da luta. Nenhum país tem o direito de negar o seu passado. Deve assumi-lo no que ele tem de grandioso e medíocre, louvável ou reprovável, claro ou sombrio. O tempo histórico é sempre relativo e raramente pode ser apagado, coisa que tem sido sobejas vezes tentado na Coreia, seja do Norte ou do Sul. É impossível reescrever a história pois os escribas estão lá para fazer "inquérito". Esta explanação resume algumas das razões históricas que mancharam de ódio e sangue as relações entre Coreia e Japão.

A história desportiva coreana entrelaça-se inexoravelmente com a do Japão. Foi durante o período da ocupação colonial japonesa que a Coreia encontrou o seu primeiro herói desportivo. Sohn Ki-chung, foi o campeão da maratona nos Jogos Olímpicos de Berlim, em 1936. Este coreano envergava uma camisola com o símbolo do sol nascente e foi a bandeira japonesa que ele viu subir no mastro para glorificar o seu feito. Podemos perguntar o que estaria Sonh a pensar naquele momento. Felicidade interior por um feito excepcional? Revolta interior por estar a glorificar o inimigo? Penso que nos momentos mais elevados de glória desportiva, naqueles em que o atleta está só consigo e com a sua legenda, vinga, fundamentalmente, a assunção solitária do feito. Uma dimensão que começa e acaba em si. Só depois é que aparecem as outras referências, família, amigos, nação, etc. O que pensou Eusébio, em 1966, quando chorou após a derrota imerecida contra a Inglaterra? Naqueles momentos cala-se a força do grupo, clã ou nação e só fala a saga individual. Eusébio queria, antes de tudo, a vitória por si e para si porque procurou a glória com toda a força do seu valor, e acima das eventuais reflexões de que estava a contribuir para glória do país que o tinha como ídolo. O desporto, antes de tudo, é o homem solitário empenhado na superação dos seus limites contra tudo e contra todos. Só depois é que assume a tessitura da agregação que congrega o outro, o grupo, a família, a nação, por vezes o continente. Por isso, penso que Sohn Ki-chung foi campeão olímpico antes de mais por si próprio, como corolário do muito que sofreu para atingir o cume do êxito. A medalha vale por si e para si e em nada é diminuída por ter sido obtida com a camisola do opressor colonial.

A análise das relações entre o desporto e a política são marcadas pelo *zeitgeist*. Devemos evitar, na análise histórica, cair em anacronismos. Só assim podemos ter o distanciamento suficiente para as análises críticas dos factos históricos. Só assim podemos compreender o facto de, em 1938, num jogo de futebol entre a Alemanha e a Inglaterra, o Ministério dos Negócios Estrangeiros Britânico ter tido o cuidado de avisar os jogadores da seleção britânica de fazerem a saudação nazi aos seus convidados.

Aquilo que em 1938 era um gesto de cortesia, seria um crime ideológico em 1944.

Se, como alguém disse, a política é a guerra sem armas temos de assumir que, por vezes, o desporto, como expressão política de uma dada sociedade pode ser assumido como arma de arremesso contra a paz entre nações. Acreditemos que quando um grupo de jovens chuta uma bola cumpre o guião de António Gedeão – o mundo pula e avança.

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Time-course of neuromuscular parameters, muscle soreness and sympatho-vagal balance following a 130-km cycling race

KEY WORDS:

Resistance exercise. Bicycling.
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ABSTRACT

