Psychophysiological Stress Response of a Paralympic Athlete During an Ultra-Endurance Event. A Case Study

Pedro Belinchón-deMiguel¹ · Pablo Ruisoto-Palomera² · Vicente Javier Clemente-Suárez^{3,4,5}

Received: 3 December 2018 / Accepted: 30 January 2019 / Published online: 9 February 2019
© Springer Science+Business Media, LLC, part of Springer Nature 2019

Abstract

Psychophysiological response of athletes with spinal cord injury has not been reported yet in scientific literature. The aim of this study is to examine the psychophysiological stress response of Paralympic athlete during competitive activities. We collected the following psychophysiological measurements: anxiety-trait, anxiety-state, locus of control, perceived psychological stress, stress-copying style, rate of perceived exertion, perceived muscle pain, body temperature, forced vital capacity, blood oxygen saturation, blood glucose and lactate concentrations, isometric hand strength, cortical arousal, heart rate variability, heart rate and velocities of a female Paralympic spinal cord injured athlete in a 11 h and 44 min ultraendurance mountain event. An ultraendurance mountain even produced an increase in the sympathetic autonomous modulation, heart rate, lactate, muscular pain and rated of perceived exertion and a decrease in cortical arousal, hand strength and respiratory muscle in a spinal cord injury female athlete during. The Paralympic athletes presented a low psychological inflexibility, high life engagement, strong internal locus of control, a low trait and state anxiety and medium perceived psychological stress. These results are consistent with the expected response during a highly stressful situation and consistent with previous findings in athletes without spinal cord injury.

Keywords Psychophysiological stress response · Rate of perceived exertion · Locus of control · Cortical arousal · Spinal cord injury · Heart rate variability

Introduction

Previous researches in athletes with spinal cord injuries (SCI) were focused on the analysis of strength, ergometry and psychological well-being scales, showing that long and short-term physical training is feasible, improving physical and

psychological well-being parameters [1–3]. Specifically, in Paralympic athletes, previous studies were focus in the study of mechanical efficiency [4], the effect of endurance strength training of the upper body musculature [5] and Intervallic training effects [6]. In this line, it was also researched the physical condition of wheelchair athletes attending to different levels of functional classification, determining specific exercise programs for cardiorespiratory improvement [7], examining physiological and performance characteristics such as maximum oxygen uptake (VO₂ max) [8] or trying to predict this parameter [9]. Despite these previous researches, the organic athlete's response in competition are understudied.

In recent years, more athletes have been involved in ultraendurance events like Ironman, 100-km or longer races performed in several days as well as mountain marathons [10–14]. A number of biochemical blood parameters have been analyzed in these ultraendurance athletes like creatinine kinase and urea, showing an increase in muscle destruction and catabolic status of athletes [15]; lactate, showing how the ultraendurance races were performed with a blood lactate concentration below the anaerobic threshold [16]; hemoglobin,

This article is part of the Topical Collection on *Education & Training*

✉ Vicente Javier Clemente-Suárez
vctxente@yahoo.es

¹ Departamento de Enfermería, Facultad de Ciencias Biomédicas y de la Salud, Universidad Europea de Madrid, Madrid, Spain

² Department of Basic Psychology, Psychobiology and Methodology of Human Behavior, University of Salamanca, Salamanca, Spain

³ Faculty of Sports Sciences, Universidad Europea de Madrid, Madrid, Spain

⁴ Grupo de Investigación en Cultura, Educación y Sociedad, Universidad de la Costa, Barranquilla, Colombia

