
Psychophysiological changes in uphill runners

Ramiro Doyenart,
Daniel Boeira da Silva,
Renato Schardosim da Silva,
Leandro Dal Ponte,
Anand Thirupathi,
Luciano Acordi da Silva.

Abstract

The increasing popularity of street racing combined with the psychophysical demands of racing competitions present new challenges for runners and trainers. The objective of this study was to investigate psychophysiological changes after an uphill race. Twenty-three runners were recruited, eleven men (35 ± 5.6 years; 1.7 ± 0.2 m; 76.6 ± 10 kg; $11.5 \pm 4.5\%$ fat) and twelve women (39 ± 9.2 years; 1.61 ± 0.1 m; 58.8 ± 3.8 kg; $20.1 \pm 3.1\%$ fat), who participated in an uphill race (distance 24.6 km, altimetry 2142 m, slope 11%, temperature 13°C, humidity 97%). Every runner was submitted to evaluations, psychophysiological and muscular strength, before and after of the race. After an uphill race, there was a significant decrease ($p < 0.05$) in muscle resistance (22%) (95% CI) 0.21 (0.041–1.12), power (27%) (95% CI) 0.64 (0.062 to 1.22) and force (30%) (95% CI), 0.078 to 1.06). There was a significant ($p < 0.05$) increase in lactate levels (100%) (95% CI) 0.77 (0.034–1.37) and perceived exertion (200%) (95% CI) 0.63 (0.104–1.25) accompanied by a significant reduction in competitive anxiety of 10% ($p < 0.05$) (95% CI) 0.81(0.038–1.19). We conclude that after an uphill race there is a significant increase in the alterations in the psychophysiology of runners.

KEYWORDS: Running, Mental Health, Psychophysiology.

Alterações psicofisiológicas durante uma corrida de subida em corredores de rua

Ramiro Doyenart, Daniel Boeira da Silva, Renato Schardosim da Silva, Leandro Dal Ponte, Anand Thirupathi, Luciano Acordi da Silva.

Resumo

A crescente popularidade das corridas de rua combinadas com as exigências psicofísicas das competições de corridas apresentam novos desafios os corredores e treinadores. O objetivo deste estudo foi investigar alterações psicofisiológicas após uma corrida de subida (uphill). Foram recrutados vinte e três corredores, onze homens ($35 \pm 5,6$ anos; $1,7 \pm 0,2$ m; $76,6 \pm 10$ kg; $11,5 \pm 4,5\%$ de gordura) e doze mulheres ($39 \pm 9,2$ anos; $1,61 \pm 0,1$ m; $58,8 \pm 3,8$ kg; $20,1 \pm 3,1\%$ de gordura), que participaram numa prova uphill (distância 24,6 km, altimetria 2142 m, inclinação 11%, temperatura 13°C e humidade 97%). Avaliações psicofisiológicas e musculares foram realizadas antes e depois da prova. Após a prova, houve uma diminuição significativa ($p < 0,05$) na resistência muscular (22%), potência (27%) e força (30%). Houve um aumento significativo ($p < 0,05$) nos níveis de lactato (100%) e no esforço percebido (200%), acompanhado isto de uma redução significativa na ansiedade competitiva de 10% ($p < 0,05$). Concluímos que após uma prova de corrida uphill houve alterações significativas dos parâmetros psicofisiológicos dos corredores.

Palavras-chave: Corrida, Força Muscular, Psicofisiologia.

Alteraciones psicofisiológicas durante una corrida cuesta arriba en corredores

Ramiro Doyenart, Daniel Boeira da Silva, Renato Schardosim da Silva, Leandro Dal Ponte, Anand Thirupathi, Luciano Acordi da Silva.

Resumen

La popularidad de las carreras, combinada con las exigencias psicofísicas de las competiciones, plantea nuevos retos para corredores y entrenadores. Este estudio investigó los cambios psicofisiológicos después de una carrera cuesta arriba. Metodológicamente, once hombres ($35 \pm 5,6$ años; $1,7 \pm 0,2$ m; $76,6 \pm 10$ kg; $11,5 \pm 4,5\%$ de grasa) y doce mujeres ($39 \pm 9,2$ años; $1,61 \pm 0,1$ m; $58,8 \pm 3,8$ kg; $20,1 \pm 3,1\%$ de grasa), participaron en una carrera cuesta arriba (uphill) (distancia de 24,6 km, altimetría de 2142 m, pendiente del 11%, temperatura de 13°C y humedad del 97%). Se realizaron evaluaciones psicofisiológicas, e musculares antes y después de la carrera. Finalmente, disminuyeron ($p < 0,05$) la resistencia muscular (22%), la potencia (27%) y fuerza (30%); y aumentó ($p < 0,05$) el lactato (100%) y el esfuerzo percibido (200%), acompañado de una reducción significativa de la ansiedad competitiva del 10% ($p < 0,05$). Concluimos que después de una prueba de carrera cuesta arriba se produjeron cambios significativos en los parámetros psicofisiológicos de los corredores.

Palabras-clave: Carrera, Fuerza Muscular, Psicofisiología.

Introduction

It is clear that there has been an increase in the number of street racing in the last decade (Alvero-Cruz et al., 2019; Gómez-Molina et al., 2017; Knechtle & Nikolaidis, 2018). Comparing worldwide scenario, studies suggest that the half-marathon is the event with the highest adherence of amateur runners, achieving increases in the order of 23% in the USA and 26% in some European countries (Alvero-Cruz et al., 2019; Gómez-Molina et al., 2017; Knechtle & Nikolaidis, 2018). In Brazil, half-marathons follow the world trend, gaining 25% of supporters in recent years (Balbinotti, Gonçalves, Klering, Wiethaeuper & Balbinotti, 2015).

In this sense, several variations of street racing, such as cross-country, uphill, and downhill running, have emerged (Costa, Knechtle, Tarnopolsky & Hoffman, 2019; Lemire et al., 2019; Scheer et al., 2020; Vernillo et al., 2017). These variations are intended to demand maximum physical and mental resistance of participants on different terrains, altimetry, and competitive levels (Costa et al., 2019; McCormick, Meijen, & Marcora, 2016; Samson, Simpson, Kamphoff & Langlier, 2015).