This study aimed identifying the effects of a 130-km cycling race on indices of physiological recovery markers of during a 72-h period. Thirteen endurance trained male cyclists underwent a collection of indices for measuring neuromuscular parameters, muscle soreness and heart rate variability at five different moments of data collections: before, after and at 24, 48 and 72-h following a cycling race. Results indicate that the neuromuscular parameters scores decreased after the race (maximal voluntary isometric contraction: 13.61%, $p < .05$; electromyography: 21.65%, $p = .002$), yet some parameters returned to baseline values at 72-h afterwards (maximal voluntary isometric contraction: $p > .05$) while other neuromuscular parameters values remained lower throughout the 72-h recover period (electromyography: 10.62%, $p < .05$). Muscle soreness increased after the race ($p < .001$) and returned to baseline values 48-h thereafter ($p > .05$). The heart rate variability values increased after the race and remained higher for 72-h afterwards ($p < .05$). These findings show that a 130-km cycling race has a noteworthy effect on indices of neuromuscular parameters, muscle soreness and heart rate variability responses. Moreover, these results suggest that a 72-h recovery period does not appear to be enough for long-distance cyclist and reinforce the propositions within scientific literature concerning athletes involved in endurance cycling need for a sufficient recovery period.

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Decurso temporal de parâmetros neuromusculares, dor muscular e equilíbrio simpático-vagal após uma corrida de ciclismo de 130 km

RESUMO

O objetivo deste estudo foi identificar os efeitos de uma competição de ciclismo de 130-km sobre os índices de recuperação fisiológica durante um período de 72-h. Treze ciclistas previamente treinados do sexo masculino foram submetidos a coletas de parâmetros neuromusculares, dor muscular e variabilidade da frequência cardíaca em cinco momentos diferentes: antes, depois, e 24, 48 e 72-h horas após a competição de ciclismo. Os resultados indicaram que todos os parâmetros neuromusculares diminuíram após a competição (contração voluntária isométrica máxima: 13.61%, $p < .05$; eletromiografia: 21.65%, $p = .002$), alguns parâmetros retornaram aos valores iniciais 72-h após (contração voluntária isométrica máxima: $p > .05$) enquanto outros valores de parâmetros neuromusculares permaneceram baixos durante as 72-h de recuperação (eletromiografia: 10.62%, $p < .05$). A dor muscular aumentou após a competição ($p < .001$) e retornou aos valores basais 48-h após a corrida ($p > .05$). A variabilidade da frequência cardíaca aumentou após a competição e assim permaneceu até as 72-h após ($p < .05$). Esses achados mostram que uma competição de ciclismo de 130-km exerce um efeito notório nas respostas dos índices dos parâmetros neuromusculares, dor muscular e variabilidade da frequência cardíaca. Além disso, esses resultados sugerem que um período de repouso de 72-h aparenta não ser o suficiente para ciclistas de longa distância e reforça as proposições da literatura científica sobre a necessidade de um período de recuperação suficiente para atletas envolvidos em ciclismo de longa distância.

PALAVRAS CHAVE:

Exercício de endurance. Ciclismo.
Recuperação. Sobretreino.

INTRODUCTION

Endurance cycling is based on the pursuit of an athlete's optimal performance, it places great demand on various physiological and biomechanical aspects ⁽³⁾ and, as such, it is extremely important to be aware of all these variables to optimize an athletes' performance ⁽¹⁶⁾. However, the increase in exercise load that accompanies endurance cycling causes muscle damage, fatigue and muscle pain ⁽²⁸⁾. Because of this, to achieve the greatest possible gains in athletic performance, it is necessary to find the perfect balance between the optimal training loads and a sufficient recovery period ^(9,42). Successful training not only involves the application of the principles of overload, of equal importance is the athlete not exceeding the point of mutual benefit that evolves from the interplay of overload and recovery. When athletes fail to achieve a synergistic balance between training and recovery, nonfunctional overreaching can occur ⁽³⁰⁾. Even though, this notion of balance between training and overtraining is often very delicate it is imperative for the pursuit of optimal performance ⁽³⁷⁾.

Even though the volume of literature on overtraining has increased of late, an inconsistent use of common terminology and the inability to establish a universally accepted process for the diagnosis of training syndrome continues to obstruct advances in the field ⁽³⁰⁾. Conventionally, the methods used to assess the biomarkers of physiological stress induced by exercise and overtraining include such practices as maximum voluntary contraction along with subjective muscle soreness ^(1, 10, 19, 23, 30, 40) and heart rate variability (HRV) ^(13, 17, 24, 31, 33, 46, 47). Beyond this, there remains a dearth of information about the recovery period between a resistance training session or competition and a subsequent session, and therefore the biomarkers of fatigue, and in particular recovery, need to be identified to obtain the right optimal training effect ⁽⁷⁾.

Considering the aforementioned ambiguity surrounding exercise load and sufficient periods of recovery, the present study is valid as it will provide reliable biomarkers of physiological stress in neuromuscular parameters such as maximal voluntary isometric contraction testing (MVICT) and surface electromyography (EMG), muscle soreness level, and sympatho-vagal balance by HRV responses following an endurance cycling race and recovery period. Furthermore, the knowledge of the behavior of these biomarkers of stress will enable scientists, coaches and athletes to better fit their training intensity load and recovery period for both enhancement of sports performance and to prevent the onset of overtraining, thus improving not only athletic performance but also their health and quality of life ⁽³⁸⁾. Therefore, the purpose of the present investigation was to identify the effects of a 130-km cycling race on indices of neuromuscular parameters, muscle soreness and heart rate variability responses during a 72-h recovery period.

METHODS

SUBJECTS

Thirteen endurance-trained male cyclists (mean $\pm$ SD; age: 28 ± 5 year; height: 178 ± 6 cm; weight: 74 ± 5 kg; body fat: 8 ± 5 %; $\text{VO}_{2\text{max}}$: 63 ± 9 mL $\cdot$ kg $^{-1}\cdot$ min $^{-1}$) volunteered for this study. All participants were competing for more than 2 years and were involved in systematic training at least of four days/wk. prior to commencing this investigation. Participants visited the laboratory twice before the experimental protocol and cycling race. During the first visit a comprehensive verbal and written explanation about the benefits and risks of the study were given to all subjects, after this, they signed the informed consent document which was institutionally approved. A health history questionnaire and a physical activity readiness questionnaire (PAR-Q) were also completed and the subjects were familiarized with the test procedures of experimental protocol. During the second visit subjects' characterization body weight and height, body fat percentage and $\text{VO}_{2\text{max}}$ were determined. Research Ethics were submitted and approved by governing institution (protocol: 1256.181.11.11).

STUDY DESIGN

Experimental protocol was conducted by five different moments of data collection: before and immediately after the cycling race and 24, 48 and 72-h thereafter. The pre-race data collection was performed 24-h before the cycling race (FIG. 1). Participants received the instructions not to perform any kind of physical exercise from 48-h prior to the first data collection and during the 72-h recovery period beyond the post-race data collection point. Delayed onset of muscle soreness (DOMS) and HRV were collected at each moment. However, neuromuscular parameters (MVICT and EMG) were not recorded after the completion of the race.

FIGURE 1. Study Design

PROCEDURES

To determine the neuromuscular parameters in this study, MVICT and EMG were performed simultaneously. At the beginning of each session, all participants performed a general warm-up protocol which consisted of a 5-min treadmill run at 8 km/h. Between the general warm-up protocol and neuromuscular parameters tests, a 60-sec passive rest period was enforced. Results concerning the MVICT were measured using an isokinetic dynamometer (Cybex – NORM™). The test protocols required participants to assume a sitting position with the trunk, thigh and lower leg stabilized with Velcro straps to prevent extraneous joint movement. The free end of the mechanical lever of the dynamometer was secured 5-cm above the lateral malleolus and the axis of rotation of the dynamometer was aligned with lateral femoral epicondyle.

