Temporal independence of perceived exertion response and heart rate in relation to run velocity at a 10 km test simulation

Rômulo Cássio de Moraes Bertuzzi[1,2,3], Fábio Yuzo Nakamura[3], Luiz Claudio Rossi[2],
Maria Augusta Peduti Dal'Molin Kiss[2] and Emerson Franchini[2,3]

ABSTRACT

The objective of this study was to investigate pacing strategy, perceived exertion and heart rate during a competitive run simulation. Eight recreational runners ran a 10 km distance in an outdoor 400 m track with 28-30ºC temperature. Before the run they were asked to run the 10 km as faster as possible. The run velocity, the perceived exertion and the heart rate were measured each 400 m. The speed of run decreased on 19th and 20th laps ($p < 0.05$). The heart rate increased significantly on 7th and 10th laps ($p < 0.05$) and achieved steady state afterwards, while the perceived exertion increased statistically until the 13th lap ($p < 0.05$). These data suggest that pacing strategy, perceived exertion and heart rate have different temporal adjustments during a competitive run. Possibly the run strategy is established before the competition simulation and has an economic aspect to the last lap. This economic effect of run strategy is determined until the half of the distance is completed by rate of perceived exertion modulation, which is a result of metabolic, context and cognitive feedbacks.

Keywords: Borg scale. Teleoanticipation. Pacing strategy. Fatigue. Afferent signals.

INTRODUCTION

Due to the low cost and the easiness of access to the practice site, the middle and long distance runs are probably within the most popular kinds of run in athletics. In these competitions, the athletes have the aim to run a certain distance in a period of time shorter than the other competitors' or than a record previously set. Such fact has leaded some researchers to discuss about the main physiological variables that determine the performance of theses athletes. Noakes(1) suggested that part of the events related to the excitement/contraction combination are essential to the success in these competitions, while Basset and Howley(2) relied the athletes' performance to the aptitude of the cardiorespiratory system.

On the other hand, it is known that provided that the middle and long distance runs have duration longer than two minutes, the energy transfer during these tasks is mainly conceived by the oxidative system(3). Moreover, it is believed that independently of the aptitude level of the individuals, the heart rate (HR) is the main responsible for the increase of the cardiac debt in the intensities between 60% and 70% of the maximum oxygen consumption(4). Therefore, the results of some studies pointed to the possibility of the use of the monitoring of the HR to represent the physiological demand in tasks predominantly aerobic(5-7).

Besides the HR, the scale of perceived exertion (PE) presented by Borg(8) has also been widely used in the control(9-10) and in the indirect determination of fulfillment of continuous cycle tasks(11) and intermittent(12) with aerobic predominance. The use of this scale is based on the premise that the physiological adjustments promoted by the physical stress produce measurable sensory signals which are able to alter the subjective perception of exertion. It is supposed that the PE processing is given by the interaction of multiple measurable signals come from the cardiorespiratory(12-13) and neuromuscular systems(14). However, Rejeski and Ribisl(15) demonstrated that the PE response can be dissociated from the exercise intensity when the individuals have some kind of information about the time of duration of the task. Furthermore, recent evidence has suggested that the muscular power and PE adjustments suffer influence of a model of anticipation program called teleoanticipation(16-17).

According to Lambert *et al.*(17), the teleoanticiaption is a result of complex interactions between the past and current cognitive and contextual metabolic feedback, which determine the rhythm to be applied in a given task, with the aim to early avoid the triggering of the physiological processes responsible for fatigue. Therefore, it is probable that the performance of middle and long distance runners does not depend only on the metabolical potential, but mainly on the elaboration of the pacing strategy (PS) adopted, with the objective to be more efficient(18).

It is relevant to highlight that the great majority of the experimental outline of the mentioned studies consisted of laboratory or field tasks which had the intensity, duration and environment control, while in the real situation of the sport practice the athletes self- select the applied rhythm and are constantly exposed to different types of internal and external feedback. Consequently, the aim of the present work was to analyze the PS, HR and PE behavior during the simulation of a 10 km run, in which the runners were asked to complete this distance in the shortest period of time as possible.