In science, sports psychophysiology seeks to study the interrelationships between brain and body that occur during the practice of this sport, from physical or psychological stress stimuli, which, in a vicious cycle, alter neuromuscular and mental responses (Bigliassi, León-Domínguez, Buzzachera, Barreto-Silva & Altimari, 2015; Lee & Kimmerly, 2016; McCormick, Anstiss, & Lavallee 2018). According to Ohrnberger, Fichera and Sutton (2017), This is important in the sports world. Also, the International Society of Sport Psychology points out that psychophysiological wellbeing should be preserved in runners because it is an important resource for sport and life after sport (Henriksen et al., 2019).

However, the psychophysiological responses of runners in extreme conditions have been little studied, and the condition is mainly caused by difficulties in the accessibility of the sample and the experimental procedure in these conditions (Chang et al., 2020; Nikolaidis & Knechtle, 2018; Rousanoglou et al., 2016).

There is evidence to demonstrate that excessive exercise combined with competitive pressure can negatively affect the psychophysiology of individuals (Chang et al., 2020; Henriksen et al., 2019; Kruk et al., 2020; Mikkelsen, Stojanovska, Polenakovic, Bosevski & Apostolopoulos, 2017). Data from the American Society of Sports Medicine states that the psychophysiological wellbeing of long-distance runners is related to the ability to deal with the emotions that naturally arise before and during an event (Chang et al., 2020). Furthermore, according to him, rigorous competitions can cause emotional problems that, if left untreated, can lead to mental health disorders (Chang et al., 2020).

In this sense the uphill race consists of a race with 1419 metres of elevation, maximum elevation gain of 2142m, 58.9% maximum positive gradient, 24.6km distance and a total of 284 closed asphalt turns. Such unique characteristics, can amplify the size of the psychophysiological effect and consequently increase the physical and mental exhaustion of amateur runners. Perhaps, this race may be the most demanding and challenging in Brazil for amateur runners.

Therefore, this study aims to investigate the changes in the psychophysiological parameters of runners submitted to an uphill race. To the present moment, to our knowledge, this is the first Brazilian study that investigated these parameters, in this specific model of race in amateur runners.

Method

Study design and participants

This was a quantitative cross-sectional study, with amateur runners submitted to an uphill race competition and voluntarily analyzed by pre- and posttest. This study was conducted in accordance with Resolution 466/12 of the National Health Council (CNS) and approved by the Ethics Committee of the University of Extremo Sul Catarinense with the CAAE protocol: 18982719.1.0000.0119. All participants signed the informed consent form.

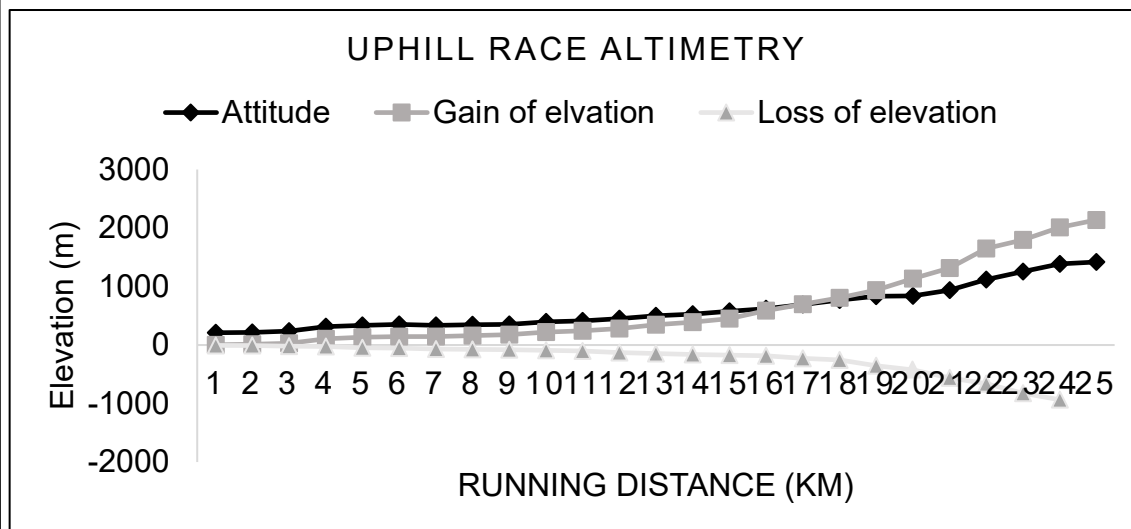
Participants

The criterion used to randomize the sample was of non-probabilistic convenience (Silva et al., 2019) using inclusion and exclusion criteria. From an original list of 40 runners (running for more than 3 years), 23 adults who usually ran long distances (weekly training volume between 35 and 42Km) were selected and included in the study and allocated to a single group. Inclusion criteria were: 1) aged more than 18; 2) trained for more than 1 year; 3) have run at least one half-marathon race. Exclusion criteria were: 1) having suffered some joint muscle injury in the previous 3 months; 2) having clinical evidence of cardiovascular diseases; 3) having never completed a race of, at least, 21 km; 4) having not completed an uphill race in less than 4 hours.

Twenty-three adult runners participated in the study: 11 were male (35 ± 5.6 years; 1.7 ± 0.2 m; 76.6 ± 10.1 kg) and 12 were female (39 ± 9.2 years; 1.61 ± 0.1 m; 58.8 ± 3.8). The nutritional status of the corridors was calculated by the body mass index (BMI) (World Health Organization, 1995). The percentage of fat was determined using the protocol of Jackson and Pollock (1978) for men and of Jackson, Andrew, Pollock and Ward (1980) for women. The maximum heart rate (HR) was obtained through the proposal of Tanaka, Monahan and Seals (2001).

