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Can young swimmers guide their pace through the rating of perceived exertion?

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ABSTRACT

Currently, the most widely used methods for evaluating internal training load rely on heart rate data as a tool to measure exercise intensity. However, there are limited practical methods available for evaluating training load in swimming. Therefore, assessing indirect methods such as the rating of perceived exertion, a psychophysiological tool to assess the subjective perception of effort during exercise, becomes practical and useful. This study aims to link swimming intensities based on rating of perceived exertion values to identify key performance markers such as velocity, stroke length, stroke rate, and heart rate-based methods to verify if the rating of perceived exertion production is a reliable method to prescribe intensity in swimming. Eight (4 male, 4 female) well-trained swimmers (age 15.8 ± 2.3 years) performed nine bouts of 200 m, three in each of the front crawl, backstroke and breaststroke at ratings of perceived exertion of 5 (strong), 7 (very strong) and 9 (extreme) in the CR-10 Borg Scale. Significant effects were observed for rating of perceived exertion in velocity, stroke rate, stroke length, mean and maximum heart rate, while effects of swimming stroke were observed on velocity, stroke rate and stroke length. These findings suggest that producing ratings of perceived exertion of 5, 7 and 9 may be a suitable approach for swimmers to guide their pace in practice settings.

KEYWORDS: water sports; athletes; performance; physiology.

INTRODUCTION

The rating of perceived exertion (RPE) scale has revolutionized training load (TL) monitoring in sports due to its validity, practicality, and cost-effectiveness (Foster et al., 2021). Originally introduced by Borg in the late 1950s (Borg & Dahlström, 1962), the concept of RPE has evolved into a widely used tool for assessing physical effort, gaining increasing attention in sport and exercise science literature. To achieve this, Borg developed a category scale with ratio properties, the CR-10 Scale, which ranges from 0 to 10, where the numbers are anchored to verbal expressions, and a true zero point is established to facilitate understanding (Borg, 1982). In swimming, as in other sports, optimizing exercise intensity is key to enhancing performance, improving fitness, and minimizing the risk of injury (McKenzie et al., 2023). Traditionally, heart rate (HR) monitoring has been used to gauge exercise intensity in swimmers. However, this method can be difficult to apply in the water due to factors like movement and equipment challenges (Sixsmith et al., 2023). As an alternative, the RPE scale provides swimmers and coaches with a simple yet effective tool to assess how hard an individual feels when they are working out during a training session. This subjective measure of effort is particularly valuable in aquatic environments and correlates closely with physiological measures like HR, making it a reliable indicator of the physical demands of a training session (Bellenger et al., 2016).

Although studies have shown that swimmers generally comply with prescribed distances and rest intervals, they often struggle to accurately judge the intensity of their training sessions without clear guidelines. As such, the RPE method provides swimmers and coaches with a common language to

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prescribe, monitor, and adjust the intensity of training sessions. When comparing the RPE predicted by a coach with that of the respective athletes for a given exercise, incongruence is apparent for low intensities (RPE < 3) and high intensities (RPE > 5); the former being an overestimation by the athlete and the latter by the coach (Wallace et al., 2009). This may create doubts about the accuracy of exercise intensity prescriptions based on RPE, as factors like age, experience, and gender may influence the results (Haddad et al., 2017). Due to the different biomechanical nature of the four swimming strokes, it is expected that some strokes have a higher energy cost and oxygen demand than others while swimming at the same prescribed exertion; this could affect RPE prescription in real-world contexts (Barbosa et al., 2006).

The purpose of this study is to compare how different swimming intensities, based on the CR-10 Borg scale and typically used in practice and real-world competition, influence HR, velocity (V) and coordinative parameters such as stroke rate (SR) and stroke length (SL) changes, and secondly, to determine whether these changes are modulated by performing different swimming strokes.

METHODS

Participants

Eight (4 male, 4 female) well-trained swimmers (mean ± SD; age 15.8 ± 2.3 years; height: 168.1 ± 8.3 cm and weight: 62.3 ± 10.1 kg), with at least three years of training experience (4 to 6 times a week in water sessions and 2 to 3 dry-land training), including one national-level swimmer of each gender. This study was conducted in accordance with the principles of the Declaration of Helsinki, and all legal guardians of the participants provided written informed consent prior to enrollment.