METHODOLOGY

Subjects

Eight recreational male runners participated in this study after reading and signing the informed consent term, which was previously approved by the local Ethics Committee. All subjects have trained for at least three years, with a minimum frequency of four days per week and have regularly participated in local competitions. The main characteristics of the runners are present in table 1.

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1. Grupo de Pesquisas em Fisiologia do Exercício – FEF – Universidade Presbiteriana Mackenzie.
2. Laboratório de Desempenho Esportivo – EEFE – Universidade do Estado de São Paulo.
3. Grupo de Estudo das Adaptações Fisiológicas ao Treinamento – GEAFIT – Universidade Estadual de Londrina.

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Correspondence to: Rômulo Cássio de Moraes Bertuzzi, Rua Clorindo de Oliveira Café, 91, Jd. Nelly, Butantã – 05371-140 – São Paulo, SP. E-mail: bertuzzi@usp.br

TABLE 1
Chronological age and anthropometrical variables of the recreational runners (n = 8)

Age (years)	17 ± 1
Total weight (kg)	59,0 ± 8,7
Height (cm)	171,2 ± 8,2
Tricipital skinfold (mm)	8 ± 2
Subscapular skinfold (mm)	10 ± 2
Abdominal skinfold (mm)	13 ± 6
Σ of the skinfolds (mm)	31 ± 10
Body fat percentage (%)	7,6 ± 0,7

The values are averages ± standard deviation

Anthropometrical measures

The total body weight was measured by means of a mechanical scale (Filizola®, Brazil). The measurement of the suscapular, tricipital and abdominal skinfolds was done three times in a rotation system, according to the standardization recommended by the International Society for the Advancement of Kinanthropometry(19) CESCORF dividers with 1 mm precision were used to take these measures, being adopted the values of the respective medium lines to represent them. The body density was estimated by the equation presented by Lohman(20), while the body fat percentage was estimated by the equation proposed by Siri(21).

10 km run

The simulation of the 10 km run was conducted in an athletics track with official dimensions. Such track was surrounded by concrete structures (locker rooms, for instance) and trees that would hamper the wind flow. Besides that, during this simulation the temperature varied between 28°C and 30°C.

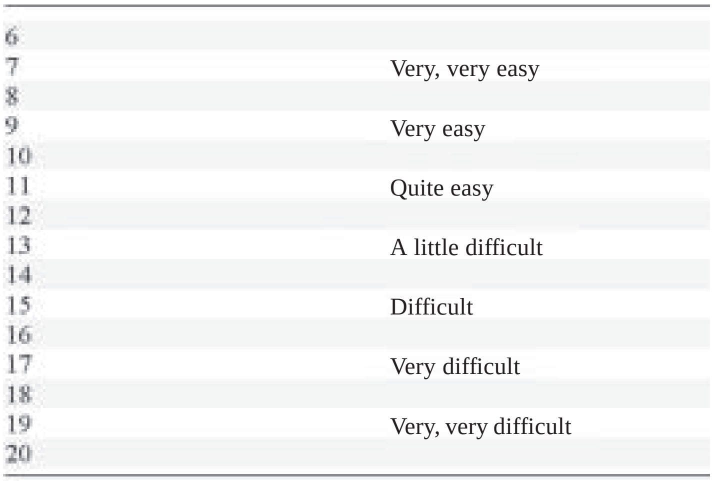
The individuals were asked not to do any vigorous training or drink alcohol in the 72 h prior the development of this investigation. The subjects were also asked not to ingest food with caffeine and to have their last meal at least 2 h prior the test simulation. The data collection was conducted in times close to the ones when the individuals were used to train.

After the general instructions which involved the study, the subjects were asked to run the 10 km distance in the shortest time as possible. The runners went off in two groups with four individuals each. The total and partial time in each 400 m lap was individually measured through a manual timer brand name Casio (HS 50 W, Japan). The PS was established in relation to the average velocity ($\bar{\upsilon}$) which the individuals kept in the 400 m partial runs [$\bar{\upsilon}$ ($m \cdot s^{-1}$) = 400 m/partial time (s)].

The monitoring of the heart rate during the 400 m partials was conducted through frequency meters brand name Polar (A1 model, Finland). The measurement of the PE was conducted through the 15 points scale presented by Borg (1982), which was previously translated to Portuguese (figure 1). The copies of this scale were laminated and reduced to 10 cm of length by 5 cm of width, being later tied close to the wrist of the dominant lower arm of the individuals. Before the beginning of the simulation of the test, it was shown to the runners how the PE should be reported. The reproducibility of the measurement of the PE in progressive test or of constant load in athletics track has been already demonstrated(22).

Statistical analysis

The data were statistically analyzed through the computerized program SPSS (10.0 version) and later presented in averages ± standard deviations. The level of association among the average velocity, the heart rate and the perceived exertion was verified through the *Pearson* correlation coefficient. The comparison of the heart rate response, of the perceived exertion and the average velocity during the 400 m laps was conducted through the variance analysis with repeated measures to a factor (lap), followed by the test for multiple comparisons by Bonferroni. The significance level of 5% was adopted for all analyses (p < 0,05).



6	
7	Very, very easy
8	
9	Very easy
10	
11	Quite easy
12	
13	A little difficult
14	
15	Difficult
16	
17	Very difficult
18	
19	Very, very difficult
20	

***Figure 1** – Fifteen points-scale of the perceived exertion translated to Portuguese*

RESULTS

The main results are in table 2 and are graphically presented in figure 2. Both the HR (r = –0,53; p = 0,006) and the PE (r = –0,60; p = 0,001) negatively correlated with the $\bar{\upsilon}$, while the HR positively correlated with the PE (r = 0,44; p = 0,027). As one can observe, the $\bar{\upsilon}$ of the second lap was statistically lower than the 19th (F = 6,041; p < 0,05) and the 20th (F = 6,041; p < 0,05) laps. Only the HR response of the 2nd lap was significantly lower than the 7th (F = 6,476; p < 0,05) and the 10th (F = 6,476; p < 0,05) laps. The PE statistically changed up to approximately half of the test, since in the 1st and the 2nd laps the values were statistically lower than in the 11th, 13th, 16th, 17th, 18th, 19th, 20th, 21st, 22nd, 23rd, 24th and 25th laps (F = 35,446; p < 0,05). In the 3rd lap the PE was also significantly lower than the 13th, 17th, 18th, 19th, 20th, 21st, 22nd, 23rd, 24th and 25th laps (F = 35,446; p < 0,05). The PE responses in the 4th, 5th, 6th, 7th and 8th laps were again lower than the 18th, 19th, 20th, 21st, 24th and 25th laps (F = 35,446; p < 0,05). Likewise, the PE of the 9th, 10th and 11th laps was lower than the 18th, 19th and 24th laps (F = 35,446; p < 0,05). In the 12th lap the PE was still lower when compared to the 20th and 21st laps (F = 35,446; p < 0,05). Finally, the PE response in the 13th lap was lower than in the 18th, 19th, 20th and 24th laps (F = 35,446; p < 0,05).

TABLE 2
Averages and standard deviation of time, velocity, heart rate and of perceived exertion during the 10 km test simulation (n = 8)

Time (min)	44 ± 2
Average velocity ($m \cdot s^{-1}$)	3,8 ± 0,2
Average velocity ($km \cdot h^{-1}$)	13,8 ± 0,6
Heart rate (bpm)	185 ± 4
Subjective exertion scale (score)	14 ± 2

DISCUSSION

As far as we are concerned, this is the first study to analyze the acute adjustments promoted in the PE and in the HR due to the PS adopted by the runners during a situation specific to the middle distance run. Commonly, the experimental outlines of the studies which also analyzed such variables as a whole were structured with laboratory tasks that allowed the control of other variables which can interfere in the response of the perceived exertion and the HR(8).

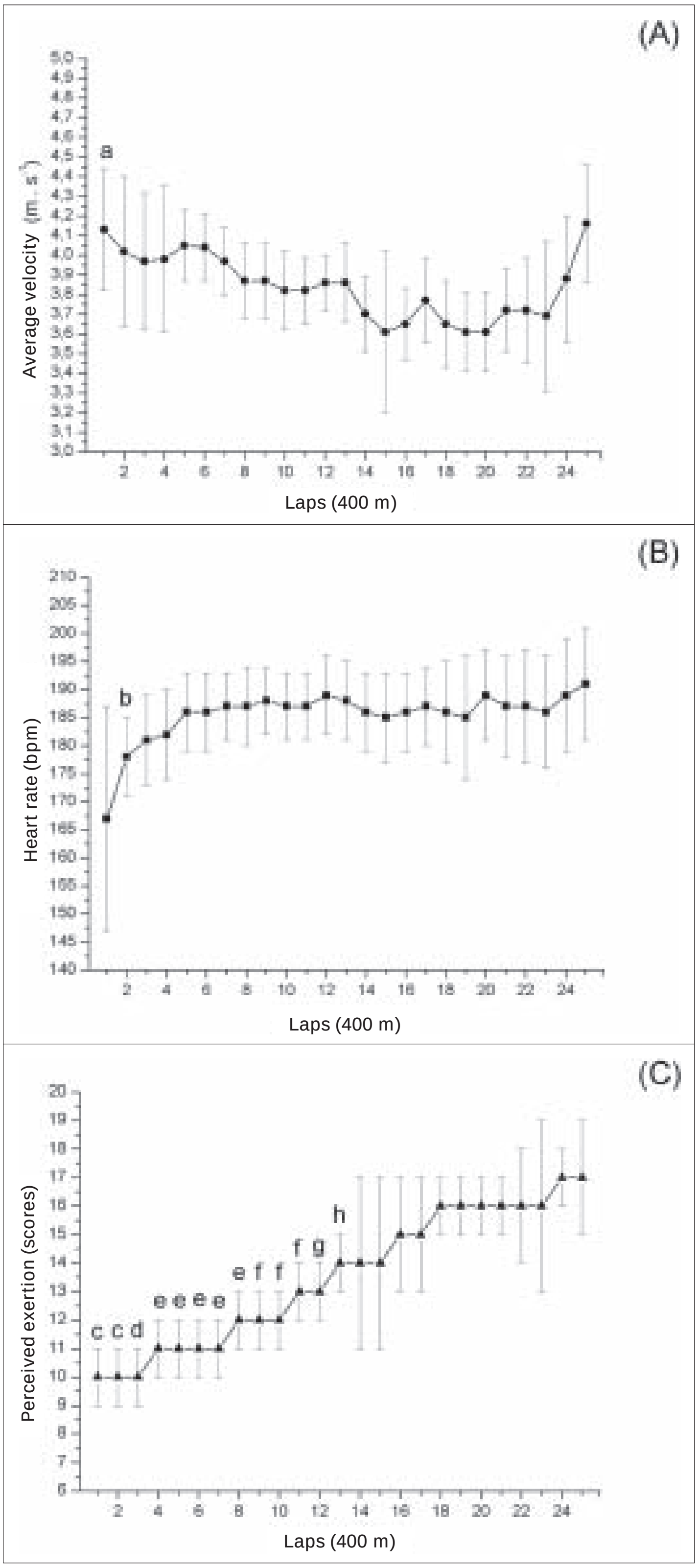


***Figure 2** – Behavior of the running strategy **(A)**, of the heart rate **(B)** and of the perceived exertion **(C)** during the 10 km simulation test (n = 8)*

The values are averages ± standard deviations. a = significant difference of the 19th and 20th laps; b = significant difference of the 7th and 10th laps; c = significant difference of the 11th, 13th, 16th, 17th, 18th, 19th, 20th, 21st, 22nd, 23rd, 24th and 25th laps; d = significant difference of the 13th, 17th, 18th, 19th, 20th, 21st, 22nd, 23rd, 24th and 25th laps; e = significant difference of the 18th, 19th, 20th, 21st, 24th and 25th laps; f = significant difference of the 18th, 19th and 24th laps; g = significant difference of the 20th and 21st laps; h = significant difference of the 18th, 19th, 20th and 24th laps. Significance level of 5% (p < 0,05).

In other sports predominantly aerobic, especially in rowing[(23)], it has been suggested that the ideal PS determination can have direct implications in the maximization of the performance of the athletes. Garland[(23)] observed that rowers champions in the 2000 m international competitions tended to do the first 500 m in the highest average velocity of the competition, however, a reduction of approximately 2% in the remaining 1500 m is common to be observed. According to Garland[(23)], despite the mentioned strategy potentializing of the processes that trigger the acute muscular fatigue, it seems the athletes tactically benefited, since they were in positions that allowed the monitoring of their opponents‘ boats. This is possible since in such sport, the athletes row facing the exit site. In the present study, the runners also started the 10 km simulation in the highest $\bar{\upsilon}$ of the whole distance, however, later, especially in the 20th lap, they expressively reduced the applied rhythm up to 13%. Moreover, close to the end of the test, the individuals increased again the applied rhythm, surpassing the velocity of the first lap. Therefore, it is clear that recreational runners adopt as PS a great reduction of the velocity during the run as a saving agent for a possible final sprint.

It is possible that in the middle and long distance competitions the PS of the runners is mainly determined by the aerobic capacity when we admit that the average velocity of the 4 mM lactate threshold of recreational runners is of approximately 14,3 km h^{-1}[(24)], which would be similar to the one in the present study (≅ 13,8 km • h^{-1}). Possibly, the influence of the aerobic capacity in the PS is due to the fact that the supra threshold velocities induce the increase in the production of lactate[(25)], which would be related to the increase of the cell acidosis and, consequently, to acute muscular fatigue[(26)]. Thus, it is probable that the recreational runners have constantly adjusted the $\bar{\upsilon}$ in a manner inverse to the contribution of the glycolytic system, at least up to the one before the last lap. It is known that with the participation of the glycolytic system in protocols with continuous load, an increase of the PE proportional to the anaerobic mobilization rate is observed [(11)]. However, such discourse should be cautiously interpreted, since in the present investigation no measurement of this physiological variable was taken.

The correlation inversely proportional detected between the HR and the $\bar{\upsilon}$ shows that, besides the aerobic ability, the stress of the cardiovascular system can be another variable that shapes the PS via central nervous system. Our results corroborate part of the hypothesis presented by Noakes *et al.*[(27)], who suggested that the limitation of physical exercise is given by a theoretical model called ‘Central Governor’. In this model, one assumes that the chimioreceptors placed in the myocardium would send inhibiting signals to the central nervous system before the maximum heart’s capacity is reached. Such fact would result in the reduction of the neural commands to the skeletal muscle, with the aim to avoid the ischemic response of the myocardium. The increase of the maximum HR and the maximum cardiac debt itself identified in exercise under hyperoxia, and the inverse response, under laboratory induced-hyperoxia, is an evidence for this hypothesis. On the other hand, the increase of the HR during physical exercise has been commonly attributed to the increase of the metabolic demand imposed by the task’s intensity[(6-7)]. However, during the 10 km, the HR had its first significant increase only from the seventh lap (approximately 12 minutes) and remained high until the end of the test, while the highest $\bar{\upsilon}$ was detected in the beginning of the run, followed by an expressive reduction in the simulation According to Achten and Jeukendrup[(5)], the HR response during the physical exercise can also be influenced by various extrinsic factors, among them, the environmental temperature and the hydration of the individuals. Nevertheless, the great majority of studies collected by Achten and Jeukendrup[(5)] used the environmental temperature above 35ºC and the reduction of approximately 5% of the body weight. Hence, it is probable that such variables have little influenced in the HR response during the simulation, once that besides the individuals being instructed not to ingest food that could induce the hypo hydration, the environmental temperature has always been below 35ºC.

Such idea is reinforced by the results of the study by Boudet *et al.*(28), in which no significant correlation between the HR response and the weather conditions in competitions of street running was obtained. Somehow, these findings can indicate that during the middle and long distance run competitions, the monitoring of the HR can be an inefficient index for the monitoring of the intensity of the exertion in these situations.

Concerning the PE, it has been widely associated to a process of sensory interaction of the physiological adjustments originated from the metabolic demand imposed by the physical exertion(8,11,22). However, information about the main physiological stimuli (central or peripherical) is still inconclusive. For instance, Noble *et al.*(14) observed that the increase of the perceived exertion is accompanied by the increases of the blood and muscular lactate concentrations. On the other hand, the results of the studies collected by Robertson(13) showed that the adjustments of the perceived exertion are mediated by the HR increases, the pulmonary ventilation, the respiratory quotient and the oxygen consumption.

In the present study though, the $\bar{\upsilon}$ and the HR of the runners statistically changed only at the beginning of the simulation of the 10 km test, while the PE significantly increased up the 13th lap. It is believed that the PE response has also been modeled by the interaction of the cognitive and contextual factors that constitute the teleoanticipation(17), which, in that occasion, was triggered by the intention to exercise at one's peak in an objective with a set distance. Thus, through the experiences and the current context evaluation (temperature, internal conditions), the teleoanticipation would guide the increase rate of the perceived exertion, which would remain in bearable levels so that the 10 km distance could be fulfilled in the shortest possible time, causing the end of the test to agree with the values of PE close to the maximum. It means that a new interpretation of the relation between indicators of overload (mechanical and physiological) and the exertion perception in situations of set objective and variable strategy. The PE would be an independent variable and the run velocity a dependent variable, inverting the given idea about conducting rectangular and/or progressive tests. The teleoanticipation and the consistency of the control of exercise intensity through the PE in a 20 km sprint simulation in cycling was experienced in the results presented by Tucker *et al.*(29). They showed that the central temperature measured at each 5 km was similar during almost the entire distance under external temperature of 35°C (hot) or 15°C (cold), except for the last measure, which was at the end of the simulation, which favored higher increase under 35°C. The average time to complete the 20 km in hot weather (29,6 ± 1,9 min) was lower than the time spent in the cold weather (28,8 ± 1,8 min), and the average power presented inverse standard (255 ± 47 W *versus* 272 ± 45 W). The point differences in the mechanical power within the different external conditions were more evident and statistically significant during the final part of the simulation (80-100% of the total duration). The highest average power kept in the conducted test in cold weather was accompanied by bigger electromyographic activity, showing that in hot situations the neuromuscular activation was reduced from 10 km. Despite the differences in the neuromuscular activity, the PE showed similar behavior to the increase under the influence of external temperatures. Therefore, the reduction of the lectromyographic activity prior to any radical changes in the central temperature seems to be related to mechanisms of central control, which would avoid severe and irreversible perturbations in the thermoregulation. Probably, the PE evolution, projected from the beginning to the end of the 20 km simulation, through the sensory feedback mechanisms and through influence of the teleoanticipation itself, may have modeled the strategy of neuromuscular activation and consequently, the mechanical performance itself. Once again a situation where the PE would be placed as independent variable is faced. The PE would model the strategy adopted to complete the distance as well.

According to Lambert *et al.*(17), the individuals previously program the running strategy that will be adopted in order to prevent the premature development of fatigue, which would lead to a time dissociation among the perception of exertion, the heart rate and the external power generated. Moreover, Gibson *et al.*(30) suggested that the processing of the perceived exertion is also altered by cognitive signals, such as the memory of a training session previously conducted and the motivation at the moment of the task. Thereby, we believe that differently from other studies in which there was the control of contextual variables that may interfere in the PE(9,11,22), the intention to exercise to the limit in real situations of sports practice, leads to a time dissociation of the PE with the HR and with the exercise intensity.

CONCLUSIONS

The results of the present study pointed to a time dissociation between the PE and the HR due to the PS adopted by recreational runners during the simulation of a middle distance run. It was proposed that the intention to exercise to the limit is determined before the beginning of the task. However, it is modeled up to the half of the test through a physiological, contextual and cognitive process of retro alimentation Such intention functions as a saving agent for a possible increase in the velocity close to the end of the test, which induces the differentiated response commonly presented between the PE and the HR in the studies that used tasks with bigger control of these variables. It has also been suggested that the HR is a physiological index not very sensitive in the determination of the run intensity in middle distance. On the other hand, other works should be elaborated in order to investigate the influence of the aerobic aptitude level and different kinds of feedback in the PS, PE and HR during the situations that are close to the 10 km tests.

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