On the uphill race in Santa Catarina, is composed of three different races, in female and male categories: the uphill-ultramarathon (67 km), the uphill-marathon (42 km), and an uphill-25 km race (24.6 km). It is the last one which was the object of the present study. The race was held between late afternoon (16h) and early evening (20h), had an altitude of 1419m, gain of elevation of 2142m, loss of elevation of 935m, average positive and negative slope in the order of 11% and 7.9%, respectively, and maximum positive and negative slope of 59% and 52%, respectively. In total, there were 284 asphalt curves, and during the test, the temperature was 13°C, relative air humidity 97%, winds up to 9.6km/h, and rainfall 8.6mm. Race started in Lauro Muller city (209 m altitude) and finished in Bom Jardim da Serra (1419 m altitude). From a total of 10.000 pre-registered runners, 1400 were raffled to participate in an uphill race. Every runner included in this study was oriented to complete the 24.6 km in the best possible time, having as cutoff points the

seventh kilometer under 50 minutes, and the arrival under 4 hours. Ten points of hydration, 2 points of fruit and isotonic, and 4 points of medical assistance were distributed all along the route. Corridors were freely supplied at each point (Figure 1).



Note: Analysis of the altimetry of the uphill race in the Serra do Rio do Rastro

Figure 1. Altimetry of the climbing race

Instruments

Each runner was equipped with individually updated Garmin® brand watches with anthropometric information to collect the variables: Resting HR, Maximum HR, Final HR, Average HR, pace measured in minutes per kilometer (min/km) and speed in kilometers per hour (km/h), caloric expenditure (kcal), and race time (min). To relate the percentage of HR maximum to the percentage of maximum oxygen consumption (VO₂max), the proposal of Marion, Kenny and Thoden (1994) was applied. Blood glucose was quantified by the self-monitoring method, using the G.Teche glycolometer. Lactate was measured by the lactate dosage method using the Accutrend GCT lactate meter.

The neuromuscular tests were performed in this order: manual, scapular, and lumbar force (dynamometer), lower limbs resistance (stand up and sit in the chair), and lower limbs power (horizontal thrust). For manual strength, a Jamar® dynamometer was used to quantify the strength in the dominant hand, adjustable, and calibrated with a scale from 0 to 100 kgf, according to the guidelines of the American Society of Hand Therapists (Crosby & Wehbé, 1994). Each runner sat down with his shoulder abducted and his elbow flexed 90°, with forearms in neutral position and wrists extended between 0° and 30°. In the lumbar traction force, runners were oriented to stand on the dynamometer platform with knees and torso slightly bent, and the dynamometer handle was adjusted in the height of the apex of the patella so that the rider could hold it with both hands and elbows extended (Doyenart et al., 2020). In the traction force of the scapular waist, the analog scapular dynamometer with scale from 0 to 100 kgf was used. The evaluators were oriented to remain in the orthostatic position, shoulders abducted, elbows flexed, forearms in neutral position, and thumbs extended (Doyenart et al.,

2020). The power of lower limbs (horizontal thrust) was measured by placing each runner at the starting point (zero line of the tape measure fixed to the ground) with feet parallel and separated at hip width. At a voice command, the evaluated person performed the jump with free contribution of the arms, followed by a simultaneous impulse from the knees bending, to reach the furthest point possible. The measurement was made between the starting point and the heel of the foot closest to the starting point (Yanci, Los Arcos, Castillo & Cámara 2017). The muscle resistance of lower limbs using the test of stand up and sit in the chair, proposed by Rikli & Jones (2008). The test starts with the rider sitting in the middle of the chair, with straight back, feet separated at shoulder width and fully supported on the ground. One foot should be slightly advanced in relation to the other to help in maintaining balance. The upper limbs are crossed at the level of the wrists and against the chest. At the "start" sign, the participant rises to the maximum extension (vertical position) and returns to the initial sitting position. The participant is encouraged to complete the maximum number of repetitions in a 30-second interval (Rikli & Jessie, 2008).

The competitive state anxiety inventory (CSAI-2) validated for the Brazilian population was applied (Coelho, Vasconcelos-Raposo, & Mahl, 2010). This tool measures the state of cognitive anxiety (insecurity about performance), somatic (physiological anxiety symptoms) and self-confidence (positive feelings about performance), with 17 questions, each question presenting four possible answers: 1—nothing, 2—a little, 3—moderate, 4—a lot, being 68 points the maximum result.

Procedures

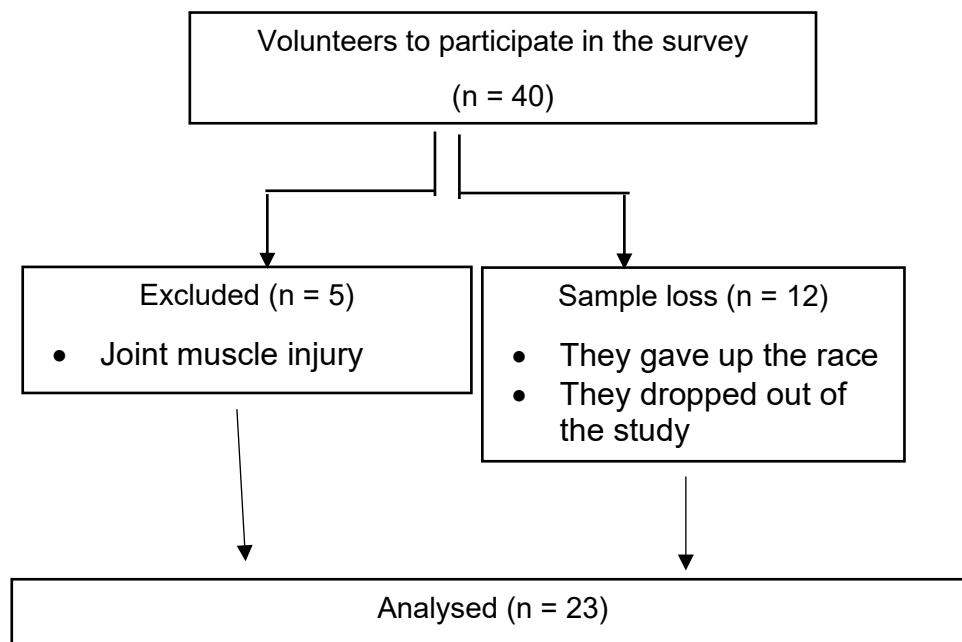
All corridors became acquainted with inventories, tests and blood collections. The first data collection took place 7 days before the test. At race day, 1 hour before starting time, the collection of lactate, glucose, body temperature, and HR at rest was performed. Immediately after the end of the race, respecting finishing order, the same physiological collections, competitive inventory and strength tests were applied following this sequence. Information from clocks was the last to be collected.