Procedures

All participants underwent two weeks of familiarization with the CR-10 Borg scale. The testing protocol was executed in two sessions (two hours) on consecutive days. Following a warm-up consisting of 400m inverted medley and a front crawl 10 × 25 m incremental set (starting the first 25 m at RPE 1, ascending to RPE 10 intensity in the last 25 m) with 15 s intervals between each 25 m, subjects performed nine bouts of 200 m, three in each of front crawl, backstroke, and breaststroke, while producing an intensity of 5 (strong), 7 (very strong), and 9 (extreme) on the CR-10 Borg scale. Exercise orders were randomized in a counterbalanced manner, and subjects had a 15-minute interval (the first 5 min being active recovery) between bouts. Time trial was registered and later used to calculate V (time/distance), and Post-exercise RPE (PE-RPE), using the CR-10 Borg scale, was assessed after each bout.

Swimmers used an HR sensor (Polar H10, Finland) during each bout; HR recording was later assessed to define mean heart rate (HR-med) and maximum heart rate (HR-Max) (Cosoli et al., 2022).

A digital video Camera (Go-Pro Hero 10, USA) was placed at a high point, 4 m from the side of the middle point of the pool, to capture the entire 25 m distance. The recordings were analyzed for each bout for the calculation of SR (strokes per 25m) (Craig Jr & Pendergast, 1979) and SL (distance/stroke) (Ferreira et al., 2019).

Statistical analysis

All statistical procedures were conducted using Jamovi (Jamovi Project, version 2.6.2). Data normality was verified using the Shapiro-Wilk test, and homogeneity of variance was assessed using the Levene test. To compare the changes between swimming stroke and RPE, a 3 x 3 repeated measures ANOVA were conducted. Statistical significance was set at $p < .05$. The Holm-Bonferroni post-hoc test was applied to assess the pairwise comparisons of RPE, within and between swimming strokes. Pearson's correlation coefficient test was conducted to evaluate the relationship between all variables. The level of statistical significance was set at $\alpha = 0.05$. Effect sizes are reported as partial eta-squared (η^2_p), whose magnitude was interpreted as: $\eta^2_p \geq$: 01, small effect; $\eta^2_p \geq$: 06, medium effect; and $\eta^2_p \geq$: 14, large effect (Cohen, 1988).

RESULTS

As seen in Table 1, significant effects were observed on V for swimming stroke ($\eta^2_p = 0.7$; $p < .001$) and RPE ($\eta^2_p = 0.49$; $p = .01$). In particular, the front crawl was significantly faster than the breaststroke. Regarding RPE, significant differences in velocity were observed between RPE 7 and 9 ($p = .039$).

Similarly, significant differences were observed for SR, swimming stroke ($\eta^2_p = 0.72$; $p < .001$) and RPE ($\eta^2_p = 0.62$; $p = .001$). Particularly, SR was significantly different between all swimming strokes ($p < .05$), and between RPE 5 and 7 ($p = .004$), and between RPE 7 and 9 ($p = .034$).

For SL, significant effects were detected for swimming stroke ($\eta^2_p = 0.69$; $p < .001$) and RPE ($\eta^2_p = 0.63$; $p < .001$). Significant differences were observed for all swimming strokes and between RPE 9 and 5 ($p = .007$) and between RPE 7 and 5 ($p = .047$).

Table 1. Mean ± standard deviation of velocity, stroke rate, stroke length, mean heart-rate, maximal heart-rate and post-exercesi rating of perceived exertion in front crawl, backstroke and breaststroke swimming strokes while producing an intensity of 5 (strong), 7 (very strong) and 9 (extreme) in the CR-10 Borg Scale.

Parameters	Front Crawl			Backstroke			Breaststroke		
	RPE 5	RPE 7	RPE 9	RPE 5	RPE 7	RPE 9	RPE 5	RPE 7	RPE 9
V (m/s)	1.1 ± 0.1[2,3]	1.2 ± 0.1[1,3]	1.2 ± 0.2[1,2]	1 ± 0[2,3]	1.1 ± 0.1[1,3]	1.1 ± 0.2[1,2]	0.9 ± 0.1[3]	0.9 ± 0.1	1 ± 0.1[1]
SR (strokes/25m)	19.6 ± 3.9	20.6 ± 4.7	20.8 ± 4.3	17.6 ± 3.8[2,3]	19 ± 3.5[1]	20 ± 4*[1]	10.7 ± 3[2,3]	11.7 ± 2.9[1]	12.9 ± 2.5[1]
SL (m)	2.6 ± 0.5	2.5 ± 0.4	2.5 ± 0.5	2.9 ± 0.6[2,3]	2.7 ± 0.5[1]	2.6 ± 0.6[1]	2.5 ± 0.6[3]	2.3 ± 0.5	1.9 ± 0.4[1]
HR-med (bpm)	123.9 ± 9.7[3]	136.4 ± 9.8	151.3 ± 12.4[1]	113.8 ± 7.6[2,3]	131.8 ± 10.2[1,3]	146.6 ± 8.8[1,2]	122.5 ± 14[2,3]	139 ± 16[1,3]	148.5 ± 15.8[1,2]
HR-max (bpm)	137.3 ± 9.9[2,3]	154.9 ± 11.8[1,3]	172.3 ± 11.6[2,3]	129.9 ± 11.7[2,3]	146.3 ± 13[1,3]	171.6 ± 10.2[1,2]	136.1 ± 17.9[2,3]	164.1 ± 13[1,3]	168.9 ± 11.6[1,2]
PE-RPE (A.U.)	5.3 ± 1.1[2,3]	7 ± 0.9[1,3]	9 ± 1[1,2]	4.63 ± 0.9[2,3]	6.8 ± 0.8[1,3]	8.6 ± 1.1[1,2]	5.3 ± 0.7[2,3]	7.6 ± 05[1,3]	9.1 ± 0.8[1,2]

V: velocity; SR: stroke rate; SL: stroke length; HR-med: mean heart-rate; HR-max: maximal heart-rate; RPE: rating of perceived exertion; PE-RPE: Post-exercise RPE; [1,2,3] Significantly different from RPE-5, RPE-7 and RPE-9, respectively.

Regarding HR-med, significant differences were observed between RPE ($\eta^2_p = 0.92$; $p < .001$). Particularly, significant differences were observed between each RPE ($p < .001$). Similarly, an effect of RPE was observed for HR-Max ($\eta^2_p = 0.93$; $p < .001$). Specifically, significant differences were observed between all RPEs ($p < .001$).

A strong and significant positive correlation was found between SL and intensity for each swimming stroke (ranging from 0.889 to 0.936, all $p < .05$), suggesting that a swimmer´s technical proficiency remains largely consistent across varying intensities. Conversely, a strong and significant negative correlation was found between SR and SL (ranging from 0.848 to 0.943, all $p < .05$), implying that as SR increased, SL tended to decrease.

These results demonstrate that swimmers, when prescribed with RPEs of 5, 7 and 9, may adjust their SR and SL in order to accurately achieve the desired velocity as well as corresponding HR measures. Meaning RPE prescriptions of 5, 7, and 9 could serve as a practical tool for guiding pace and consequently physiological responses in the absence of physiological measurements. However, given the limited sample size, caution is advised when extrapolating these findings to broader field applications.

DISCUSSION

The aim of this study was to compare how different swimming intensities, based on the CR-10 Borg scale, assist swimmers in guiding their pace during practice and competition. More specifically, the present study evaluated how RPEs of 5, 7, and 9 influence HR, V, SR and SL in well-trained swimmers. Furthermore, we assessed whether different swimming strokes modulate these changes. Based on our results, significant effects were observed on all the studied variables for the different RPE intensities and swimming strokes. Alongside the effect of the prescribed intensity with the respective stroke on the selected variables, the differences between the same intensities in different strokes were also assessed.

In competitive swimming, V is strongly correlated with swimming performance across the different events (Craig Jr et al., 1985), being highly dependent on a combination of different variables that interact with each other (Figueiredo et al., 2010; Morais et al., 2021). The differences observed in V across RPE and swimming stroke may be attributable to the recognized differences between front crawl and breaststroke, which were expected, as the former is recognized as the fastest and most economical stroke (Barbosa et al., 2010; Deschodt et al., 1999). Regarding the effect of intensity and the differences between the different intensities, this could be explained by the relationship between V and SR and SL (Craig Jr & Pendergast, 1979). As stated before, the different intensities influence both coordinative parameters, which could explain the impact of intensity on V. However, based on our results, only significant differences were found between RPE 7 and 9. This suggests that transitioning from moderate to high intensity may play a crucial role in modifying swimming velocity, and the RPE prescriptions proved to be effective in differentiating exercise intensity, likely due to increased reliance on anaerobic energy systems and adjustments in stroke mechanics (Barbosa et al., 2008).

During swimming events, pacing is influenced by SR and SL (Hellard et al., 2008), with an existing trade-off between the two parameters (Morais et al., 2022). In other words, if one of them increases, the other should decrease (Psycharakis et al., 2008; Seifert et al., 2010). In our study, significant, medium-sized effects of swimming stroke and RPE were found on SR. Concerning SL, significant, medium-sized effects of swimming stroke and RPE were also observed. When the different swimming strokes were compared, significant differences were found between all strokes, which was expected, since different strokes lead to different limb mechanics influenced by stroke mechanics in swimming (Barbosa et al., 2011). Regarding the differences in intensity on these parameters, they could be explained by the relationship between V and the pacing strategy, which influences both SR and SL (Craig Jr & Pendergast, 1979).

HR reflects the internal load of a training session (Sixsmith et al., 2023), and as such, it was expected that the RPE levels, and not the swimming stroke, would have an impact on these variables. It was anticipated that the RPE levels, and not the swimming stroke, would influence HR-med and HR-max because HR is a reflection of the internal load of a training session (Sixsmith et al., 2023). Our results confirm this hypothesis, as significant effects were found for RPE in both HR-med and HR-max. When all RPEs were compared, significant differences were found in both parameters, as RPE has been shown to accurately reflect the HR levels of elite swimmers (Psycharakis, 2011). The present data corroborate some findings reported by Robertson and Noble (1997), which demonstrated that eliciting an RPE correspondent to the lactate threshold point provides an appropriate stimulus to improve functional aerobic power and can be a physiologically valid prescriptive procedure. This may be of high interest for coaches and swimmers to monitor, regulate and prescribe swimming intensity during different training periods.

Similarly to Papadimitriou et al. (2023), SR seem to have no significant difference between intensities, even when distances were equalized, which may indicate that V is mainly influenced by SL. Regarding the effect of swimming strokes on HR parameters, no differences were found for the different swimming strokes. This aligns with our hypothesis, since it refers to a physiological measure in response to swimming intensity.

Although the findings of the present study support the use of RPE for prescribing training intensity in swimmers, several limitations should be acknowledged. First, the sample size of eight swimmers was relatively small (Jesus et al., 2016) and increasing the number of participants would enhance the statistical power of the analysis and minimize the likelihood of observing type I and type II errors. In the context of swimming studies, this sample size is below the typical standard, which generally includes around ten swimmers. Additionally, this study was conducted within a specific age group; thus, caution is warranted when generalizing the findings to other populations. Furthermore, factors such as the participants' familiarity with the scale, the absence of more rigorous physiological assessments and the competitive level of participants may also limit the generalizability of our results.

CONCLUSIONS

In conclusion, these results demonstrate that swimmers, when prescribed with RPEs of 5, 7 and 9, may adjust their SR and SL in order to achieve the desired velocity and corresponding HR measures accurately. Meaning RPE prescriptions of 5, 7 and 9 could serve as a practical and inexpensive tool for guiding pace. Consequently, obtain physiological responses in the absence of physiological measurements. Accordingly, coaches may be able to use this strategy to manipulate the effort of specific practice sets and individuals in real time, accounting for different daily conditions such as fatigue, stress, menstrual cycles, or water temperature, and therefore, obtain the desired adaptations from each of their swimmers. However, given the limited sample size, caution is advised when extrapolating these findings to broader field applications. Further research is needed to gain a deeper understanding of the effectiveness of RPE in swimming practices.

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