The mechanical axis of the dynamometer was aligned with the lateral epicondyle of the femur with the knee joint fixed at a ROM of 60°, this ROM angle is consistent with other studies^(7,27). The test consisted of three trials of 5-sec maximal voluntary isometric contraction by the dominant leg with a 3-min rest interval between trials. The best effort from these three trials was considered the representative measure. EMG data were taken from the same best effort of MVICT. All measurements were evaluated after the limb's gravitation correction. The dynamometry variable used as MVICT data was the peak torque (PT) expressed in N $\cdot$ m $^{-1}$. The same experienced investigator performed all MVICT test and verbal encouragement was given during every effort.

An electromyography device (Miotool 400®) was used to record the EMG signal. As such a pair of surface EMG recording electrodes with a third reference electrode located at an equal distance from the two electrodes was used to record and validate the signal. The electrodes, pre-assembled in a small box, were attached over the belly of the rectus femoris (RF), vastus lateralis (VL) and vastus medialis (VM) muscles. Each pair of recording electrodes, with an inter-electrode distance of 20-mm⁽¹⁵⁾, was placed in a longitudinal direction to the muscle fibre^(6,25). Before application of the electrodes, the skin surface was shaved and cleansed with alcohol and mildly abraded to reduce impact impedance. The outline of the electrode box was drawn with a marker pen on the skin to allow the accurate repositioning for following moments of data collection 24, 48 and 72-h after race.

The raw EMG signals were recorded with a sampling frequency of 2000-Hz. This signal had a gain of thousand fold and presented a common mode rejection ratio > 120-dB. The EMG signals were recorded for 5-sec at the same point of the MVICT. Thereafter, the first and the last 0.5-sec of the recording were eliminated, leaving a remaining 4-sec of recorded data to be used for signal treating (such procedure was performed to avoid the interference of the electromechanical delay at the beginning and at the end of the muscular contraction). The EMG signal data was then band-pass filtered to 20-500Hz⁽⁴³⁾ to minimize interference on the EMG signal. After that, a Root Mean Square (RMS) value was determined to qualify

the EMG signal. Finally, the average millivolts (mV) of the 4-sec of recorded EMG signal were extracted. All procedures for capture and analysis of the EMG signal followed the recommendations of the International Society of Electrophysiology and Kinesiology (ISEK) ⁽⁴⁵⁾. In this study, we present the EMG signal data of RF, VL and VM muscles separately and the sum of these three signals as the Electromyography Total (EMG-Total).

The DOMS was determined by the 0-6 points Likert scale of muscle soreness as advocated by Vickers ⁽⁴⁸⁾. The Likert scale of muscle soreness scores were recorded at the time of contraction of the quadriceps and hamstrings muscle along with palpation on the muscles belly. To record the HRV, a heart rate monitor (RS800cx; Polar Electro, Kempele, Finland) was used. Every HRV analysis were performed at same period of the day (between 6:00pm and 7:00pm), after an adaptation period of 5-min in supine decubitus and in the absence of noise with no negative atmosphere the HRV was recorded for a 15-min' period. HRV was determined by the data drawn from the heart rate monitor and the beat-to-beat signal of an R-R Tachogram. The subjects were asked to remain silent, to not move and to maintain their breathing rate as low as possible. The heart rate data were transferred and stored to a software of the same monitor (ProTrainer 3.2), abnormal intervals were detected and thus filtered. After the filtered intervals, the signal processing was performed using the 'Kubios HRV analysis' software (version 2.0; University of Kupio, Finland). A Fast Fourier Transform of the R-R tachogram signal was used for the HRV frequency domain analysis. The spectral response provided by the system was broken down into 2 bands: low frequency (LF) (0.04-0.15 Hz) and high frequency (HF) (0.15-0.4 Hz). Regarding the physiological meaning, HF indices represent the parasympathetic nervous system modulation while LF indices are representative of both sympathetic and parasympathetic autonomic nervous systems, although with a predominance of sympathetic activity ⁽²⁾. The LF/HF ratio reflects the absolute and relative changes between the sympathetic and parasympathetic components of the autonomic nervous system featuring the sympathetic-vagal balance of the heart rate, and it is also used as a sympathetic nervous system modulation marker ⁽³⁶⁾.