Data analysis

The research variables were analyzed by SPSS software version 20 using as mean and standard error. The Shapiro–Wilk test was used to assess normality. Based on which, the data were not normally distributed and thus, nonparametric test (Wilcoxon) were used to compare the pre-test and post-test results. The established significance level for the statistical test is $p < 0.05$. The effect size was calculated (Cohen's $d = 0.29$), and determine the magnitude ES (95% CI).

Results

From a list of 40 endurance runners enrolled in the uphill race, provided by the main race groups of the cities of Criciúma and Içara, 5 were excluded due to joint muscle injury, and 12 were considered losses for giving up the race or research. In total, 23 amateur runners were analyzed (Figure 2).



Note: Flowchart of the randomization process

Figure 2. Flowchart

The race started with 1500 runners, 84% of them finished in less than 4h. Of the 23 runners analyzed in this study, 100% finished the race in 4h.

Eleven men (48%) and 12 women (51%), aged 30 to 40, participated in the study. Regarding body composition, both sexes indicated low subcutaneous adiposity ($11 \pm 4.5\%$ men; $20 \pm 3\%$ women) and body mass index ($25 \pm 3 \text{ kg/m}^2$ men; $20 \pm 3 \text{ kg/m}^2$ women). Regarding training indicators, weekly training frequency was 4 ± 1 days a week, daily distance was $11 \pm 3.9 \text{ km}$, training duration $76 \pm 22 \text{ min}$, and practice time 3 ± 1.3 years. Regarding professional orientation of runners, 61% reported to be orientated by a physical education professional, while the remaining 35% and 4% have only the running group experience or none orientation (Table 1).

Table 1. Description of the population

VARIABLE		RUNNERS (N=23)	
Anthropometric characteristics	Gender	Male (n=11)	Female (n=12)
	Age (years)	35 ± 5.6	39 ± 9.2
	Body Mass (Kg)	76.6 ± 10.1	58.8 ± 3.8
	Stature (m)	1.7 ± 0.2	1.61 ± 0.1
	BMI (Kg/m ²)	24.7 ± 3.1	22.5 ± 1.1
	% Fat	11.5 ± 4.5	20.1 ± 3.1
Training indicators	Weekly frequency	4 ± 1.1	
	Km of daily training	10.5 ± 3.9	
	Minutes of daily training	75.7 ± 22.2	
	Years of practice	3 ± 1.3	
It has guidance	Physical Education Professional	61%	
	Racing group	35%	
	No guidance	4%	

Note: BMI = body mass index; HR = heart rate. The values are presented as average ± SD.

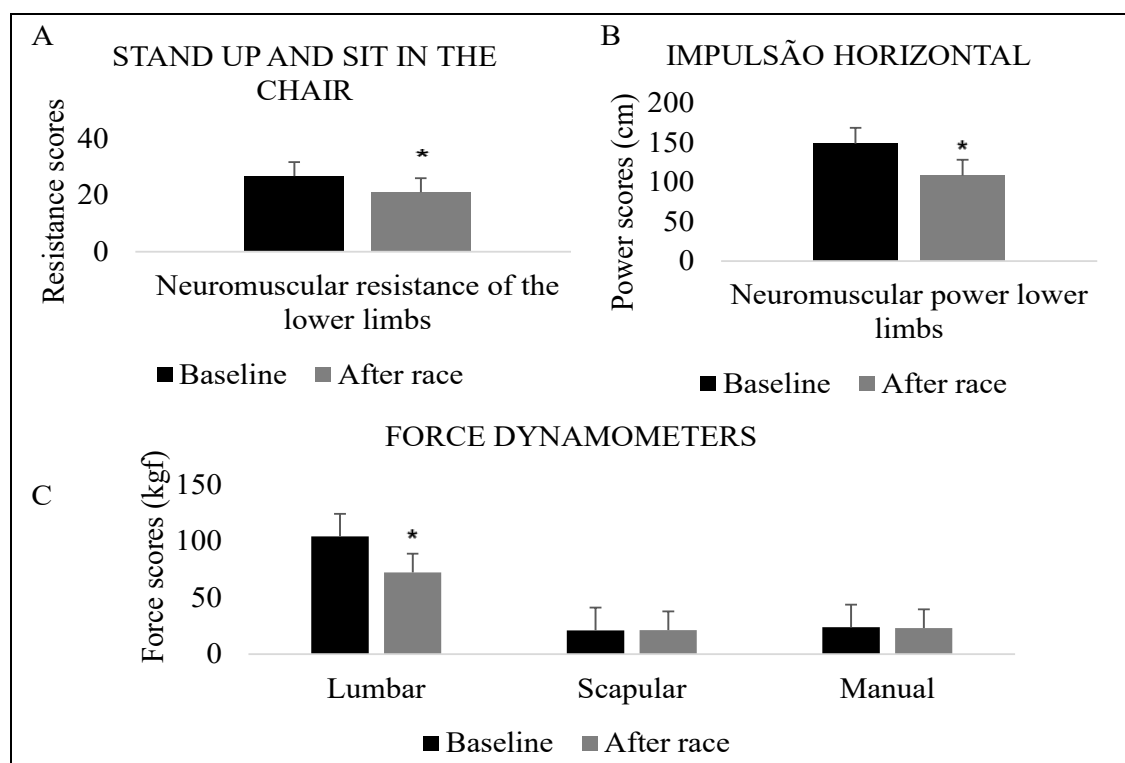
We observed a significant increase ($p < 0.05$) of 59% (effect size (95% CI), 0.86 (0.09–1.65) in average HR and 60% (effect size (95% CI), 0.74 (0.09–1.87) in final HR in relation to HR at rest (66 ± 10 bpm), respectively. The oxygen consumption during the test was $82 \pm 9\%$ VO₂max. About the race time, 23 runners finished the race in just over 3h (193 ± 23 min) running at a speed of 8 ± 1 km/h, with a pace of 7.31 ± 1.15 min/km. It was observed that the effort made during the race resulted in a high energy expenditure (2114 ± 901 kcal). Similarly, perceived exertion increased significantly ($p < 0.05$) by 200% after running (pre 3 ± 2.3 points; post 9 ± 1.1) effect size (95% CI), 0.63 (0.104–1.25). On metabolic changes, the plasma lactate level doubled ($p = 0.049$) and reached the anaerobic threshold after completing the test (4 ± 1.32 mmol/l), when compared with the pretest (2 ± 0.47 mmol/l) effect size (95% CI), 0.77 (0.034–1.37). Body temperature at the end of the test decreased to $35 \pm 1.23^\circ\text{C}$, indicating a possible hypothermia (Table 2).

