between 90% and 100% BW conditions in the DEC trial. There were significant between-trial differences [$F(2, 32) = 19.36$, $p < 0.001$, $\eta_p^2 = 0.58$] in HR at the 60% and 100% BW conditions. While there were significant within-trial differences [$F(2, 23) = 113.3$, $p < 0.001$, $\eta_p^2 = 0.89$] in HR for both conditions, none occurred in BW conditions within 10% of the other and are therefore not reported. All physiological data can be seen in Table 2; 95% confidence intervals for between-trial analyses can be seen in Table 3.

**** Table 2 near here ****

**** Table 3 near here ****

**** Figure 1 near here ****

DISCUSSION

The purpose of the present study was to examine the effect of varying intensity patterns on RPE by manipulating the direction of unloading. The primary aim was to determine if the direction of unloading during a treadmill task would impact RPE; specifically it was hypothesized that RPE would be significantly higher at increased WL during the INC (low-to-high) condition, as compared to the DEC (high-to-low) condition. RPE was significantly lower at 80-100% BW when starting with a greater metabolic challenge as opposed to arriving there after lower workloads, supporting the hypothesis that direction of unloading affects RPE without an apparent physiological explanation.

Our findings are supportive of previous research which suggests that RPE is a multifaceted construct that is influenced by both physiological and non-physiological factors (22). Additionally, they extend upon recent investigations into varied intensity patterns on RPE (14), as subjects in both conditions were under the same metabolic demand as indicated by VO_2 and

EE although their RPE differed. These findings indicate that varying patterns of exercise intensity can influence perceptions of effort. Moreover, the use of a positive-pressure treadmill to manipulate WL was supported as a method of influencing RPE.

Specifically, our study found that RPE was lower when exercisers experienced a WL that progressively decreased as opposed to progressively increased. This supports the work of Kilpatrick et al. (14); within their study, Kilpatrick and colleagues found that high intensity stimuli was perceived as less exertive in a high to low condition as compared to a low to high condition. Similar to Kilpatrick and colleagues, within the present study the higher intensity in the early stages of the task was not interpreted as such by the subjects' reported RPE, even though their metabolic output reflected the imposed WL intensity. These findings suggest that when exercise is planned such that the most intense aspects are during the initial stages, perceptions of exertion are lower. Thus, it may be beneficial to create exercise regimens in which the most intense portions are structured within the early stages.

A potential explanation for the lower RPE within the DEC condition may be related to subjects' template RPE. Often, exercise bouts are designed so that the most intense aspects of the exercise occur towards the end. In such circumstances, RPE follows a scalar linear relationship with task duration. That is, RPE increases steadily until reaching its height at the end of the exercise. Previous exposure to such exercise bouts could potentially cause hesitation in giving maximal ratings at the beginning of exercise when the majority of task duration has not been completed, and metabolic reserves are plentiful (8). In other words, prior experience with exercise in general and information about the duration of the specific task may be the primary factors in guiding

RPE, not information about the intensity. This is in line with the work of Noakes (20) which intimates the importance of relative task duration on RPE determinations. Specifically, knowledge regarding the duration of the task allows the exerciser to anticipate the probable metabolic demands and create an effort-based strategy; doing so can provide the exerciser with a pacing template to utilize in order to maximize performance. This explanation fits with the reported lower RPE in the beginning stages of the DEC condition as compared to similar intensities in the INC condition. These results are consistent with previous research which suggests that one's RPE strategy is impacted by previous experience and the degree of certainty of the task's endpoint, as well as its duration (8).

There are two potential explanations for the significant between-trial differences in HR at 60% and 100% BW conditions, as well as in RER at 60% BW. It is possible that 4 min and 45 sec was an inadequate duration for subjects to reach a steady-state HR during the first stage of either trial. However, given the high VO_2 peaks of our subjects, it is unlikely they would not have reached steady-state conditions at 70% VO_2 peak within this time frame, regardless of loading condition. The differences in RER also suggest that steady-state conditions were reached, with lower within-trial RERs suggestive of greater reliance on fat metabolism observed during the first stages of both trials. Alternatively, we propose that the comparatively higher HRs observed in the last stage of exercise and higher RER in the last stage of the DEC trial at 60% BW is reflective of increased sympathetic drive due to subject anticipation of exercise cessation. This contention is indirectly supported by the work of Eston and colleagues (9) which used an exercise intensity similar to that used in the present study and reported higher HRs during exercise when subjects knew the duration of the task versus an unknown duration. Interestingly, they too observed an elevated HR with no significant change in VO_2.