The cycling race happened at a racetrack which contains seven curves to the right, four to the left and five line segments, with the longest being 980-m. Totaling 3,695-m long and 4.57-m wide, where the athletes completed 35 rounds of racing cumulating in a total distance of 130-km. The first cyclist finished the race in 3-h and 21-min and the last cyclist finished in 3-h and 58-min, the mean race time was 3-h and 39-min (± 14 -min). The cycling race was convened in a temperature of 12.3°C and relative humidity of 59.7%, with characteristics of cloudy weather. During the race, hydration and replenishment of energy substrates were determined as free for the cyclists. All participants declared not to be using any medication, supplements containing stimulants and/or anabolic steroids during the race or even for the whole stage of the experimental protocol.

STATISTICAL ANALYSIS

Results are reported as descriptive statistics (Mean $\pm$ Standard Error). The comparison between treatments was done using 'generalized estimating equations' (GEE) at statistical package (IBM SPSS Statistics 20). To determine the level of significance "Wald test" was used and "post-hoc" analysis was made by 'least significant difference' (LSD) ($p < .05$). All charts were done by using the software GraphPad Prism® V 5.0.

RESULTS

The results demonstrate that the MVICT of knee extension by dynamometer decreased 24-h after the race. 48-h after the race, MVICT scores remained lower than pre-race values but higher than 24-h afterwards. Whereas 72-h after the race, the MVICT parameters had returned to the pre-race data scores showing no statistic differences (FIG. 2). The EMG-RF muscle signal decreased 24-h after the race; however, at the moments of 48 and 72-h after the race, the EMG-RF signal did not differ with any other moments. EMG-VL signal decreased 24-h after the race and remained lower until 48-h afterwards, returning to the pre-race values at 72-h afterwards. EMG-VM signal decreased 24-h after the race and remained lower until 72-h after race (FIG. 3). EMG-Total signal decreased 24-h after the race ($p = .002$) and remained lower than pre-race values for 48 and 72-h afterwards ($p < .05$). However, 72-h after the race, the EMG-Total had recorded a statistical increase when compared with results drawn 24-h afterwards (FIG. 4).

FIGURE 2. Maximal voluntary isometric contraction testing (MVICT) averages following a cycling race. Values shown as mean $\pm$ SE. Different letters means statistically differences between the moments of data collection ($p < .05$). Same letters means no statistically differences between the moments of data collection ($p > .05$).

FIGURE 3. Surface electromyogram signal of the rectus femoris (EMG-RF), vastus lateralis (EMG-VL), and vastus medialis (EMG-VM) muscle changes following a cycling race. Values shown as mean $\pm$ SE. Different letters means statistically differences between the moments of data collection ($p < .05$). Same letters means no statistically differences between the moments of data collection ($p > .05$).

FIGURE 4. Electromyography Total (EMG-Total) signal changes following a cycling race. Values shown as mean $\pm$ SE. Different letters means statistically differences between the moments of data collection ($p < .05$). Same letters means no statistically differences between the moments of data collection ($p > .05$).

Evaluated by the 0-6 points Likert scale, the subjects reported a significant increase of muscle soreness post-race ($p < .001$). At the moment of 24-h after the race, the DOMS remained higher than pre-race data but lower than post-race ($p < .05$). At 48-h after the race, no differences were recorded when the DOMS score were compared with the data collected at the pre-race moment. Moreover, DOMS values recorded at the moment of 72-h after the race were even lower than the data recorded at the pre-race moment (FIG. 5). HRV represented by Sympatho-vagal balance from LF/HF ratio values increased post-race and at 24-h after the race LF/HF ratio was lower than moment post-race; however, its data remained higher than pre-race values throughout of 72-h recovery period after the race ($p < .05$) (FIG. 6).