Table 2. Cardiorespiratory control variables

PHYSIOLOGICAL VARIABLES	RESULTS		VALUE P
Estimated maximum HR	182 ± 5.5		
HR rest (bpm)	66 ± 10		
HR average (bpm)*	162 ± 11		0.034
HR final (bpm)*	163 ± 15		0.041
%HR maximum	89 ± 6		
% VO₂max	82 ± 10		
Energy dispensing (Kcal)	2114 ± 901		
Pace (min/km)	7.31 ± 1.15		
Speed (km/h)	8 ± 1.13		
Race time (min)	193 ± 23		
	BEFORE RACE	AFTER RACE	
Perceived effort (score)	3 ± 2.3	9 ± 1.1	0.001
Lactate (mmol/l)	2 ± 0.47	4 ± 1.32	0.049
Glicose (ml/dl)	140 ± 37.01	119 ± 23.63	0.087
Body temperature (°C)	37 ± 0.41	35 ± 1.23	0.061

Note: HR = heart rate; VO₂max = maximum oxygen consumption. The values are presented as average ± SD

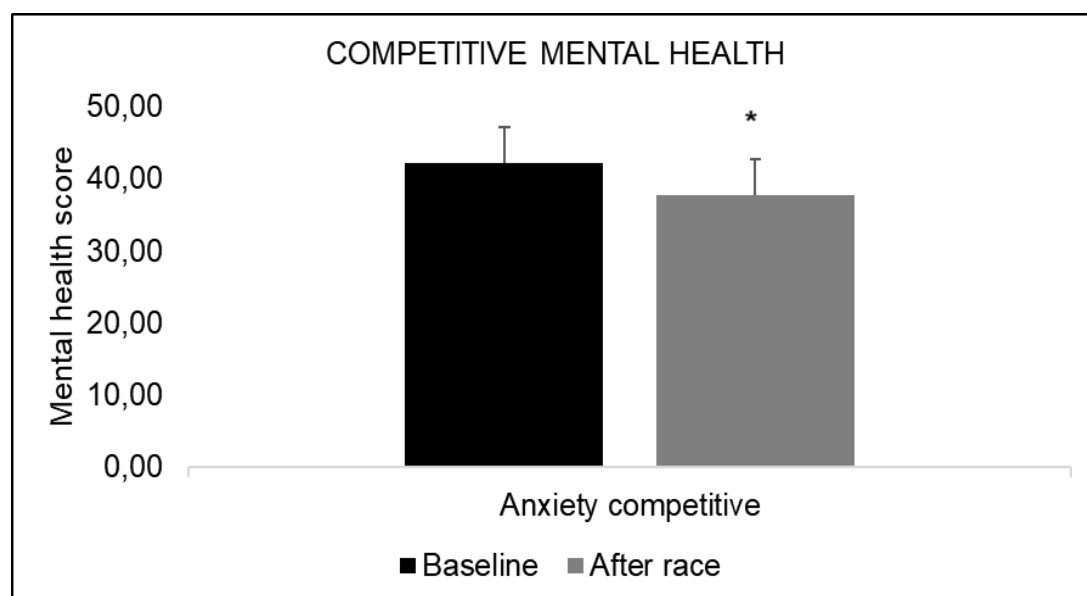
In Figure 3 (panels a; b; c), we observe significant decreases for the lower limbs of resistance 22% (pre 27 ± 4.5 times; post 21 ± 4.2 times; p = 0.021; effect size (95% CI), 0.21 (0.041–1.12), power 28% (pre 149 ± 53.7 cm; post 108 ± 45.3 cm; p = 0.045; effect size (95% CI), 0.64 (0.062 to 1.22), and lumbar force 31% (pre 104 ± 35.1 kgf; post 72 ± 14.2 kgf; p = 0.033; effect size (95% CI), 0.078 to 1.06). On the other hand, no significant changes in scapular force and manual pressure (p > 0.05) were observed.



Note: Neuromuscular analysis between the basal moment and after the race. *Level of significance was $p < 0.05$ in relation to pre and post test.

Figure 3. Analyses of neuromuscular strength

We observe from Figure 4 that the competitive state anxiety reduced 10% (pre 42.1 ± 4.2 points; post 37.8 ± 5.5 points; $p = 0.048$; effect size (95% CI), 0.81 (0.038 to 1.19) to posttest when compared with baseline values.

Figure 4. Levels of competitive state anxiety

Note: Competitive mental health inventories in 24.6 km adult runners. *Level of significance was $p < 0.05$ in relation to after 24.6 km.

Discussion

It is known that the competitive condition of a race is a factor of alteration of mental and muscular, and can generate psychophysiological disorders in runners (Chang et al., 2020; Henriksen et al., 2019). Specifically in relation to uphill running and amateur runners, however, the literature lacks studies. We emphasize that until the present moment, this is the first Brazilian study that investigated the alterations in the psychophysiological parameters after an uphill race, accomplished in Brazil.

The present study showed that this race significantly alters the runners' physiological and psychological scores in a differentiated manner. In this sense, the literature has highlighted the protective effect of controlled running (Cooper, Moon, & Van Praag, 2018; Vorkapic-Ferreira et al., 2017) and changes on the risk of excessive running for the health of runners (Henriksen et al., 2019). Our study partially refutes this evidence, showing that a run (uphill - 25km), even being excessive, no damage to the psychophysiological well-being.

Physiological changes during a run can increase heart rate, oxygen consumption, lactate production and glucose consumption (Gómez-Molina et al., 2017; Gonzalez et al., 2016; Marion et al., 1994; Martínez-Sánchez et al., 2017; Olney et al., 2018; Vorkapic-Ferreira et al., 2017). In our study we demonstrated that uphill running changes heart rate and lactate production in a moderate way in amateur runners. Therefore, for amateur runners, this type of race presents a predominantly aerobic metabolic behavior of moderate intensity (Araujo et al., 2019; Hernando et al., 2020; Piacentini et al., 2015). However, the elevation of mean lactate levels and glucose depletion seen in this study are due to the response to the breakdown of physiological muscle homeostasis, which occurs during this type of long-duration race (193 ± 23 min) (Martínez-Sánchez et al., 2017). According to our results, we point out that during an uphill race, the predominantly aerobic metabolism is activated

to meet the high energy demand (ATP), which in turn contributes to the neuromuscular fatigue process, as seen in our results (Table 2 and Figure 3).

