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ORIGINAL ARTICLE

Perceived Exertion Responses to Exercise Differ for Progressively Increasing and Decreasing Order of Intensity: A Crossover Design Study

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ABSTRACT

Background. The effects of exercise intensity on the rating of perceived exertion (RPE) have been widely studied. However, in most of these studies, the contraction intensities were provided in a randomized order. **Objectives.** This study aimed to examine the influence of intensity order on RPE. **Methods.** During the first period, three trials of isometric contractions were performed at three different target intensities in the following order: 25%, 50%, and 75% of maximal voluntary contraction (MVC) in group A and the reverse order: 75%, 50%, 25% of MVC in group B. Each group's intensity order provided during the first period was reversed during the second period. The RPE was measured at each target intensity. **Results.** There was a significant difference in the perceived intensity at 75% of MVC between groups during the first period. The perceived intensity of 75% of MVC in group A during the second period and group B during the first period was significantly lower than the target intensity. **Conclusion.** The order of exercise intensity affected the perceived exertion responses in this study. When establishing an exercise program consisting of varying intensities, practitioners should consider the order of intensity implementation.

KEYWORDS: ***Exercise, Hamstring Muscles, Isometric Contraction, Physical Exertion.***

INTRODUCTION

Resistance exercise is essential for maintaining a healthy body, and intensity is considered essential in exercise. It can be challenging to improve muscle strength if the intensity is too low, and excessive high-intensity exercise can cause exercise-induced injuries. To establish an effective exercise program, it is vital to measure the exercise intensity. One-repetition maximum (1RM) is widely used to determine the appropriate dose for resistance exercise in clinical practice. However, equipment may be needed to measure 1RM accurately (1), and the computation of complex calculations is necessary to achieve accurate prediction (2). In addition, since it is time-consuming, the applicability of 1RM measures may decrease in large groups (3). Thus, the rating of perceived exertion (RPE) has been proposed as an alternative method to evaluate exercise intensity (4).

RPE is used in the general population and target groups, including patients and athletes (5–7). RPE relies on the individual's subjective judgment and has reasonably high validity and reliability (8, 9). Many studies have shown that RPE correlates with exercise intensities and physiological properties such as maximum oxygen consumption, heart rate,

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and respiration rate (10, 11). RPE may be used for aerobic exercise; however, it is an effective method to evaluate exercise intensity, especially for monitoring resistance training intensity. However, most prior studies on exercise intensity had considerable limitations. Some studies applied different intensities after randomization (12–15). Even at the same intensity, RPE responds differently depending on the muscle and exercise duration (16, 17), and its ratings tend to be higher during concentric exercise than during eccentric exercise (18).

Additionally, prior resistance exercise can affect the performance of the muscles subsequently used (19). Even if the exercise program consists of the same intensities, the RPE may differ depending on the order of intensities. The present study compared the RPE between two groups of three different intensities that were progressively increased or decreased.

Currently, two main types of RPE are widely used—the Borg scale (6-20) and the modified Borg category ratio (CR-10). The OMNI-Resistance Exercise Scale (OMNI-RES) is also used less frequently (9). The OMNI-RES uses an easy-to-understand visual scale, but its use during aerobic exercise is limited (20). The Borg 6-20 can be useful for both aerobic and resistance exercises, but because of its wide range from 6 to 20, it is difficult for people to intuitively match their exercise intensity to the Borg 6-20. It is easier to match the exercise intensity to the CR-10 as it only uses 0-10; however, this range can also be too narrow to capture subtle changes, which might be meaningful in clinical practice. In this study, the range of RPE was set as 0-100 (100 was anchored as maximal). This exactly matched the contraction intensity, ranging from 0-100 (21). Based on the maximum voluntary contraction (MVC), the target intensities were composed of three submaximal contraction intensities—75%, 50%, and 25% of MVC.

This study aimed to examine the influence of intensity order on RPEs between two groups. The groups performed isometric contractions at three different submaximal intensities that were progressively increased or decreased. The study followed a crossover design; hence, the order of intensity presentation during the first period was reversed during the second period.

MATERIALS AND METHODS

Participants. Thirty healthy adults were randomly divided into two groups (Table 1). Participants with no prior surgeries on the hip, knee, and ankle joints in the past six months were included. The study was conducted after the Institutional Review Board of ooooooo University reviewed and approved the protocol, and informed consent was obtained from all study participants before any study-related procedures.

Table 1. Demographics of participants

	Group A (n=15)	Group B (n=15)	*p*
Age	21.9±1.3	22.0±1.6	0.801
Weight	59.7±10.9	62.7±13.8	0.506
Height	164.7±8.4	165.7±8.9	0.852

Procedures. When the participant lay on the treatment table in a supine position, the examiner attached a strap connected to a sling rope to the participant's ankle. The other end of the sling rope was connected to the sling system attached to the ceiling, and the angles of the rope and lower extremity were adjusted to 90 degrees (22). The examiner performed passive straight leg raises. Slowly, the examiner induced hamstring elongation before the participant felt any discomfort or pain. In the end range, each participant performed three trials of MVC. During MVC, the examiner motivated the participant to use maximum effort. The isometric contraction was performed for 5 s, and 10 s of rest was given between trials during each trial.

After performing three trials of MVC, a break of 3 min was provided before performing the isometric contractions at three different submaximal intensities. After setting the submaximal target intensity in 25%, 50%, and 75% of MVC, Group A performed isometric contractions at each assigned target intensity. Group B performed the contractions in the reverse order of group A: 75%, 50%, and 25% of MVC. Similar to MVC, three trials of isometric contractions were performed at each target intensity. Rest was given for 10 s between trials and 3 min between target intensities. The perceived intensity was recorded after three trials of isometric contractions at each target intensity. The examiner asked each participant to evaluate the intensity, the relative perceived exertion compared to the maximum intensity, in the range of 0%-100%, with 100% being the maximal intensity. After performing isometric contractions at three different submaximal intensities with a progressive increase or decrease depending on the groups, which was the first period, a 10-min break was given before starting the second period. During the second period, the order was reversed. Group A performed the target intensities in the following order: 75%, 50%, and 25% of MVC, while group B performed the target intensities in the reverse order: 25%, 50%, and 75% of MVC. During the second period, the perceived intensity was verbally requested and recorded after three trials of isometric contractions at each target intensity (Figure 1).

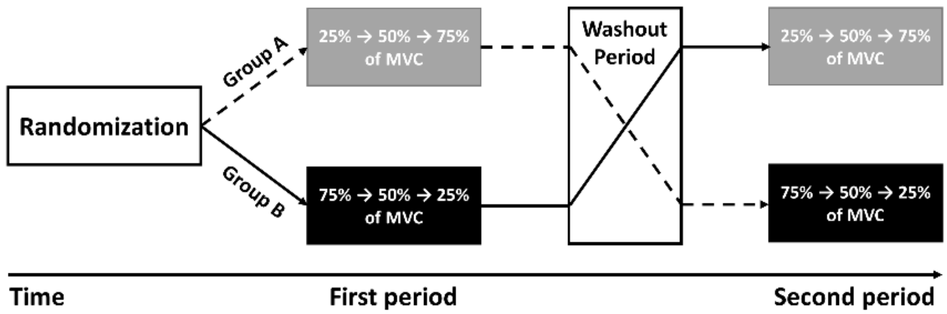

Figure1. ***Study flow chart:*** a crossover study design**.**

Statistical analysis. Normally distributed data were assessed using the Shapiro–Wilk test. Differences in age, weight, height, and perceived intensity between groups A and B were statistically compared using an independent t-test or the Mann–Whitney U-test. The Wilcoxon signed-rank test examined within-group differences (between the first and second periods). The carryover effect was also assessed using an independent t-test. The differences in perceived intensities among three submaximal intensities within each group were statistically compared using the Friedman test with the Wilcoxon signed-rank test as a post hoc. The target intensity was compared with the perceived intensity using the one-sample Wilcoxon signed-rank test. Data analysis was performed using IBM SPSS Statistics 25 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$. All values are reported as mean ± standard deviation.

RESULTS

There were no significant differences in age, weight, and height between groups A and B (Table 1). At 75% of MVC, the perceived intensity was significantly different between groups A and B ($p = 0.017$) during the first period, but it was not significantly different during the second period (Table 2). No significant differences between groups A and B were observed at 50% and 25% of MVC during the first and second periods. There was a statistically significant difference in perceived intensity among three different submaximal intensities in group A during the first and second periods (Table 3) and group B during the first and second periods (Table 4). There was no carryover effect on perceived intensities from the first to the second period. The perceived intensity of 75% of MVC in group A during the second period ($p = 0.011$) and in group B during the first period ($p = 0.003$) was significantly different from the target intensity (Figure 2).

DISCUSSION

RPE during isometric contraction with various intensities is widely studied. In most studies, the contraction intensities were provided in a randomized order. However, unlike in research settings, the clinical settings allow us to vary the order of intensities in a progressively increasing or decreasing manner, especially in resistance exercise programs. Hence, it is essential to study the effects of intensity ordering. RPE is not solely determined by the information received from the sensory receptor in the joint and muscle during muscle contraction (23–25). Even in the same program, RPE may be different if the intensity order is not the same. This study confirmed the RPE at 75%, 50%, and 25% of MVC. The order of these three different intensities was provided in a progressively increasing or decreasing manner. A crossover design was used to reduce potential confounding variables.

Table 2. The difference in perceived intensity between Group A and B

Target intensity (% MVC)	75%	50%	25%
First period			
Group A	73.1±5.6	46.5±7.3	24.7±3.1
Group B	67.7±6.6	50.2±6.5	25.0±6.8
p	0.017	0.354	0.800
Second period			
Group A	70.1±5.8	48.3±6.9	24.5±4.5
Group B	73.7±4.6*	49.5±4.7	23.1±4.8
p	0.118	0.883	0.317

* Significant difference compared to the one during the first period.

Table 3. The significant difference in perceived intensity among three different submaximal intensities in Group A

Target intensity (% MVC)	75%	50%	25%
First period			
75%	-	0.007	<0.001
50%		-	0.021
25%			-
Second period			
75%	-	0.009	<0.001
50%		-	0.012
25%			-

Table 4. The significant difference in perceived intensity among three different submaximal intensities in Group B

Target intensity (% MVC)	75%	50%	25%
First period			
75%	-	0.022	<0.001
50%		-	0.007
25%			-
Second period			
75%	-	0.010	<0.001
50%		-	0.010
25%			-

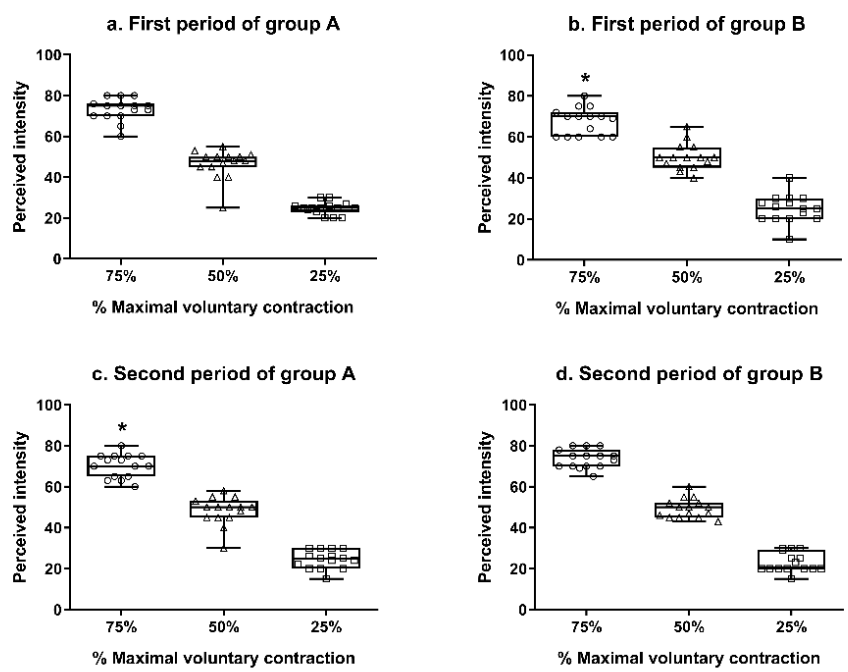

Figure 2. ***Box and whisker plots with the minimum, maximum, first and third quartile, and median values of perceived intensity.*** *****Significant difference compared to the target intensity.

In the first period, the participants reported higher perceived intensity when the isometric contraction intensity was progressively increased than when the isometric contraction intensity was progressively decreased. However, the significantly higher perceived intensity was only noted at 75%. Between-group differences in perceived intensity were similarly observed in the second period, where the intensities were presented in reverse after crossover. Additionally, even when each group's first and second periods were compared, the higher perceived intensity was observed at 75% of MVC only when the intensity progressively increased. In conclusion, similar between- and within-group patterns were observed in this study. Thus, RPE values may differ even in the same exercise program when the program consists of various intensities in various orders. This difference is particularly noticeable during high-intensity exercises. High-intensity muscle contractions may differ in RPE depending on whether the contraction occurred in the last step of the progressive escalation or the first step of progressive de-escalation. The physical and/or psychological fatigue produced during high-intensity exercises may be affected by the order of intensity implementation.

If repeated muscle contractions at submaximal intensities are performed, and subsequent muscle contractions are additionally requested at different intensities, the muscle may experience physical fatigue before entering the final step, resulting in high-intensity muscle contractions. When exercise-induced physical fatigue occurred in previous studies, decreased physical effort and decreased motivation were observed during subsequent motor tasks (26). In the present study, repeated muscle contractions, performed in the first step of progressive escalation, resulted in physical fatigue and affected subsequent muscle contractions at high intensities. Specifically, greater physical exertion might be required to maintain consistent muscle activity in this study. In the Guo 2017 study, the fatigue group with a short rest interval during repetitive tasks showed a higher RPE than the control group (27). In the Pincivero 2000 study, RPE gradually increased when the contraction time was increased at 80% of MVC (17). In recent years, attention has been paid to physical and mental workloads (16, 28). Thus, many studies on the relationship between physical exercise load and cognitive performance have been conducted (29, 30). According to the Marcora 2009 study, mental fatigue can impair motor performance and muscle capacity. This results in significantly higher RPE during physical exercise of the same intensity (31, 32). This is probably because mental factors affect cortical centers associated with perceived exertion (33). However, similar results were observed after a short rest during this study's first and second periods. It can be inferred that the effect on RPE, whether physical or physiological, is only temporary. If RPE is monitored in clinical practice, it is necessary to recognize that different RPEs can be measured at the same intensity, depending on the implemented exercise intensities. In particular, when the high-intensity muscle contraction is first applied in a gradually decreasing order, RPE may be somewhat lower than expected.

When comparing the perceived intensity at three different target intensities within the group, this was differentiated between target intensities. The perceived intensity measured at 75% of MVC was significantly higher than at 50% and 25% of MVC. The perceived intensity at 50% of MVC was also significantly higher than at 25% of MVC. In prior studies, participants could clearly distinguish the contraction force when the subsequent intensity level differed by 30%–50% (15). When comparing target intensity and perceived intensity in this study, the perceived intensity at 75% of MVC was significantly lower than the target intensity that de-escalated from high to low intensity in both groups. There were no significant differences between target intensity and perceived intensity in all other cases. In prior studies, underestimation was often reported. However, there is no clear consensus as to at what level of intensity underestimation occurs. In the quadriceps femoris muscle, the CR-10 scales were 1.2, 1.6, 2.9, 3.5, and 4.9 during 20%, 30%, 40%, 50%, and 60% of 1RM, respectively. In other words, RPE values were significantly lower than the target intensities, which were considered low- to moderate-intensity. However, there was no difference in the high intensity of 70%–90% (13). In another study, underestimation was reported at 10–90% (34) or 50%–90% (35). In most prior studies, intensity levels were assigned after randomization. It is, therefore, possible that the order of intensity was not uniformly randomized. In this study, when the level decreased from high to low intensity, the perceived intensity at high intensity was significantly lower than the target intensity. In a previous study that examined pain after maximal and submaximal isometric contractions, the subject complained of significantly increased pain during high-intensity exercise than during low- to moderate-intensity exercise (36, 37).

Additionally, an increase in exercise intensity can decrease pleasure. Further, if the examiner imposes the exercise intensity and is not self-selected, this could decrease tolerance to higher intensities, which can be more easily linked to displeasure (38). Taken together, it may be more advantageous, in terms of emotional state and pain, to perform the exercise at high intensity first.

CONCLUSION

In conclusion, the order of intensity can affect the RPE value when various intensities are applied. Additionally, RPE is similar to target intensity when the intensity is gradually increased from low to high. However, when the intensity gradually decreases from high to low, the RPE at the high intensity is significantly lower than the target intensity. Unlike in research settings, in clinical settings, intensity can be progressively increased or decreased depending on the purpose. When constructing an exercise program in which various intensities are used, practitioners should consider the order of intensity implementation.

APPLICABLE REMARKS

- The order of intensity can affect the perceived exertion responses when the intensity is gradually decreased from high to low.
- When establishing an exercise program consisting of varying intensities, practitioners should consider the order of intensity implementation.

CONFLICT OF INTERESTS

The author has no conflict of interest to disclose.

SUPPORT

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