Study Limitations

The use of both genders, while unimportant to RPE results (4), creates a larger variance in VO_2 and EE data, consequently making significant differences more difficult to find. However, given the moderately low effect sizes reported by partial eta squared, it is unlikely a type II error occurred in regard to these variables. Additionally, the use of a participant pool with such a high aerobic capacity and weekly training mileage may reduce the generalizability of our results.

The theoretical nature of template RPE also poses a limitation for the present study. As it cannot be directly measured, inferences must be made in explaining the mechanisms behind our findings. However, there is a line of research which could provide a concretized measurement for template RPE. Recent research (14, 15) has investigated the utility of a measure of predictive RPE. While the construct of predictive RPE has promising implications, investigations into the construct have been limited. Further, while the predictive RPE appears to assess a similar construct to that of template RPE, it is unclear whether predictive RPE could be a valid indirect assessment of template RPE. Future research should examine the utility of predictive RPE as a measure of template RPE.

Also, future investigations should explore the specific mechanisms that underlie the differing RPEs associated with varying intensity patterns found within this study. We contend that predictive RPE may yield some insight. Accordingly, continued research examining predictive

RPE and momentary RPE is due. Future studies should also consider investigating how varying intensity patterns may impact exercise performance within an applied setting and within a sample of subjects with a lower aerobic capacity.

In conclusion, this study provides additional evidence for the existence of template RPE, an emerging concept in exercise psychology. The results suggest that RPE can be impacted by non-physiological factors, and that varying the intensity of an exercise can alter an exerciser's template RPE. These results not only expand the current conceptualization of RPE but also provide an opportunity for coaches, trainers, and athletes themselves to manipulate RPE to potentially maximize training effects.

PRACTICAL APPLICATIONS

Coaches, athletes, and exercisers can all benefit from the knowledge that RPE can be influenced by simple changes to the structure of workload during physical exertion. By altering the timing of intensity stimuli during an exercise task, athletes may be able to work at higher intensities without actually perceiving the increased WL or effort that the body is producing. Such manipulations may allow athletes to complete more physically challenging tasks without experiencing the mental fatigue and physical exhaustion that typically accompany it. This same rationale may aid a non-elite exerciser to complete high intensity workloads by scheduling the most challenging aspects of a workout near the commencement of the exercise. This could help increase exercise adherence, especially for individuals who are resistant to highly strenuous tasks.

ACKNOWLEDGMENTS

None. We have no conflicts of interest to report.

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FIGURE LEGENDS

FIGURE 1. Participant mean ratings of perceived exertion (RPE) ± *SD*. *Note.* INC = low-to-high progression trial; DEC = high-to-low progression trial. *Significant within-trial difference compared to 10% lower condition ($p < 0.001$). ^ Significant between-trial difference ($p < 0.001$).

Table 1. Mean ± *SD* of Subject Characteristics*

	Male (N=7)		*Female (N=8)*	
	Mean	*SD*	*Mean*	*SD*
Age (years)	20	1	20	1
Height (cm)	183.7	5.6	167.8	3.7
Body Mass (kg)	68.2	4.8	54.9	3.7
Body Fat (%)	7.6	1.9	20.6	3.5
VO_2 peak (ml/kg/min)	70.2	4.0	52.8	3.6

*subject characteristics provided for subjects who completed all testing procedures; VO_2 = oxygen consumption

Table 2. Mean ± *SD* for Physiological Variables (*N* = 15)

	60% BW		*70% BW*		*80% BW*		*90% BW*		*100% BW*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
				Oxygen Consumption (ml/kg/min)						
INC	29.0	5.4	31.5*	5.5	34.0*	5.6	36.6*	6.1	39.6*	6.5
DEC	30.1	5.3	31.7*	5.4	34.2*	5.3	36.9*	5.5	39.1*	5.5
				Energy Expenditure (kcals/min)						
INC	8.6	2.8	9.3*	2.9	10.3*	2.8	11.1*	3.1	12.0*	3.3
DEC	9.1	2.5	9.6*	2.7	10.4*	2.8	11.2*	2.9	11.7*	3.0
				Respiratory Exchange Ratio						
INC	0.83^	0.05	0.86*	0.03	0.86	0.04	0.87	0.04	0.87	0.04
DEC	0.87	0.04	0.88	0.00	0.88	0.04	0.88	0.04	0.85*	0.05
				Heart Rate (beats/min)						
INC	128.1^^	14.0	135.7	13.1	143.3	11.4	152.9	12.2	161.3^^	10.4
DEC	136.3	13.0	139.5	12.2	144.1	10.5	147.5	10.2	151.2	13.7