In our study, we observed that the average energy expenditure of the uphill runners was higher (2114 kcal), when compared to the energy expenditure (1857 kcal) of the Hernando et al. (2020) study, which quantified the expenditure after 25km of normal running. It is possible that running up, during the uphill, demanded a higher energetic expenditure compared to other races with less altimetry (Vernillo et al., 2017). However, when we observed the speed (8 ± 1.13 km/h) and race time (193 ± 23 min) of runners in the present study, their performance was lower than those reported in other half-marathon studies with flat altimetry and official distances of 21,095km (Alvero-Cruz et al., 2019; Knechtle et al., 2014; Wiewelhove et al., 2018). Studies have pointed out, for example, that the speed and time of half-marathoners, not performance athletes, is around 12 km/h and 100min, respectively, (Knechtle et al., 2014). In another study, 45 amateur runners ran in an average time of 112min, with a perception of effort of 7 points (scale of 0 to 10 points) (Wiewelhove et al., 2018). Alvero-Cruz et al. (2019), after a half-marathon, found a speed of 13 km/h and a time of 93min, in 23 half-marathoners (Alvero-Cruz et al., 2019). Rousanoglou et al. (2016) analyzed 27 male amateur runners, who completed a mountain race with a time of 180min, at a speed of 9.7 km/h, with a heart rate of 90% of HR maximum

Although the results are similar to the findings of the present study, the altimetry of mountain racing is characterized by alternating climbs and descents, whereas uphill racing is practically without descents (Figure 1). We believe that an uphill race practiced in this study, besides extending for more than a half-marathon (24.6 km), and a high component of positive slope and smaller measure of negative slope, added to the particular altimetry of the mountain increases the degree of difficulty of the race, making it an extremely exhausting race.

Regarding the neuromuscular parameters (Figure 3), there was a decrease in post-race resistance (22.2%), power (27%), and lumbar strength (30%), which is possibly justified by the mechanical and metabolic stress of the uphill (Rousanoglou et al., 2016; Vernillo et al., 2017). According to Vernillo et al. (2017), the power (especially in the hip) is worn as a function of the positive slope of this type of race (uphill). Because of this, muscle activity and energy expenditure during ascent are higher when compared to descent or level. Also, Rousanoglou et al. (2016) verified a drop in the mechanical production of the lower limbs, after a 23-km mountain race. Although fatigue after running is related to central and peripheral factors (Wiewelhove et al., 2018), the fact that there is no change in manual and scapular strength in this study (Figure 3) suggests that uphill race fatigued more the specific muscles recruited (quadriceps, ischiotibial, and lumbar) during exercise, which was proven by the reduction in sitting and standing, jumping and pulling tests.

Regarding competitive state anxiety, it has been defined as a negative emotional state associated with the athlete's capacity to respond to stress (Tanguy et al., 2018). The literature has pointed out that athletes (professional or amateur) who participate in competitions are exposed to increases in anxiety, caused by the inherent competitive character (Chang et al., 2020;

McCormick et al., 2016; Pluhar et al., 2019; Schinke, Stambulova & Moore, 2018).

Our results signal out that competitive state anxiety is reduced 10% ($p < 0.05$) (Figure 4). The literature points out that street races (10km, 21km, and 42km) naturally activate the functioning of the HPA axis, generating elevations of anxiety, which contribute to altering the psychophysiological response (Tanguy et al., 2018; Vorkapic-Ferreira et al., 2017). However, chronically, the running training seems to increase the psychophysiological efficiency, teaching the body to deal with these elevations (Mikkelsen, Stojanovska, Polenakovic, Bosevski & Apostolopoulos, 2017). In this sense, all the runners analyzed in our study, reported to train regularly for at least 18 months (Table 1), enough to expect an adequate response in the levels of anxiety and stress after competition. It is suggested that despite the competitive nature of the race, the fact that the runners finished it satisfactorily has been evaluated psychologically positive by themselves. Consequently, confidence in the psychophysical abilities of the runners increased, and therefore, anxiety decreased (Mikkelsen, Stojanovska, Polenakovic, Bosevski & Apostolopoulos, 2017).

According to Vorkapic-Ferreira et al. (2017), the race improves the perceived emotional state, as a consequence of neurological changes induced by increased brain metabolism, which is due to increased oxygenation and blood flow. Animal studies have found that running, both chronic and acute, increases neurotrophic factors, and synaptic networks that modulate inhibitory (GABA) and excitatory neurotransmitters (glutamate, noradrenaline, acetylcholine, dopamine, serotonin) (Cooper et al., 2018).

It is possible that an uphill race in the present study caused an increase in endocannabinoid and opioid synthesis, which caused a synaptic deceleration and neuromuscular relaxation effect, reduced competitive anxiety in the runners, after the end of the race (Figure 4) (Vorkapic-Ferreira et al., 2017). It is still a fact that the myokines released by the muscles during the race may have contributed to the increase in neuronal plasticity and consequently in the psychophysiological well-being state after the race (Cooper et al., 2018).

Conclusion

The uphill running resulted in significant psychophysiological changes in the runners. The present study concludes that this type of competition physiologically presents a high cardiorespiratory load and neuromuscular wear. However, we point out that psychologically an uphill race can decrease the runners' competitive anxiety. These findings allow us to think that uphill running, as well as adequate training to prepare for the competition, can contribute to psychophysiological well-being. As a limitation, we highlight the lack of well-being scores. Future studies are recommended.