FIGURE 5. Delayed onset of muscle soreness (DOMS) by Likert scale changes following a cycling race. Values shown as mean $\pm$ SE. Different letters means statistically differences between the moments of data collection ($p < .05$). Same letters means no statistically differences between the moments of data collection ($p > .05$).

FIGURE 6. Heart Rate Variability (HRV) from sympatho-vagal balance (LF/HF ratio) changes following a cycling race. Values shown as mean $\pm$ SE. Different letters means statistically differences between the moments of data collection ($p < .05$). Same letters means no statistically differences between the moments of data collection ($p > .05$).

DISCUSSION

This study aimed to verify the effects of a 130-km cycling race on indices of neuromuscular parameters, muscle soreness and heart rate variability responses during a 72-h recovery period. The present investigation suggests that a 130-km cycling race induces time-dependent changes in all indices tested. This suggests a negative performance in neuromuscular parameter and increase of muscle soreness and sympatho-vagal balance indexes. 24-h after the race all neuromuscular parameters decrease, noting that the MVICT returned to baseline values after a 72-h recovery period and the EMG-Total did not return to baseline within 72-h. Furthermore, while the DOMS and LF/HF ratio increased immediately after the race, the DOMS returned to pre-race values 48-h afterwards, but LF/HF ratio did not reach the baselines values throughout 72-h recovery period. This would indicate that the sympatho-vagal balance remained effected by the cycling race.

It is very important to monitor the behavior of indirect markers for muscle damage after strenuous exercise^(29, 41). Furthermore, the knowledge of the behaviour of these indirect markers enables scientists, coaches and athletes in the area to better fit their training intensity for both enhancement of sports performance and to prevent the onset of over-training – thus improving not only athletic performance but also their health and quality of life^(34, 38). Measurement of post-exercise neuromuscular parameters has been constantly used and described as a marker of muscle fatigue induced by exercise^(7, 23), and even as an indirect marker of muscle damage^(5, 44). Studies have evaluated MVICT by isokinetic dynamometer^(7, 27). In addition, cycle ergometer protocols have been used to determine post

exercise EMG signal parameters of the muscle fatigue induced exercise. One of these studies⁽²⁷⁾ found a significant decrease of MVICT immediately after exercise and for up to 30-min afterwards. In addition, the EMG-VM and EMG-VL signals recorded the same response to the aforementioned MVICT results.

In a study by Bentley et al.⁽⁷⁾, the researchers observed a decrease in the MVICT results at 10-min after the protocol and that these remained lower for up to 6-h afterwards. In addition, the EMG-VL signal level showed no differences after the exercise, but the EMG-VM signal decreased 10-min after the protocol and returned to the pre-cycling protocol levels 6-h afterwards. The EMG-RF signal however, decreased 10-min after the protocol and remained so for up to 6-h afterwards. The present study has also found a reduction in neuromuscular parameters following a cycling exercise. However, even though our investigation and the two studies cited above have used the same indices of neuromuscular parameters for before and after cycling exercises, there is a limitation to comparing the data from the present investigation with these studies as the data collection occurred at different moments.

Those studies observed neuromuscular fatigue by MVICT and EMG signal immediately after the cycling protocols. In our investigation, it was not possible to observe neuromuscular fatigue acutely, since the first data collection of neuromuscular parameters by MVICT and EMG signal was 24-h after the exercise period. This is dissimilar to the study by Leppers et al.⁽²⁷⁾ and Bentley et al.⁽⁷⁾ who each suggest last moment of data collection in the study by Leppers and colleagues was 30-min after the exercise period while Bentley and colleagues concluded their data collection process 6-h after the exercise period. Both of these aforementioned studies fall short of protocols employed in this study, which follows the changes in neuromuscular parameters up to 72-h after the exercise period.

In the case of this study, the MVICT parameter values decreased at 24-h after the race, yet at 72-h after the race these values returned to the pre-race values (FIG 2). Regarding the neuromuscular parameters evaluated by EMG muscle signal after the race, all muscles tested separately (RF, VL and VM) showed a decrease in the EMG response 24-h after the race indicating a neuromuscular fatigue induced by the 130-km cycling race (FIG 3). As these three muscles act together to produce the maximal contraction of knee extension the results of the EMG-Total are very interesting since it decreased 24-h after and did not return within the 72-h recovery period. This clearly indicates that following a 130-km cycling race, the cyclists had not returned (completely recovered) to their initial neuromuscular activity within 3 days of completing the exercise (FIG 4).

It is common to measure muscle performance in correlation to the DOMS after exercise. Abad et al.⁽¹⁾ and Ispirlidis et al.⁽²³⁾ each suggest that this process is often adopted so that researchers can observe the relationship between exercise and the onset of muscle soreness. Furthermore, DOMS is also constantly described as an indirect marker of muscle damage induced by exercise^(12, 21, 35, 44). Studies^(1, 11) observed muscle damage induce by

eccentric exercise protocol and found similar responses to the DOMS after protocols, however the muscle performance behaved differently between these studies. Whereas DOMS increased significantly during the first 24-h recovery period, peaked at 48-h and returned to baseline values 96-h after protocol in both studies, the study of Abad et al. ⁽¹⁾ observed no changes in muscle performance after protocol.

However, the study by Chapman et al. ⁽¹¹⁾ demonstrates that the muscle performance test decreased post-protocol and remained lower until 96-h afterwards. Ispirlidis et al. ⁽²³⁾ also measured muscles soreness, along with neuromuscular parameter responses following a soccer game. This research noted a significant increase in DOMS 24-h after the completion of the game, before peaking at 48-h and returning to pre-game values 72-h afterwards. In addition, Ispirlidis and colleagues also noted a decrease in muscle performance 24-h after the game and that these remained lower until a period of 72-h had passed. In the present research, DOMS had a different response after strenuous exercise, as there was a significant increase and peak in the DOMS scores immediately after the cycling race and these remained higher for 24-h of recovery. 48-h after race, the DOMS data showed no difference with pre-race moment (FIG. 5). These differences in behavior could be explained by the specificity of exercise performed in the present study, which differs from the other studies cited.

HRV is an emerging area of research, which has potential for monitoring the effect of exercise on the adaptability of athlete's autonomic nervous system ^(2, 4). Moreover, HRV has emerged as one of the most practical and popular methods to monitor positive and negative aspects in training and recovery responses in athletes ^(14, 33). HRV reflects the cardiovascular control in the physical exercise by the sympathetic and parasympathetic nervous systems, which has been used to evaluate the changes of autonomic functions occurred by acute exercise or training session ⁽³²⁾. Iellamo et al. ⁽²²⁾ and Garet et al. ⁽¹⁸⁾ each suggest that HRV offers important information about the physiological process of recovery after physical exercise, and that it used as an appropriate physiological indicator for training condition.

Heffernan et al. ⁽²⁰⁾, have used HRV data collected at pre-exercise and at 30-min after an exercise protocol to compare the effects of an aerobic training (30-min at 65% of VO_{2max}) and a resistance training (3-set X 10-rep in several exercises). These authors found similar changes in both interventions: increased levels of the LF/HF ratio 30-min after the interventions in comparison with the pre-exercise HRV tests. This would suggest a predominance of the cardiac Sympathetic activity post-exercise. Reflecting on the research of Heffernan and colleagues, Kylosov et al. ⁽²⁶⁾ observed that when exercise is performed with greater volumes, there will be a significant increase in LF and LF/HF ratio and reduction of HF indices post-exercise.

The above-referred suggests a predominance of sympathetic nervous systems over the parasympathetic activity in the autonomic regulation of heart rhythm in athletes after the exercise. Pichot et al. ⁽³⁹⁾ analysed the HRV in middle distance runners with increased training load, and concluded that when the training load is increased there is a proportional increase in the sympathetic response, with increase of LF/HF ratios. The responses of HRV regarding of the LF/HF ratio showed similar results across these studies ^(20, 26, 39), which demonstrates an increase of sympathetic nervous systems activity by LF/HF ratio levels post-exercise. All these studies, including our own, showed that LF/HF ratio is a valuable marker of exercise load. However, it is with great caution that we compare the present study with those studies cited above as each study engaged a different mode of exercise, intensity and volume. Moreover, there is a notable limitation in comparing those studies with the present investigation as no other study followed the physiological recovery of each exercise up to a moment of 72-h after the exercise period.

On the other hand, James et al. ⁽²⁴⁾ did investigate the LF/HF ratio prior to, and up to 72-h period following a single bout of interval training. However, James and colleagues did not observe changes in the LF/HF ratio after 72-h of the interval training session. These authors affirm that the autonomic nervous system is known to be important in the aetiology of the overtraining syndrome and it is generally assumed that HRV recovery should be fully recovered after 72-h of a single bout of running exercise. However, they also claim some exceptions for extremely high intensity exercises (e.g. marathon run) where the fatigue and recovery period can extend beyond 72-h. In the present research, the LF/HF ratio levels increased post-race (reaching peak) and did not return to pre-race values even after 72-h of passive recovery (FIG 6). This would indicate an effect of the 130-km cycling race on sympatho-vagal balance of the heart and a high sympathetic activity up to 72-h recovery period.

This study observed that after strenuous long distance exercise, neuromuscular parameters, muscle soreness and heart rate variability responses peak at different moments in the recovery and require different lengths of recovery periods. Moreover, long distance cycling has a different impact on the rates of all these indices compared to other sports or exercises. This alone reinforces the importance of each variable collected in this research and the specificity of each exercise performed. Demonstrating for coaches and trainers the importance of testing their athletes and comparing results with other research involving same sport subjects and same variable to avoid signs of overtraining and subsequently decrease the rates of injury and fatigue caused by the practice of high intensity sports without an enough rest period.

CONCLUSION

The findings of the present investigation demonstrate that a 130-km cycling race has a noteworthy effect on indices of neuromuscular parameters, muscle soreness and heart rate variability responses, providing compelling evidence to suggest that 72-h may not be enough period of time for long-distance cyclist to recovery. Furthermore, these findings reinforce the earlier propositions of scientific literature about the need of a sufficient recovery period for cycling endurance athletes, pointing out the importance of monitoring those biomarkers of physiological stress and recovery by professionals and coaches for better scheduling and planning of training and competition for athletes.

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RESUMO

A competição apresenta grande valor social em diversos ambientes. No alto rendimento, esta é ainda mais dimensionada necessitando de um incremento maior nas relações humanas. Em esportes de combate como o judô, o contato físico impõe elementos comportamentais variados como resultado da concorrência. Conjectura-se que resultados de confrontos anteriores poderiam influenciar em novos resultados em função das experiências adquiridas pelos indivíduos. O objetivo deste estudo foi investigar através de fonte documental, resultados competitivos de quinze atletas de judô do sexo masculinos (19.10 ± 3.6 anos) em um período de três anos e, verificar se tais resultados (lutas anteriores) foram determinantes para a manutenção de vitórias e/ ou derrotas subsequentes. Os resultados encontrados indicam que: 1 – existia uma coerência entre vencer e perder e luta posterior apenas entre as duas primeiras lutas ao longo do tempo observado; 2 – tal efeito (derrota) tendia a diminuir ao longo do tempo; 3 – as correlações de ganhar ou perder apenas para perdedores podia ser decorrente do nível técnico da amostra; 4 – a distribuição conhecida de habilidades e o efeito observador dos atletas durante os campeonatos analisados podem ter tido influência nos resultados encontrados.

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