INC = low-to-high progression trial; DEC = high-to-low progression trial; BW = bodyweight
* Significant within-trial difference compared to 10% lower condition ($p < 0.001$)
^ Significantly different compared to DEC condition ($p < 0.001$)
^^ Significantly different compared to DEC condition ($p < 0.05$)

Table 3. Between-trial 95% Confidence Intervals for Physiological Variables (*N* = 15)

	60% BW	*70% BW*	*80% BW*	*90% BW*	*100% BW*
			Oxygen Consumption (ml/kg/min)		
INC	[26.4, 32.4]	[28.5, 34.5]	[30.9, 37.1]	[33.3, 43.2]	[36.0, 43.2]
DEC	[27.2, 33.0]	[28.8, 34.7]	[31.2, 37.1]	[33.9, 40.0]	[36.0, 42.1]
			Energy Expenditure (kcals/min)		
INC	[7.4, 10.2]	[8.1, 10.9]	[8.7, 11.8]	[9.4, 12.8]	[10.2, 13.9]
DEC	[7.7, 10.5]	[8.1, 11.1]	[8.8, 11.9]	[9.6, 12.8]	[10.1, 13.4]
			Respiratory Exchange Ratio		
INC	[0.80, 0.85]	[0.84, 0.88]	[0.85, 0.89]	[0.85, 0.89]	[0.85, 0.89]
DEC	[0.85, 0.89]	[0.86, 0.90]	[0.86, 0.90]	[0.86, 0.90]	[0.82, 0.87]
			Heart Rate (beats/min)		
INC	[120.4, 135.9]	[128.4, 142.9]	[136.9, 149.6]	[146.2, 159.7]	[155.6, 167.1]
DEC	[129.1, 143.6]	[132.8, 146.3]	[138.3, 149.9]	[141.8, 153.1]	[143.6, 158.8]

INC = low-to-high progression trial; DEC = high-to-low progression trial; BW = bodyweight

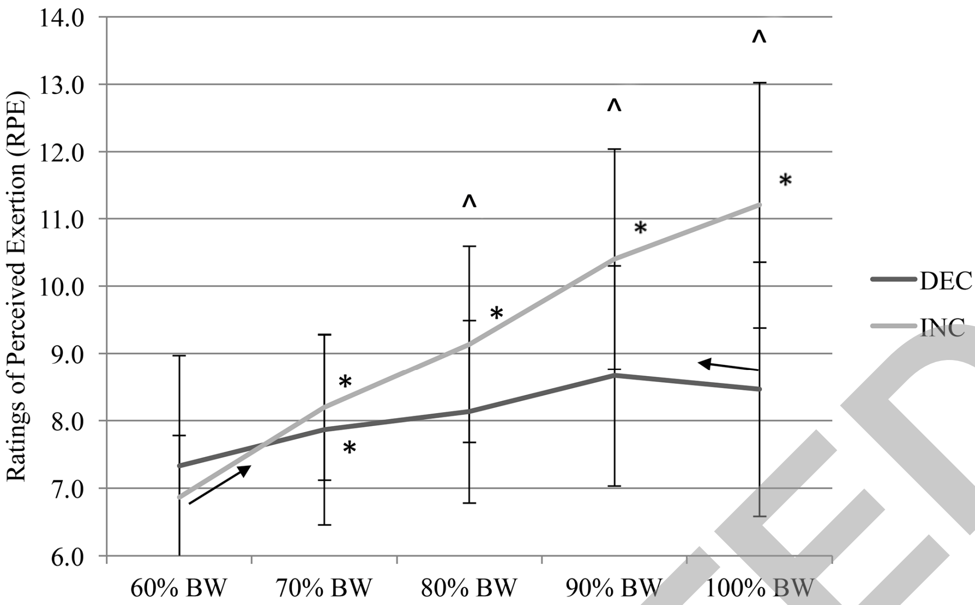

FIGURE 1. Participant mean ratings of perceived exertion (RPE) ± *SD*. *Note.* INC = low-to-high progression trial; DEC = high-to-low progression trial. *Significant within-trial difference compared to 10% lower condition ($p < 0.001$). ^ Significant between-trial difference ($p < 0.001$).