References

- Alvero-Cruz, J. R., Carnero, E. A., Giráldez García, M. A., Alacid, F., Rosemann, T., Nikolaidis, P. T., & Knechtle, B. (2019). Cooper Test Provides Better Half-Marathon Performance Prediction in Recreational Runners Than Laboratory Tests. *Frontiers in Physiology*, 10(1349), 1–9.
- Araujo, N. C., Neto, A. M. M., Fujimori, M., Bortolini, M. S., Justino, A. B., Honorio-França, A. C., & Luzia França, E. (2019). Immune and Hormonal Response to High-intensity Exercise During Orienteering. *International Journal of Sports Medicine*, 40(12), 768–773.
- Balbinotti, M. A. A., Gonçalves, G. H. T., Klering, R. T., Wiethaeuper, D., & Balbinotti, C. A. A. (2015). Motivational profiles of road runners presenting different levels of practice. *Revista Brasileira de Ciências Do Esporte*, 37(1), 65–73.
- Bigliassi, M., León-Domínguez, U., Buzzachera, C. F., Barreto-Silva, V., & Altimari, L. R. (2015). How does music aid 5 km of running? *Journal of Strength and Conditioning Research*, 29(2), 305–314.
- Chang, C., Putukian, M., Aerni, G., Diamond, A., Hong, G., Ingram, Y., Reardon, C. L., & Wolanin, A. (2020). Mental health issues and psychological factors in athletes: Detection, management, effect on performance and prevention: American Medical Society for Sports Medicine Position Statement— Executive Summary. *British Journal of Sports Medicine*, 54(4), 216–220.
- Coelho, E. M., Vasconcelos-Raposo, J., & Mahl, Á. C. (2010). Confirmatory factorial analysis of the brazilian version of the competitive state anxiety inventory-2 (CSAI-2). *Spanish Journal of Psychology*, 13 (1): 453-60.
- Cooper, C., Moon, H. Y., & van Praag, H. (2018). On the Run for Hippocampal Plasticity. *Cold Spring Harbor Perspectives in Medicine*, 8(4), a029736.
- Costa, R. J. S., Knechtle, B., Tarnopolsky, M., & Hoffman, M. D. (2019). Nutrition for ultramarathon running: Trail, track, and road. *International Journal of Sport Nutrition and Exercise Metabolism*, 29(2), 130–140.
- Crosby, C. A., & Wehbe, M. A. (1994). Hand strength: Normative values. *The Journal of Hand Surgery*, 19(4), 665–670.
- Doyenart, R., Olímpio, M., Boeira, D., Sombrio, F., Milhomes, Y. P., Gomes, K., Thirupathi, A., & DA SILVA, L. A. (2020). Psycho-physiological changes after a half marathon in amateur runners. *Journal of Physical Education and Sport*, 20(4), 1768–1774.
- Gómez-Molina, J., Ogueta-Alday, A., Camara, J., Stickley, C., Rodríguez-Marroyo, J. A., & García-López, J. (2017). Predictive Variables of Half-Marathon Performance for Male Runners. *Journal of Sports Science & Medicine*, 16(2), 187–194.
- Gonzalez, J. T., Fuchs, C. J., Betts, J. A., & van Loon, L. J. C. (2016). Liver glycogen metabolism during and after prolonged endurance-type exercise. *American Journal of Physiology-Endocrinology and Metabolism*, 311(3), E543–E553.
- Henriksen, K., Schinke, R., Moesch, K., McCann, S., Parham, W. D., Larsen, C. H., & Terry, P. (2019). Consensus statement on improving the

mental health of high-performance athletes. *International Journal of Sport and Exercise Psychology*, 18(5), 1–8.

Hernando, C., Hernando, C., Martinez-Navarro, I., Collado-Boira, E., Panizo, N., & Hernando, B. (2020). Estimation of energy consumed by middle-aged recreational marathoners during a marathon using accelerometry-based devices. *Scientific Reports*, 10(1), 1523.

Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. *British Journal of Nutrition*, 40(3), 497–504.

Jackson, Andrew S., Pollock, M. L., & Ward, A. (1980). Generalized equations for predicting body density of women. *Medicine & Science in Sports & Exercise*, 12(3), 175–182.

Knechtle, B., & Nikolaidis, P. (2018). Sex- and age-related differences in half-marathon performance and competitiveness in the world's largest half-marathon – the GöteborgsVarvet. *Research in Sports Medicine*, 26(1), 75–85.

Knechtle, Beat, Barandun, U., Knechtle, P., Zingg, M. A., Rosemann, T., & Rüst, C. A. (2014). Prediction of half-marathon race time in recreational female and male runners. *SpringerPlus*, 3(1), 1–8.

Kruk, J., Kotarska, K., & Aboul-Enein, B. H. (2020). Physical exercise and catecholamines response: benefits and health risk: possible mechanisms. *Free Radical Research*, 54(2-3):105-125.

Lee, S., & Kimmerly, D. S. (2016). Influence of music on maximal self-paced running performance and passive post-exercise recovery rate. *The Journal of Sports Medicine and Physical Fitness*, 56(1–2), 39–48.

Lemire, M., Hureau, T. J., Remetter, R., Geny, B., Kouassi, B. Y. L., Lonsdorfer, E., Isner-Horobeti, M.-E., Favret, F., & Dufour, S. P. (2019). Trail Runners Cannot Reach V̇O₂max during a Maximal Incremental Downhill Test. *Medicine & Science in Sports & Exercise*, 52(5), 1135–1143.

Marion, A., Kenny, G., & Thoden, J. (1994). Heart rate response as a means of quantifying training loads: Practical considerations for coaches. *Sports*, 14(2), 1–11.

Martínez-Sánchez, A., Ramos-Campo, D. J., Fernández-Lobato, B., Rubio-Arias, J. A., Alacid, F., & Aguayo, E. (2017). Biochemical, physiological, and performance response of a functional watermelon juice enriched in L-citrulline during a half-marathon race. *Food & Nutrition Research*, 61(1), 1–11.

McCormick, A., Anstiss, P. A., & Lavallee, D. (2018). Endurance athletes' current and preferred ways of getting psychological guidance. *International Journal of Sport and Exercise Psychology*, 18(2), 187–200.

McCormick, A., Meijen, C., & Marcora, S. (2016). Psychological demands experienced by recreational endurance athletes. *International Journal of Sport and Exercise Psychology*, 16(4), 415–430.

Mikkelsen, K., Stojanovska, L., Polenakovic, M., Bosevski, M., & Apostolopoulos, V. (2017). Exercise and mental health. *Maturitas*, 106, 48–56.