⁵ Faculty of Sport Sciences, Department of Sport Science, Calle Tajo, s/n, 28670 Villaviciosa de Odón, Madrid, Spain

maintaining the hemoglobin values due to increased erythropoiesis to compensate for exercise-induced hemolysis [17]; triglycerides, showing an increase in the consumption of triglycerides as energetic substrate [18]; creatinine, showing normal renal function [19]. Also, novel studies tried to improve performance by using of vitamin E megadose to compensate muscular catabolism [20]. It has been large studied the use of caffeine and nonsteroidal anti-inflammatory drugs (NSAIDs) in ultraendurance races. Previous researches found how in longer distance probes, athletes consumed significantly higher number of NSAIDs, being especially dangerous when is combined with a poor hydration strategy. Regarding caffeine intake, has been reported an increase in caffeine consumption in higher distance probe that could be explained since they consume more gels and isotonic drink with caffeine [21]. Regarding nutrition and hydration strategies in ultraendurance events previous researchers reported how higher performance athletes of longer distance presented higher water and nutritional ingestion than the lower ones [21].

Regarding the heart rate (HR) response, during a 21-h ultraendurance event athletes reached the 71% of maximum heart rate (HRmax) [22], and the heart rate variability (HRV) after an Ironman showed the increase in sympathetic modulation [23] and the increase in the rated of perceived exertion (RPE) [24]. In these extreme probes, different psychological variables are showing their importance, especially the constructs of vital commitment, coping with anxiety, self-perception, stress perception and psychological inflexibility [25–29]. Low perception of pain may predispose a person to become a long-distance athlete [30], examining a greater automatic suggestibility of ultraendurance athlete's behaviour than normal population [31]. These ultraendurance athletes perceived problems and challenges as a positive experience, assuming them as a challenge to test their own abilities [31, 32], showing the expert athletes more proactive cognitions than novices [33]. The unique case research, in the field of sports psychology, has steadily increased in recent years [34] and ratifying this interest among researchers and professional psychologists, some authors suggest that the work of applied psychologists represents an important component of any scientific literature [35]. The unique case designs allow researchers to work in applied environments and apply procedures in the professional field, as well as establish protocols for action with elite, professional or top-level athletes [36]. And regarding the study of cases in Paralympic athletes, it must be considered that they represent a unique case each of them.

The inclusion of SCI athletes to the new sport modalities as ultraendurance and mountain event have been previously limited by technical deficiencies in wheelchairs, then the preparation of these athletes for this new modality is already unknown. In this context, there is a lack of research focused in the psychophysiological response of athletes with SCI during competitive activities, even less in the female population and in ultraendurance

events. For this reason, the present research aimed to study the psychophysiological response of a Paralympic female athlete in an ultraendurance mountain event.

Methods

Participant

We analyzed the athlete G.H.B., Paralympic fencing medallist in sword and foil modes, and one of the few Spanish elite athletes who has participated in five consecutive Paralympic Games - Atlanta, Barcelona, Sydney, Athens and Beijing. She obtained twelve Olympic titles, remaining between the best eight Paralympic athletes in her modality for years. She was also in podium in a National European and World Championships. The athlete participated voluntarily, filling up an informed consent in which the disclosure of her personal data was included, following the procedures of the Helsinki Protocol.

Ultraendurance probe

We analyzed an ultraendurance race consisted in run to the top of the Abantos mountain (Madrid, Spain) defined by the following parameters: 11.5 km of length and 1640 m of altitude, accumulative altitude changes of 1240 m and 620 m uphill. The participant completed the race in a time of 11 h and 44 min in a proposed mountain handbike prototype (Fig. 1).

Procedure

The day before the ultraendurance event a psychological test battery was completed by the athlete. The following tests were delivered: Spielberger State-Trait Anxiety Inventory (STAI) that is one of the most frequently used to measure anxiety in applied psychology research. Since its reliability and sensitivity [25]; Rotter locus of Control, internal versus external control of reinforcement, often referred to as locus of control, is

Fig. 1 Hand bike prototype used during the ultraendurance mountain event

currently one of the most studied variables in psychology and social sciences [26]; the Perceived Stress Scale (PSS), that evaluate the degree of which people find that life is unpredictable, uncontrollable, or overloaded [27]; the AFQ-8 to study the relationship between psychological inflexibility [28]; and the Life Engagement Test, designed to measure purpose in life, defined in terms of the extent to which a person engages in activities that are personally valued [29].

The probe day, we measured before, during and after the mountain ultraendurance event different psychophysiological parameters depending of the availability of the athlete and the possibility of move the equipment to the different part of the mountain race. The parameters and the procedure to measure were as follow.

- Rate of perceived exertion (RPE) by the 6–20 scale (Borg 1970).
- Perceived muscle pain in a self-reported 1–100 scale.
- Body temperature (BT) by a digital infrared thermometer (Temp Touch; Xilas Medical, San Antonio, TX).
- Forced vital capacity (FVC) using a QM-SP100 (Quirumed, Spain) spirometer in a maximum inhale-exhale cycle.
- Blood oxygen saturation (BOS) and Heart Rate (HR) by a pulse oximeter (PO 30 Beurer Medical).
- Blood glucose concentration by the analysis of 5 μ l of capillary finger blood using a portable analyzer (One Touch Basic, LifeScan Inc. Madrid)
- Blood lactate concentration taking a sample of 5 μ l capillary blood from a finger of subjects and analyzed with the Lactate Pro II Arkay, Inc. system (Kyoto, Japan).
- Isometric Hand Strength (IHS) of both hands, by a grip dynamometer (Takei Kiki Koyo, Japan).
- Cortical arousal through the Critical Flicker Fusion Threshold (CFFT) in a viewing chamber (Lafayette Instrument Flicker Fusion Control Unit Model 12,021) following the procedures conducted in previous studies [37, 38]. An increase in CFFT suggests an increase in cortical arousal and information process, by contrast, when the values fall below the baseline, it suggests a reduction in the efficiency to process information and fatigue of central nervous system [39].

The athlete also wore a GPS device (SPI Elite; GPSports Systems, Canberra, Australia) inserted in a purpose-built backpack that recorded speed and distance, as well as a HR transmitter belt (Polar Electro, Kempele, Finland) to incorporate HR data. Athlete's accelerations were also recorded using a triaxial built-in accelerometer with an operational sampling rate of 100 Hz. After collection, data were downloaded to a personal computer where further analysis was carried out with Team AMS software (GPSports, V1.2, Canberra, Australia) following the procedure of previous research [40, 41]. In addition, the

participant wore a polar v800 heart rate monitor (Polar Electro Oy, Finland) validated to analyze RR function to analyze heart rate variability (HRV) and used by previous researchers [42, 43]. We analyzed (i) 20 min of HRV before the race as a HRV baseline, (ii) the first 3:35 probe time (iii) the time period between 3:35 and 6:12 probe time, (iv) the time period between 6:12 and 8:00 probe time, (v) the time period between 8:00 and 11:44 probe time. We used Kubios HRV software (University of Kuopio, Kuopio, Finland) to analyze the sum of the squared differences between adjacent normal R-R intervals (RMSSD) variable of HRV temporal domain. The complete moments of measurements are shown in Table 1.

Results and discussion

Psychological measurements

Reported trait anxiety [17] and state-anxiety [10] were below percentile 50. Score in the locus of control scale was 5, indicating a strong internal locus of control, in other words, the athlete attributes the cause of success or failure is perceived as the result of variables of which the subject has some degree of control and direct responsibility: his own abilities, effort or persistence. Reported perceived psychological stress [30] was above percentile 50. However, it is characterized by a healthy coping style: low psychological inflexibility and high life engagement, both good predictors of well-being and psychological health, that would mitigate the harmful effects of stress [25–29].

Psychophysiological measurements

The athlete's metabolic response (Table 1) showed how blood lactate concentration was maintained below the anaerobic threshold, as well as previous ultraendurance studies conducted with cyclists, swimmers or kayakers [11, 16]. The long duration of the event prevented the maintenance of a high intensity and thus the accumulation of large quantities of lactate; in addition, the low intensity of the race permitted the use of the accumulated lactate as an energy substrate, decreasing its concentration [14]. However, blood glucose fluctuated, showing a decrease in the middle of the event (over the 6 h), possibly due to a poor nutritional strategy planning [24], fact that occasioned discomfort, headache and dizziness to the athlete. Despite this fluctuation and taking into consideration the normal glucose limits [44], she did not presented hypoglycemia, remarking her lower glucose values as professional athletes, being both lower than healthy sedentary population [45].

Despite the low values of blood lactate obtained during the ultraendurance event, the RPE increased progressively reaching the maximum value at the end of the event. These values were higher than those recorded in triathletes (Ironman

Table 1 Changes in physiological measurements during the ultraendurance event

Parameter	Unit	Previous day	Pre race	3:35	6:12	8:00	11:44	post 10 h	post 15 h	post 21 h
Sat O ₂	%	99	97	97	96	94	96			
HR	bpm	60	99	117	128	119	125			
RPE	—	6	6	10	16	18	20			
RIHS	kg	34.3	37.3	41.3	35.5	33.1	32.6			
LIHS	kg	35.5	38.7	37.4	38.1	39.4	32.5			
FVC	ml	3900	3700	3400	3600	3100				
Temperature	°C	36.2	35.1	37.4	33.1	35.4				
Lactate	mmol/l	1.8	2.1	3.1	3	3.1				
Glucose	mmol/l	8.6	9	8.5	6.7	9.2				
Cortical arousal	Hz	27.6	29.6	30	28.1	25.2	26.1			
Muscular Pain	1–100	10	5	5	40	60	75	90	27	25
RMSSD	Ms	16.4	17.3	8.9	7.4	7.0	6.5			

Sat O₂ Blood oxygen saturation, HR Heart rate, RPE Rating of perceived effort, RIHS Right isometric hand strength, LIHS Left isometric hand strength, FVC Forced vital capacity, RMSSD Sum of the squared differences between adjacent normal R-R intervals

modality) or after a 3 and 5 h cycloergometer tests [16, 24]. The cortical accumulation of adenosine in neurons due to the high consumption of ATP during the event may have produced these high RPE values [46]. Thus, despite a low concentration of blood lactate, the Paralympic athlete perceived the ultraendurance event as a highly stressful effort. However, muscle pain remained low and moderate during the event reaching the highest peak ten hours after the event, which is in line with previous research that determines that the low perception of pain can predispose an athlete to become a long-distance athlete [30]. Also, this low value could be explained since the higher increases of Creatine Kinase, enzyme related with muscle destruction, occurs after 24 h of finishing ultraendurance events [15].

Previous studies have shown the efficacy of cortical arousal evaluation to control neuromuscular fatigue during strength training. In the present research, cortical arousal was evaluated using the CFFT as a potentially useful measure for the direct and efficient estimation of central nervous system status as previous studies demonstrated [47]. In addition, this procedure could be useful in preventing injuries and avoiding overload during strength training sessions as well as ultraendurance races. The results of the athlete showed a decrease in the cortical activation at the end of the race, as well as after a mountain marathon, fact that could decrease the brain ability to voluntarily send a signal to the neuromuscular junction, decreasing the muscular contraction and performance, being considered a cause of sport fatigue [47]. This fact is related with the decrease in hand strength that showed the athlete at the end of the race [48]. Also, is important to remark the similar response in cortical arousal and hand strength, following the same increases and decreases tendencies during the race and showing the connection between cortical arousal and strength performance.

The HR (Fig. 2) shown a low basal HR explained by the high training status of the Paralympic athlete as well as professional athletes [22]. We can see a dentate shape in his HR, due to continuous small stops after pedaling, not being a continuous work. In addition, we can observe how in the second and third race sections the HR was higher and in the recovery phase did not decrease as in the first section, showing the effect of fatigue. Therefore, the results obtained were consistent with previous studies that determined that ultraendurance athletes require the ability to maintain a steady long-term performance at a high exercise intensity [15]. In this line, the sympathetic activation presented by the Paralympic athlete since the previous moments of the race showed an anticipatory anxiogenic response, also during the race an increase in sympathetic response was observed, as previous studies conducted in mountain ultraendurance runners [14], but with lower values of RMSSD, showing a higher impact of the ultraendurance race for the Paralympic athlete. The HRV seems to be an important tool to control, asses and predict sport performance, especially in ultraendurance events, since previous studies could differentiate fastest and lowest athletes in this probe only using this parameter [49], and it has been identified as an efficiency tool to control workload during training and physiological response in extreme ambient as well [50].

Regarding the respiratory muscle response, we found a decrease of FVC values after the race, fact that reflect a fatigue of respiratory muscle and remark the necessity for specific training of these musculature. The respiratory muscle fatigue may be involved in limiting exercise tolerance or that other factors, including alterations in the sensation of dyspnea or mechanical load, may be important. The major consequence of respiratory muscle fatigue is an increased sympathetic vasoconstrictor outflow to working skeletal muscle through a respiratory muscle metaboreflex, thereby reducing limb blood

Fig. 2 Changes in heart rate and speed during the ultraendurance event

flow and increasing the severity of exercise induced locomotor muscle fatigue. In terms of O₂ saturation the results show

constant levels during the race which helped the athlete to delay the onset of muscle fatigue [51].

An important fact observed in the present research was the no difference in the psychophysiological response of the Paralympic spinal cord injured athlete and athletes without injury. This fact allows us that training methodologies used in no injured athletes could be used in spinal cord injured athletes to improve their performance in ultraendurance events [8]. In this line new training model based on high intensity as reverse training periodization could be an effective election for these athletes [52, 53].

Current research sets the foundations for future studies on ultraendurance in athletes with spinal cord injury. Due to the special condition of athletes suffering from spinal cord injury, the psychological aspect has been extensively studied in the present study because it is a key point in the ultraendurance probes and it may be that the athletes with this injury have it specially developed, which It needs more research. Regarding the more physical aspects, the present investigation has proved to be consistent with previous findings in athletes without spinal cord injury therefore it can help athletes suffering from spinal cord injury to develop more suitable training in ultraendurance events.

Conclusion

An ultraendurance mountain even produced an increase in the sympathetic autonomous modulation, heart rate, lactate, muscular pain and rated of perceived exertion and a decrease in cortical arousal, hand strength and respiratory muscle in a spinal cord injury female athlete during. The Paralympic athletes presented a low psychological inflexibility, high life engagement, strong internal locus of control, a low trait and state anxiety and medium perceived psychological stress.

Funding This study was partially founded by the project 2016/UEM26.

Compliance with ethical standards

Conflict of interest None.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

- Hicks, A., Martin, K., Ditor, D., Latimer, A., Craven, C., Bugaresti, J. et al., Long-term exercise training in persons with spinal cord injury: effects on strength, arm ergometry performance and psychological well-being. *Spinal Cord* 41(1):34, 2003.
- Jacobs, P. L., Nash, M. S., and Rusinowski, J. W., Circuit training provides cardiorespiratory and strength benefits in persons with paraplegia. *Med. Sci. Sports Exerc.* 33(5):711–717, 2001.
- Ditor, D., Latimer, A., Ginis, K. M., Arbour, K., McCartney, N., and Hicks, A., Maintenance of exercise participation in individuals with spinal cord injury: effects on quality of life, stress and pain. *Spinal Cord* 41(8):446, 2003.
- Brizuela, G., Polo, M., Martos, J., Sanchis, E., Influencia del diámetro del aro de propulsión sobre la frecuencia cardiaca y la lactacidemia en un atleta en silla de ruedas de elite mundial. *Motricidad. Eur. J. Hum. Mov.* 16, 2006.
- Turbanski, S., and Schmidtleicher, D., Effects of heavy resistance training on strength and power in upper extremities in wheelchair athletes. *J. Strength Cond. Res.* 24(1):8–16, 2010.
- Tordi, N., Dugue, B., Klupzinski, D., Rasseneur, L., