

Assessment of perceived exertion among runners: exploring the interplay of heart rate, performance and sports habits

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Abstract:

The rate of perceived exertion (RPE) is an indicator that uses numerical scales and verbal and/or visual descriptors and is used at a sports level to determine the intensities of physical exercise. The objective of this study was to examine the relationships between the RPE among runners and various factors including age, gender, BMI, average heart rate (HRmean), maximum heart rate (HRmax), performance and sports habits. The ultimate goal was to advocate for the use of the CR-10 test as a means of monitoring effort levels in athletes. The study comprised a sample size of 278 participants. The normal distribution of data was assessed using the Kolmogorov-Smirnov statistical test, while the Kruskal-Wallis test was employed to compare the variables. To verify the association between variables, Spearman's coefficient and principal component analysis (PCA) were used. In the PCA, three components were obtained that explain 57.4% of the variance; RPE is grouped with HRmax and HRmean, while age and volume of weekly training are grouped by the other. The performance variables (final time in race; $r = -0.151$, $p < 0.05$) and physiological variables (HRmax; $r = 0.223$, $p < 0.05$), show correlation with respect to RPE levels. There are also correlations between age/BMI, age/HRmax, HRmax/HRmean and final time in race/PA volume training. The results indicate that there were no significant differences in RPE levels between trained and untrained runners during the race, or between regular runners with different training volumes. It could be concluded that the use of the Borg CR10 scale could be used in sport as a useful instrument for establishing the degree of intensity of exercise during physical exertion, irrespective of level.

Key Words: - athletes, subjective perception, intensity, fatigue, training

Introduction

Rating of perceived exertion (RPE) is an indicator that uses numerical scales, and verbal and/or visual descriptors to calculate intensities of physical exercise (Bakhareva, Aminov, Cherepanov, Latypova & Stepanov, 2022; Eston, 2012). As Robertson and Noble (1997) point out, RPE can be understood as the subjective intensity of effort, strain, discomfort and/or fatigue experienced during physical exercise. RPE levels during exertion are linked to physiological and psycho-cognitive changes, and can therefore be used to determine the intensity of a particular physical task.

The most commonly used physiological markers by coaches and athletes are oxygen uptake (VO₂), heart rate (HR), blood lactate concentration and respiratory rate (RR). Various studies have demonstrated how these physiological variables combine with RPE levels during incremental and ongoing exercise (Chen, Fan & Moe, 2002; Gros Lambert & Mahon, 2006). Specifically, Chen et al. (2002) results indicate that the highest correlations between ratings of perceived exertion and various physiological criterion (VO₂, ventilation) measures occur when male participants are required to maximally exert themselves or when the exercise task is unusual (e.g. swimming, when measuring heart rate or when the 15-point RPE scale measuring blood lactate concentration is used).

The results of this meta-analysis also suggest that respiration rate is probably the best indicator of physical exertion. On the other hand, Gros Lambert & Mahon (2006) show in their study that before 4 years, children are not able to rate their perceived exertion with a high degree of accuracy. From 4 years, it seems that the peripheral cues provided from muscles and joints are at first involved in perceived exertion. After five years, the cardio-respiratory factors are progressively involved and allow six-year-old children to estimate and produce accurately three levels of running intensity from their perceived exertion. From eight to 12 years of age, children are able to discriminate up to four levels of exertion but are sensitive to the exercise mode and also the rating scale used. In adolescents, it appears that the RPE-HR correlation is less pronounced than adults and RPE values are influenced, like in children, by the mode of protocol used. Other variables that have been studied in different

sports along with the RPE have been core temperature, mean-weighted skin temperature, metabolic rate, air temperatures (Iyoho, MacFadden & Ng, 2015) or hormonal indicators (Balsalobre-Fernández et al., 2014).

According to various authors, RPE increases during exercise and reaches maximum levels when physical exhaustion is reached, and can be used to predict the level of fatigue during exercise (Crewe, Tucker & Noakes, 2008; Eston, Faulkner, St Clair Gibson, Noakes & Parfitt, 2007). RPE levels can also act as a benchmark for a given level of physical activity (PA) in a way that enables us to complete the task (De Koning et al., 2011; Tucker, 2009). Based on these aspects, and based on the findings of Cuadrado-Reyes, Chiroso Ríos, Chiroso Ríos, Martín-Tamayo & Aguilar-Martínez (2012), RPE can be a useful tool for preventing injuries, avoiding overtraining points, as well as acting as a support tool for quantifying optimal training loads.

Nevertheless, we share the view of Bergstrom et al. (2015), who conclude that RPE levels will depend on the intensity of the race, the physiological parameter analysed (HR, blood lactate concentration, RPE etc.), and the type of task. In this sense, several studies have suggested that intermittent training is perceived as being more intensive than ongoing training, although both protocols reflect similar internal loads in terms of autonomous equilibrium and blood lactate concentration (Cerdeira-Kohler, Pullin & Cancino-Lopez, 2015; Okuno et al., 2011) or that the longer warm-up protocols (25 min and 15 min) produced a higher RPE than the shorter ones (8 min) (Yanci, Iturri, Castillo, Pardeiro & Nakamura, 2019).

As regards physiological and cognitive factors, Eston (2012) points out that RPE is moderated by psychological factors (cognition, memory, previous experience, understanding of the task) and situational factors (knowledge of the end point, duration, temporal characteristics of the task). Meanwhile, other studies have analysed sensory and social variables, where results indicate that runners who listen to music on their workouts, or who train with others, have lower RPE values (Montero, Rodríguez & García-de-Alcaraz, 2018).

Other aspects to consider when studying RPE include the influence of caffeine, food or alcohol intake before recording RPE levels. Astorino et al. (2019) examined the effect of meal on RPE during self-selected high intensity interval exercise (HIIE). Studies such as the one by Cerda-Kohler et al. (2015) restrict intake of caffeinated drinks, alcohol and exercise for 24 hours before testing.

Based on the foregoing analysis, and understanding the potential boundaries involved in using RPE scales, their simplicity and justified validity makes them popular as a useful instrument in clinical and sports contexts for establishing the intensity of exercise with an acceptable degree of reliability (Bakhareva et al., 2022). Different RPE evaluation scales have been used, with the Borg 6-20 scale being the most used, and to a lesser extent the Borg CR-10 and Borg CR-100 scales. The correlation of RPE with physiological markers of exertion in adults (Arruza, Alzate & Valencia, 1996; Borg, 1985; Costa et al., 2020; Noble, Borg, Jacobs, Ceci & Kaiser, 1983; Scherr et al., 2013; Seiler & Kjerland, 2006) and children (Rodríguez & Gatica, 2016; Rodríguez, Zambrano & Manterola, 2016) have been clearly demonstrated by these scales.

The use of the Borg physical exertion scale (CR-10), used in our paper, has also been used with children in running tests (Marinov, Mandadjieva & Kostianev, 2008).

In adult runners, RPE correlated significantly with blood lactate training zone boundaries (Abe, Yoshida, Ueoka, Sugiyama & Fukuoka, 2015; Dantas et al., 2015). Previous papers rated 2 and 4 mmol/L blood lactate concentration training zone boundaries as 4.3 and 6.5, according to the CR10 scale (Dantas et al., 2015). Abe et al. (2015) establish lower levels for the blood lactate threshold, rating it between 3.2 and 3.8 depending on the three groups of the sample they use in their study (trained runners, race walkers and untrained females). Other papers indicate that ventilatory anaerobic threshold and RPE score close to five, in sedentary and active women on a cycloergometer (Zamunér et al., 2011) and in beginner and experienced amateur runners (Castro, 2016). Some studies conducted in runners conclude that the maximum RPE values are close to 8, with no differentiation of RPE levels between beginner or inexperienced runners and experienced runners, although these levels are reached more slowly in beginners. Studies show that the correlation between RPE and running speed depends on the sensitivity of the instrument used in the study to detect the intensities of the effort (Abe et al., 2015; Castro, 2016).

In the same vein, the paper by Held and Marti (1999) describes how at the same proportional level of maximal running velocity, poorly endurance-trained athletes showed a 2-3 4 mmol/L higher capillary lactate concentration than endurance-trained athletes, although both groups indicated the same RPE (Borg 6-20).

Finally, some studies point out that runners with higher average values of RPE during a season tend to be those who had run more kilometres and had higher average concentrations of cortisol during that season (Balsalobre-Fernández, Tejero-González & del Campo-Vecino, 2014), so it could be concluded that training volume is linked to RPE. Our study was carried out in runners during a medium-distance competitive race (7 km), the “II Carrera Popular WeAreReady Málaga” organised by the University of Malaga, Spain, in which the possible differences in RPE after the competition were analysed based on the different variables: age and gender, anthropometric (BMI), physiological (HRmean and HRmax), performance in the race (final time), and sports habits of the participants, to analyze if there are differences in the RPE of runners and the variables mentioned above. The objective of the study was to determine the differences in the RPE of the runners and the variables mentioned above, with the aim of establishing possible guidelines in sports planning or implementing the use of CR-10 habitually as effort control in athletes.

Methods

Participants

The participants were 278 runners (201 men; age, 33 ± 11 years; weight, 74 ± 10 kg; height, 176 ± 8 cm; BMI, 23.8 ± 2.5 kg m⁻² and 77 women; age, 32 ± 10 years; weight, 58 ± 7 kg; height, 164 ± 6 cm; BMI, 21.7 ± 2.1 kg m⁻²) out of a total of 882 competitors. After the competition, data on running and PA habits (whether they ran or engaged in any regular PA, weekly training volume, types of sports practiced, frequency and type of competitions practiced) were collected through a questionnaire. The HRmax and HRmean during the competition were obtained using multi-brand heart rate monitors, due to the size of the sample, heart rate monitors were placed on a randomly selected subsample of the 278 runners (98, 85 men and 13 women). The Borg CR10 scale (0, nothing at all; 3, moderate; 5, hard, 10, very, very hard) was used to evaluate RPE after the competition. In the same protocol, informed consent was collected from all runners, and the Declaration of Helsinki regarding human experimentation was complied with World Medical Association (WMA, 2013).

Procedure

The inclusion criteria of the participants in the study were that they were of legal age (+18 years old) and were in good health. During a meeting before the competition, participants received comprehensive information about the aim of research, levels of the Borg CR10 scale (0, nothing at all; 3, moderate; 5, hard, 10, very, very hard) to evaluate RPE after the competition and anthropometric data (height and weight) were collected. Body height was measured to the nearest 0.1 mm, and body mass (measured to the nearest 0.1 kg), on a calibrated WB-150 medical scale with a stadiometer (ZPU Tryb Wag, Poland) according to standardized guidelines, and the BMI was calculated on their basis. The research was performed in observance of the Declaration of Helsinki and upon the prior consent of the Bioethical Committee and the authorities of the University of Malaga and every participant signed a written consent form before the study.

Subjects were instructed to wear the same kind of clothing (light shorts, light t-shirt, and running shoes) in the competition. All subjects were participants of the same race, so the temperature and humidity conditions were the same. Subjects performed a five min warm up before the competition. Time in the 7-km running competition was measured and registered by a chip, managed by the company GES&CON-CHIP.

On the finish line of the competition a tent was set up where each participant with the help of the researchers, had to complete a questionnaire. This questionnaire collected levels of perception of effort through CR-10 scale, different questions about the participant's sports habits and the physiological results provided by the heart rate monitor.

The questionnaire collects sports patterns from the participants as whether they run regularly, their weekly running volume, whether they compete regularly, the number of competitions they usually participate in monthly, whether they practice other sports and according to the sport discipline practiced.

Physiological parameters (heart rate – HRmax and HRmean) were measured indirectly with multi-brand heart rate monitors. Every heart rate monitor was calibrated based on gender, year of birth and weight before the run.

Statistical analysis

The mean and standard deviation were calculated and the normal distribution of the data was checked using the Kolmogorov-Smirnov statistical test. Hypothesis testing was done with the Kruskal Wallis statistical test (non-parametric). To verify the association between variables, Spearman's coefficient and principal component analysis (PCA) were used. A PCA was applied to the independent variables to identify the sources of common variance between age, RPE, BMI, final time in the competition, HRmean, HRmax, weekly running volume and weekly PA volume; the principal component (PC) extracted was considered significant if its eigenvalue was greater than one. For all comparisons, a significance level of 0.05 was used and the control of this level of significance for the post hoc tests was done with Bonferroni's correction. The calculations were made with the statistical program Statgraphics Centurion XVI for Windows.

Results

From descriptive and graphical analysis of the main variables studied (Table 1 and Figure 1), what emerges is that the mean sample shows BMI levels within normal weight values (23.2 ± 2.7 kg m⁻²) and within weight levels considered healthy. The participants had an average running training volume of 3.08 ± 3.06 and PA of 6.18 ± 4.14 hrs per week. More specifically, 81.3% ran regularly, and 61.2% participated in a competitive race monthly. The RPE presented similar values between men and women.

Table 1. Mean results in runner variables by gender

	Male	Female	Total
Anthropometric			
Height (m)	1.76 ± 8	1.64 ± 6	1.73 ± 9
Weight (kg)	74 ± 10	58 ± 7	70 ± 12
BMI (kg.m ⁻²)	23.8 ± 2.5	21.7 ± 2.1	23.2 ± 2.7
Performance of the runners in the race			
Race time (min)	34.39 ± 6.11	42.28 ± 7.01	36.50 ± 7.00

Running pace (min x km)	4.57 ± .53	6.04 ± 1.00	5.50 ± .56
Physiological and Psychological			
HR _{mean} (ppm)	162 ± 15	170 ± 14	163 ± 15
HR _{max} (ppm)	182 ± 12	186 ± 11	182 ± 12
RPE	4.2 ± 1.8	4.3 ± 1.8	4.2 ± 1.8
Weekly training volume			
Running (h)	3.4 ± 3.3	2.3 ± 2.1	3.1 ± 3.1
Physical activity (h)	**6.5 ± 4.1	**5.4 ± 4.3	6.2 ± 4.1
Competitions per month			
Number of competitions	**1.3 ± 1.3	**0.9 ± 1.3	1.2 ± 1.3

Nb. The values are reported as the mean (standard deviation).
Statistically significant difference (* $p < 0.05$, ** $p < 0.01$)

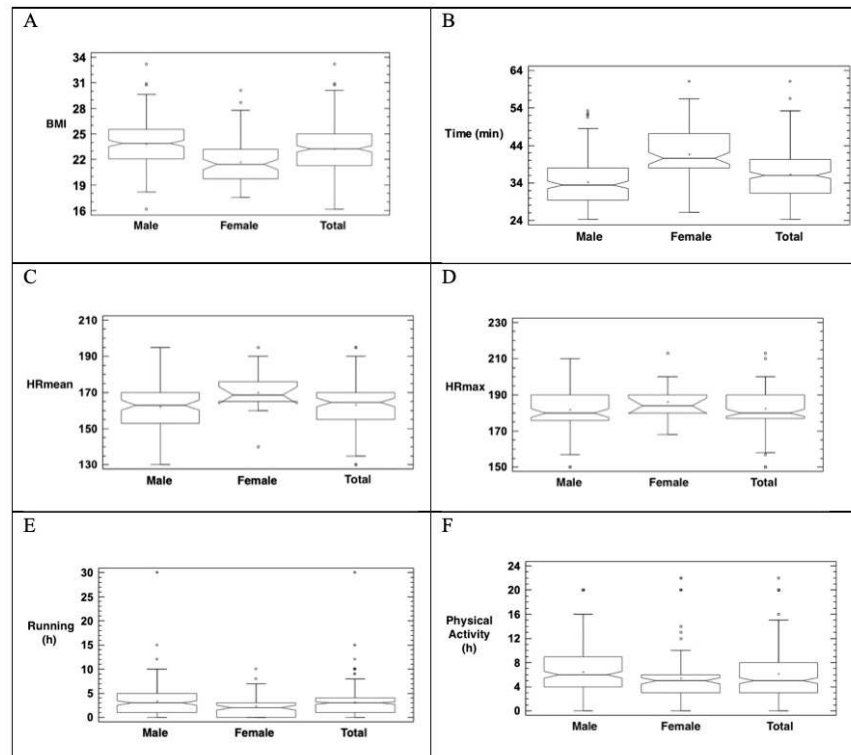


Figure 1. Box- Whisker plots by gender and totals of the variables, BMI (A), final time in the competition (B), HRmean (C), HRmax (D), weekly running volume (E) and weekly PA volume (F). (The notch in the box indicates the median value).

Table 2. Weekly training volume for age groups

Weekly training volume	Age group*	Mean ± s
Weekly running Volume (h)	18-30	2.5a ± 2.3
	31-45	3.3b ± 2.4
	> 45	3.9b ± 3.3
Weekly PA Volume (h)	18-30	6.4a ± 4.0
	31-45	5.7a ± 4.0
	> 45	6.8a ± 4.7

*Kruskal-Wallis Test, the same letter implies equality, at a level of $p = 0.05$.

Table 3 shows the data obtained in the exploratory analysis, using gender, age, BMI group and sports habits as categorical variables, and employing the RPE levels for these variables. The means obtained are close to those achieved by the participants in the competition (4.2 ± 1.8), and are therefore very similar in the majority of the variables studied.

The highest RPE values are found in those who compete in triathlon (4.9 ± 2.8), do it four times or more monthly (4.9 ± 2.4) and in those with a weekly PA volume of more than 8 hours per week (5.7 ± 2.5).

Table 3. Means of the gender, age, BMI group and sports habits variables, taking into account the mean of RPE as a factor

Independent variable	Feature	Mean $\pm$ SD of RPE
Gender	Male	4.2 $\pm$ 1.8
	Female	4.3 $\pm$ 1.8
Age	18-30	4.4 $\pm$ 1.8
	31-45	4.1 $\pm$ 1.8
	> 45	4.4 $\pm$ 2.0
Run regularly	Yes	4.2 $\pm$ 1.9
	No	4.5 $\pm$ 1.7
Practice another sport	Yes	4.2 $\pm$ 1.8
	No	4.6 $\pm$ 1.8
Compete regularly	Yes	4.3 $\pm$ 2.0
	No	4.2 $\pm$ 1.7
Type of competition	Triathlon	4.9 $\pm$ 2.8
	Swimming	4.0 $\pm$ 1.0
	Team sports	4.6 $\pm$ 2.1
	Running	4.3 $\pm$ 1.8
	Do not compete	4.2 $\pm$ 1.7
N° competitions per month	None	4.2 $\pm$ 1.8
	1	4.1 $\pm$ 1.8
	2	4.5 $\pm$ 2.1
	3	4.2 $\pm$ 1.7
	4	4.9 $\pm$ 2.4
	5	4.7 $\pm$ 1.7
Weekly PA volume	Do not run	4.4 $\pm$ 1.7
	0-2 hours	4.1 $\pm$ 1.8
	2-4 hours	4.0 $\pm$ 1.6
	4-6 hours	4.9 $\pm$ 2.1
	6-8 hours	4.6 $\pm$ 2.6
	More than 8 hours	5.7 $\pm$ 2.5
BMI Levels	Underweight	4.0 $\pm$ 1.5
	Normal weight	4.3 $\pm$ 1.8
	Overweight	4.1 $\pm$ 1.8

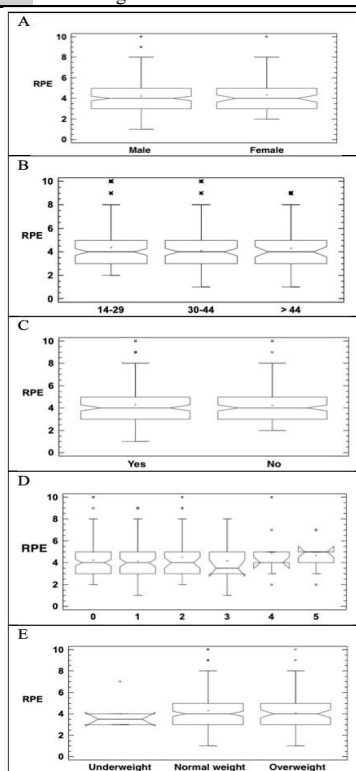


Figure 2. Box-Whisker plots of RPE levels according to gender variables (A), age (B), whether they compete regularly (C), according to the number of competitions they participate in monthly (D) and the BMI group to which they belong (E). (The notch in the box indicates the median value)

The analysis carried out using the Kruskal Wallis test confirms that there are no significant differences in RPE values in the variables set out above. On the other hand, there are significant gender differences in the weekly PA volume ($p < 0.01$) and the number of competitions they participate in monthly ($p < 0.01$). According to this, men are more active per week and participate in more competitions than women.

Even so, the analysis of the correlations using Spearman's range correlation coefficient (Table 4) for the performance variables (race time) with respect to the RPE, show a negative correlation, whereby if the race time falls, the runners' RPE increases. This means that athletes with better performance have higher levels of RPE. In turn, these performance variables correlate with running and PA training volume; the greater the volume, the better the test results. One of these variables, HRmax, also correlates negatively with age: as age increases.

Other variables that correlate with RPE, but this time positive, if HRmax increases, RPE increases. We also have among those that present a positive correlation: age/BMI and HRmax/HRmean, aspects already widely studied in the scientific literature.

Table 4. Correlations of variables age, BMI, performance (race time), psico-physiological (HRmax, HRmean and RPE) and sports affiliation variables (running training and physical activity volume)

Spearman's rho		BMI	Race Time	HR _{max}	HR _{mean}	Weekly running volume	Weekly PA volume	RPE
Age	r	0.2418	-0.0581	-0.2895	-0.1732	0.1110	-0.0010	-0.0299
	Sig	0.0001***	0.3479	0.0050**	0.0986	0.1005	0.9866	0.6264
BMI	r		0.0186	0.0176	0.0637	-0.0700	0.0639	0.0035
	Sig		0.7671	0.8665	0.5500	0.3083	0.3001	0.9555
Race time	r			-0.0951	-0.0371	-0.3745	-0.2458	-0.1511
	Sig			0.3590	0.7249	0.0000***	0.0001***	0.0158*
HR _{max}	r				0.6765	-0.1270	-0.0137	0.2234
	Sig				0.0000***	0.2362	0.8957	0.0331*
HR _{mean}	r					-0.0464	-0.0574	0.1929
	Sig					0.6725	0.5861	0.0704
Weekly Run vol.	r						0.4392	-0.0037
	Sig						0.0000***	0.9560
Weekly PA vol.	r							0.0053
	Sig							0.9316

The PCA carried out, extracted three principal components (PC) with eigenvalues greater more 1, which together account for 57.42% of the variability observed in the data (Table 5).

Table 5. Number of extracted components, eigenvalues and variability explained

PC	Eigenvalues	Percentage variability	Cumulative variability	Percentage
1	1.94745	24.343	24.343	
2	1.47916	18.490	42.833	
3	1.16728	14.591	57.424	
4	0.938945	11.737	69.160	
5	0.858988	10.737	79.898	
6	0.685007	8.563	88.460	
7	0.640834	8.010	96.471	
8	0.282336	3.529	100.000	

The Bi-plot of PC 1 and 2, shows an association between HRmax, HRmean and RPE, physical and psychological variables related to effort, which has already been widely reported in other studies. The relationship between weekly training volume and age suggests different training times according to age.

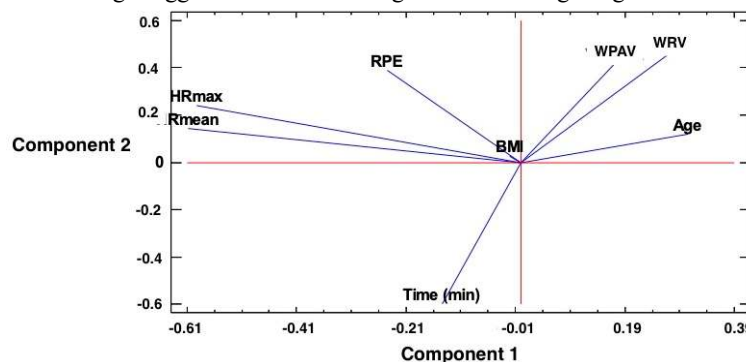


Figure 3. Bi-plot of weight of the components 1 and 2.

Discussion

RPE, age and BMI

The results of our study indicate that there are no significant differences between the RPE of male and female runners in a 7 km race (4.2 ± 1.8 ; 4.3 ± 1.8), since their means are very similar (Figure 2A). Studies such as the one by Muyor, Vaquero Cristóbal, Alacid & López Miñarro (2015), in which different indoor cycling sessions were evaluated, support the fact that there are no significant differences in RPE means between men and women. However, differences have been found in judocas, with the RPE of women 5.4% lower than that of men (Arruza, 1996). On the other hand, the RPE levels obtained among sedentary and active women (Zamunér et al., 2011) and amateur runners (Castro, 2016) indicate that scores close to 5, classed as 'strong' on the Borg CR-10 scale, may be linked to the anaerobic threshold, although other papers focusing on moderately trained runners (89 men, 6 women) establish RPE values in 2/4 mmol/L training zones at 4.3/6.5 (Dantas et al., 2015). The RPE ratings obtained among the runners in our study could be placed, based on the above estimates, within the 'strong' exertion boundaries close to the Anaerobic Threshold.

For age, there is no correlation with RPE levels, although there is a negative correlation with HRmax and positive correlation with BMI (Table 4), an aspect that has already been acknowledged in scientific literature, with HRmax decreasing and BMI increasing as we move up the age groups. The PC analysis (Figure 3) also shows the relationship between age and volume of weekly PA or weekly running volume, suggesting different training times according to age. According to Table 2, age groups over 31 years run longer weekly ($p < 0.05$), while there are no differences between the age groups for the weekly PA volume ($p > 0.05$).

Nor has any significant correlation been found between BMI and RPE (Table 4). Other authors are in line with the results of our study (Castañer, Saüch, Camerino, Sánchez-Algarra & Anguera, 2015).

RPE and sports habits There are no significant differences in RPE levels among the runners and their relationship with the sports habits or affiliations data collected. Even so, reviewing Table 3, it is noticeable that participants who do not run regularly have higher means than those who do (4.5 ± 1.7 ; 4.2 ± 1.9), and higher than those who do not practise another sport, compared with those who do (4.6 ± 1.8 ; 4.2 ± 1.8). It could be said that those who run or practice a sport regularly have slightly lower means of RPE before a competitive race, but it was not significant ($p > 0.05$). Other studies indicate that there are no significant differences between mean RPE scores when comparing sedentary/amateur and active/trained participant groups (Castro, 2016; Zamunér et al., 2011).

Similarly, it is also worth highlighting the slightly higher means of RPE (Table 3) among runners who train for more than 8 hours per week (5.7 ± 2.5), compete more than 4 times in monthly (4.9 ± 2.4) or those who participate in triathlons (4.9 ± 2.8), a sport that requires a high volume of weekly training its practitioners. Results from other papers show that athletes with higher average RPE values during a season tend to be those who run more kilometres and had higher average concentrations of salivary cortisol (Balsalobre-Fernández et al., 2014). On the other hand, there are significant gender differences in the weekly PA volume ($p < 0.01$) and the number of competitions they participate monthly ($p < 0.01$). In both cases, men have a higher weekly volume of PA and a higher amount of competition participation per month.

RPE and performance variables

About the correlation of the performance variables analysed, final time in the competition ($r = -0.151$, $p < 0.05$) shows a negative correlation with RPE levels (Table 4). And this is also true among the final race time and volume of weekly PA ($r = -0.245$, $p < 0.001$) or weekly running volume ($r = -0.374$, $p < 0.001$). This means that the runners with better results (fastest position, total race time and running pace) had some degree of correlation with the higher RPE levels. These results could, in turn, have a potential relationship with the variable mentioned above, whereby those who engage in a greater volume of training in general would have better results in these performance variables, and therefore higher RPE means, even though they are not statistically significant.

RPE and physiological variables

The PCA shows a grouping between the RPE, HRmax and HRmean (Figure 3). The correlation of the HRmax ($r = 0.223$, $p < 0.05$) indicate that there is a positive correlation with regards to RPE levels (Table 4). Other studies point to RPE correlating strongly with high HR ($r = 0.74$, $p < 0.001$) in Scherr et al. (2013) or mean HR ($r =$ between 0.40 and 0.50) in sports such as Judo, in Arruza et al. (1996). Although there is a positive correlation between HR and RPE levels, researchers suggest that both variables have different temporal adjustments during a medium-distance race (10 km), so that the HR of the runners changed statistically only at the beginning of the 10 km race simulation, while the RPE increased significantly in lap 13 of the athletics track (Bertuzzi, Nakamura, Rossi, Kiss & Franchini, 2006).

Conclusion

The results of our study indicate that there are no significant differences between the RPE of male and female runners. The RPE ratings obtained among the runners in our study could be placed, based on the above estimates, within the 'strong' exertion boundaries close to the Anaerobic Threshold. For age, there is no correlation with RPE levels, although there is a negative correlation with HRmax and positive correlation with BMI, with HRmax decreasing and BMI increasing as we move up the age groups.

There are no significant differences in RPE levels among the runners and their relationship with the sports habits or affiliations data collected. About the correlation of the performance variables analysed, the runners with better results (fastest position, total race time and running pace) had some degree of correlation with the higher RPE levels. The PCA shows a grouping between the RPE, HRmax and HRmean.

It could be concluded that no significant differences have been found between RPE levels and the age, gender, BMI and sports habits of the runners, although higher means of RPE were observed in those with higher running training volumes (at least eight hours per week), and triathlon participants, a sport that requires a high volume of training in those who practise it. The performance variables (final time) and physiological variables (HRmax) analysed show a correlation with RPE levels among the runners.

Conflicts of interest - If the authors have any conflicts of interest to declare.

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References:

- Abe, D., Yoshida, T., Ueoka, H., Sugiyama, K., & Fukuoka, Y. (2015). Relationship between perceived exertion and blood lactate concentrations during incremental running test in young females. *BMC Sports Science, Medicine and Rehabilitation*, 7(1), 5. <https://doi.org/10.1186/2052-1847-7-5>
- Arruza, J. (1996). Estado de ánimo, esfuerzo percibido y frecuencia cardiaca. Un estudio aplicado al judo [Mood, perceived exertion and heart rate. A study applied to judo]. *Revista Española de Educación Física y Deportes*, 3(2).
- Arruza, J., Alzate, R., & Valencia, J. (1996). Esfuerzo percibido y frecuencia cardiaca: El control de la intensidad de los esfuerzos en el entrenamiento de judo [Perceived effort and heart rate: controlling intensity of effort in judo training]. *Revista de Psicología del Deporte*, 5(2), 29-40.
- Astorino, T. A., Sherrick, S., Mariscal, M., Jimenez, V. C., Stetson, K., & Courtney, D. (2019). No effect of meal intake on physiological or perceptual responses to self-selected high intensity interval exercise (HIIE). *Biology of Sport*, 36(3), 225-231. <https://doi.org/10.5114/biolsport.2019.85557>
- Bakhareva, A. S., Aminov, A. S., Cherepanov, V. S., Latypova, E. F., & Stepanov, D. S. (2022). Comparative analysis of perceived exertion and objective physiological standards of load intensity in the exercise test among skilled cross-country skiers. *Journal of Physical Education and Sport*, 22(7), 1799-1803. <https://doi.org/10.7752/jpes.2022.07224>
- Balsalobre-Fernández, C., Tejero-González, C. M., & del Campo-Vecino, J. (2014). Relationships between training load, salivary cortisol responses and performance during season training in middle and long-distance runners. *PloS one*, 9(8). <https://doi.org/10.1371/journal.pone.0106066>
- Bergstrom, H. C., Housh, T. J., Cochrane, K. C., Jenkins, N. D., Zuniga, J. M., Buckner, S. L., Goldsmith, J. A., Schmidt, R. J., Johnson, G. O., & Cramer, J. T. (2015). Factors underlying the perception of effort during constant heart rate running above and below the critical heart rate. *European journal of applied physiology*, 115(10), 2231-2241. <https://doi.org/10.1007/s00421-015-3204-y>
- Bertuzzi, R. C. D. M., Nakamura, F. Y., Rossi, L. C., Kiss, M. A. P. D. M., & Franchini, E. (2006). Temporal independence of perceived exertion response and heart rate in relation to run velocity at a 10 km test simulation. *Revista Brasileira de Medicina do Esporte*, 12(4), 179-183. <https://doi.org/10.1590/S1517-86922006000400003>
- Borg, G. (1985) An introduction to Borg's RPE scale. Movement Publications, Ithaca, New York.
- Castañer, M., Sañich, G., Camerino, O., Sánchez-Algarra, P., & Anguera, M. T. (2015). Percepción de la intensidad al esfuerzo: un estudio multi-method en actividad física [Perception of intensity of effort: a multi-method study on physical activity]. *Cuadernos de Psicología del Deporte*, 15(1), 83-88.
- Castro, T.S.S. (2016). Percepção subjetiva de esforço como um marcador de intensidade de treino em corredores recreacionais [Subjective perception of effort as a marker of training intensity in amateur runners]. *Salão UFRGS 2016: SIC- XXVIII Salão de iniciação científica da ufrgs. Porto Alegre, Brasil*.
- Cerda-Kohler, H., Pullin, Y., & Cancino-Lopez, J. (2015). Efectos del ejercicio de resistencia continuo e intermitente sobre el balance autonómico, la escala de esfuerzo percibido y los niveles de lactato en sangre en sujetos sanos [Effects of continuous and intermittent exercise on autonomous equilibrium, the rating of perceived exertion scale and blood lactate levels in healthy subjects]. *Apunts Medicina de l' Esport (English Edition)*, 50(185), 29-34.
- Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *Journal of sports sciences*, 20(11), 873-899. <https://doi.org/10.1080/026404102320761787>
- Costa, P. D. L., Cabral, L. L., Conde, J. H. S., De Souza, R. O., De Oliveira, F. R., & Osiecki, R. (2020). Perceived exertion threshold predicts the second ventilatory threshold in elite mountain runners. *Journal of Physical Education and Sport*, 20(3), 1272-1278. <https://doi.org/10.7752/jpes.2020.03177>

- Crewe, H., Tucker, R., & Noakes, T. D. (2008). The rate of increase in rating of perceived exertion predicts the duration of exercise to fatigue at a fixed power output in different environmental conditions. *European journal of applied physiology*, 103(5), 569. <https://doi.org/10.1007/s00421-008-0741-7>
- Cuadrado-Reyes, J., Chiroso Ríos, L. J., Chiroso Ríos, I. J., Martín-Tamayo, I., & Aguilar-Martínez, D. (2012). La percepción subjetiva del esfuerzo para el control de la carga de entrenamiento en una temporada en un equipo de balonmano [The subjective perception of effort for the control of training load in a handball team season]. *Revista de psicología del deporte*, 21(2), 0331-339.
- De Koning, J. J., Foster, C., Bakkum, A., Kloppenburg, S., Thiel, C., Joseph, T., Cohen, J., & Porcari, J. P. (2011). Regulation of pacing strategy during athletic competition. *PloS one*, 6(1), e15863. <https://doi.org/10.1371/journal.pone.0015863>
- Dantas, J. L., Doria, C., Rossi, H., Rosa, G., Pietrangelo, T., Fanò-Illic, G., & Nakamura, F. Y. (2015). Determination of blood lactate training zone boundaries with rating of perceived exertion in runners. *The Journal of Strength and Conditioning Research*, 29(2), 315-320. <https://doi.org/10.1519/JSC.0000000000000639>
- Eston, R. (2012). Use of ratings of perceived exertion in sports. *International journal of sports physiology and performance*, 7(2), 175-182. <https://doi.org/10.1123/ijsp.7.2.175>
- Eston, R., Faulkner, J., St Clair Gibson, A., Noakes, T., & Parfitt, G. (2007). The effect of antecedent fatiguing activity on the relationship between perceived exertion and physiological activity during a constant load exercise task. *Psychophysiology*, 44(5), 779-786. <https://doi.org/10.1111/j.1469-8986.2007.00558.x>
- Gros Lambert, A., & Mahon, A. D. (2006). Perceived exertion: influence of age and cognitive development. *Sports Med*; 36(11), 911-28.
- Held, T., & Marti, B. (1999). Substantial influence of level of endurance capacity on the association of perceived exertion with blood lactate accumulation. *International journal of sports medicine*, 20(01), 34-39. <https://doi.org/10.1055/s-2007-971088>
- Iyoho, A. E., MacFadden, L. N., & Ng, L. J. (2015). Prediction of performance reduction in self-paced exercise as modulated by the rating of perceived exertion. *European journal of applied physiology*, 115(4), 675-690. <https://doi.org/10.1007/s00421-014-3054-z>
- Marinov, B., Mandadjieva, S., & Kostianev, S. (2008). Pictorial and verbal category-ratio scales for effort estimation in children. *Child: care, health and development*, 34(1), 35-43. <https://doi.org/10.1111/j.1365-2214.2007.00767.x>
- Montero, F. J. O., Rodríguez, J. F., & García-de-Alcaraz, A. (2018). Influencia de la música y la compañía sobre la percepción del esfuerzo y el estado de ánimo en corredores amateur [Influence of music and company on the perception of effort and mood in amateur runners]. *Cuadernos de Psicología del Deporte*, 18(2), 110-124.
- Muyor, J. M., Vaquero Cristóbal, R., Alacid, F., & López Miñarro, P. Á. (2015). Percepción subjetiva del esfuerzo como herramienta en el control de la intensidad en la actividad de ciclismo indoor [Subjective perception of effort as a tool for controlling the intensity of indoor cycling activity]. *Revista de Psicología del Deporte*, 24(1).
- Noble, B. J., Borg, G. A., Jacobs, I. R. A., Ceci, R., & Kaiser, P. (1983). A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. *Medicine and science in sports and exercise*, 15(6), 523-528.
- Okuno, N. M., Perandini, L. A., Bishop, D., Simões, H. G., Pereira, G., Berthoin, S., Kokubun, E., & Nakamura, F. Y. (2011). Physiological and perceived exertion responses at intermittent critical power and intermittent maximal lactate steady state. *The Journal of Strength and Conditioning Research*, 25(7), 2053-2058. <https://doi.org/10.1519/JSC.0b013e3181e83a36>
- Robertson, R. J., & Noble, B. J. (1997). Perception of Physical Exertion: Methods, Mediators, and Applications. *Exercise and sport sciences reviews*, 25(1), 407-452.
- Rodríguez, I., & Gatica, D. (2016). Perceived exertion during exercise: is their measurement valid in children?. *Revista chilena de enfermedades respiratorias*, 32(1), 25-33.
- Rodríguez, I., Zambrano, L., & Manterola, C. (2016). Validez de criterio de las escalas de medición de esfuerzo percibido en niños sanos: una revisión sistemática y metaanálisis [Validity of criteria used by scales for measuring perceived effort in healthy children: a systematic review and meta-analysis]. *Archivos argentinos de pediatría*, 114(2), 2-3. <https://doi.org/10.5546/aap.2016.120>
- Scherr, J., Wolfarth, B., Christle, J. W., Pressler, A., Wagenpfeil, S., & Halle, M. (2013). Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *European journal of applied physiology*, 113(1), 147-155. <https://doi.org/10.1007/s00421-012-2421-x>
- Seiler, K. S., & Kjerland, G. Ø. (2006). Quantifying training intensity distribution in elite endurance athletes: is there evidence for an "optimal" distribution?. *Scandinavian journal of medicine y science in sports*, 16(1), 49-56. <https://doi.org/10.1111/j.1600-0838.2004.00418.x>
- Tucker, R. (2009). The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. *British journal of sports medicine*,

- 43(6), 392-400. <https://doi.org/10.1136/bjsm.2008.050799>
- World Medical Association [WMA] (2013). Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA* 310, 2191– 2194. <https://doi.org/10.1001/jama.2013.281053>
- Yanci, J., Iturri, J., Castillo, D., Pardeiro, M., & Nakamura, F. Y. (2019). Influence of warm-up duration on perceived exertion and subsequent physical performance of soccer players. *Biology of Sport*, 36(2), 125-131. <https://doi.org/10.5114/biolSport.2019.81114>
- Zamunér, A. R., Moreno, M. A., Camargo, T. M., Graetz, J. P., Rebelo, A. C., Tamburús, N. Y., & da Silva, E. (2011). Assessment of subjective perceived exertion at the anaerobic threshold with the Borg CR-10 scale. *Journal of sports science and medicine*, 10(1), 130-136.