Nikolaidis, P. T., & Knechtle, B. (2018). Pacing Strategies in the 'Athens Classic Marathon': Physiological and Psychological Aspects. *Frontiers in Physiology*, 9(11), 1–9.

Ohrnberger, J., Fichera, E., & Sutton, M. (2017). The relationship between physical and mental health: A mediation analysis. *Social Science & Medicine*, 195(2017), 42–49.

Olney, N., Wertz, T., Laporta, Z., Mora, A., Serbas, J., & Astorino, T. A. (2018). Comparison of acute physiological and psychological responses between moderate-intensity continuous exercise and three regimes of high-intensity interval training. *Journal of Strength and Conditioning Research*, 32(8), 2130–2138.

Piacentini, M. F., Minganti, C., Ferragina, A., Ammendolia, A., Capranica, L., & Cibelli, G. (2015). Stress related changes during a half marathon in master endurance athletes. *The Journal of Sports Medicine and Physical Fitness*, 55(4), 329–336.

Pluhar, E., McCracken, C., Griffith, K. L., Christino, M. A., Sugimoto, D., & Meehan, W. P. (2019). Team sport athletes may be less likely to suffer anxiety or depression than individual sport athletes. *Journal of Sports Science and Medicine*, 18(3), 490–496.

Rikli, R. E., & Jessie, J. C. (2008). *Senior Fitness Test* (3rd ed.). Barueri São Paulo: Manole.

Rousanoglou, E. N., Noutsos, K., Pappas, A., Bogdanis, G., Vagenas, G., Bayios, I. A., & Boudolos, K. D. (2016). Alterations of vertical jump mechanics after a half-marathon mountain running race. *Journal of Sports Science and Medicine*, 15(2), 277–286.

Samson, A., Simpson, D., Kamphoff, C., & Langlier, A. (2015). Think aloud: An examination of distance runners' thought processes. *International Journal of Sport and Exercise Psychology*, 15(2), 176–189.

Scheer, V., Basset, P., Giovanelli, N., Vernillo, G., Millet, G. P., & Costa, R. J. S. (2020). Defining Off-road Running: A Position Statement from the Ultra Sports Science Foundation. *International Journal of Sports Medicine*, 41(5), 275–284.

Schinke, R. J., Stambulova, N. B., Si, G., & Moore, Z. (2018). International society of sport psychology position stand: Athletes' mental health, performance, and development. *International Journal of Sport and Exercise Psychology*, 16(6), 622–639.

Silva, L. A. Da, Doyenart, R., Henrique Salvan, P., Rodrigues, W., Felipe Lopes, J., Gomes, K., Thirupathi, A., Pinho, R. A. De, & Silveira, P. C. (2019). Swimming training improves mental health parameters, cognition and motor coordination in children with Attention Deficit Hyperactivity Disorder. *International Journal of Environmental Health Research*, 30(5), 584–592.

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, 37(1), 153–156.

Tanguy, G., Sagui, E., Fabien, Z., Martin-Krumm, C., Canini, F., & Trousselard, M. (2018). Anxiety and Psycho-Physiological Stress Response to Competitive Sport Exercise. *Frontiers in Psychology*, 9(8), 1–9.

Vernillo, G., Giandolini, M., Edwards, W. B., Morin, J.-B., Samozino, P., Horvais, N., & Millet, G. Y. (2017). Biomechanics and Physiology of Uphill and Downhill Running. *Sports Medicine*, 47(4), 615–629.

Vorkapic-Ferreira, C., Góis, R. S., Gomes, L. P., Britto, A., Afrânio, B., & Dantas, E. H. M. (2017). Born to run: the importance of exercise for the brain health. *Revista Brasileira de Medicina Do Esporte*, 23(6), 495–503.

World Health Organization. (1995). Physical status: the use and interpretation of anthropometry. Technical Report Series No. 854. In Technical Report Series No. 854. Geneva: World Health Organization.

Wiewelhoeve, T., Schneider, C., Döweling, A., Hanakam, F., Rasche, C., Meyer, T., Kellmann, M., Pfeiffer, M., & Ferrauti, A. (2018). Effects of different recovery strategies following a half-marathon on fatigue markers in recreational runners. *PLoS ONE*, 13(11), e0207313.

Yanci, J., Los Arcos, A., Castillo, D., & Cámara, J. (2017). Sprinting, Change of Direction Ability and Horizontal Jump Performance in Youth Runners According to Gender. *Journal of Human Kinetics*, 60(1), 199–207.

About the author

Ramiro Doyenart

Laboratory of Exercise Psychophysiology, Advanced Aquatic Exercise Research Group, University of Southern Santa Catarina (UNESC), Criciúma, SC, Brazil Orcid: <https://orcid.org/0000-0001-8288-6586>

Daniel Boeira da Silva

Laboratory of Exercise Psychophysiology, Advanced Aquatic Exercise Research Group, University of Southern Santa Catarina (UNESC), Criciúma, SC, Brazil, Brasil Orcid: <https://orcid.org/0000-0003-3745-0315>

Renato Schardosim da Silva

Laboratory of Exercise Psychophysiology, Advanced Aquatic Exercise Research Group, University of Southern Santa Catarina (UNESC), Criciúma, SC, Brazil. Orcid: <https://orcid.org/0000-0002-8242-0281>

Leandro Dal Ponte

Laboratory of Exercise Psychophysiology, Advanced Aquatic Exercise Research Group, University of Southern Santa Catarina (UNESC), Criciúma, SC, Brazil. Orcid: <https://orcid.org/0000-0002-8547-4453>

Anand Thirupathi

Faculty of Sports Science, Ningbo University, Ningbo, China. Orcid: <https://orcid.org/0000-0002-0924-2538>

Luciano Acordi da Silva

Laboratory of Exercise Psychophysiology, Advanced Aquatic Exercise Research Group, University of Southern Santa Catarina (UNESC), Criciúma, SC, Brazil. Barriga Verde University Center, Faculty of Physical Education, Orleans, SC, Brazil. Orcid: <https://orcid.org/0000-0001-5650-9672>

Corresponding author

ENDEREÇO PARA CORRESPONDÊNCIA

Ramiro Doyenart

Av. Universitária 1105, Criciúma (SC), Brasil. CEP 88806-000

TELEFONE (48) 34314553

E-MAIL ramirodoyenart@unesc.net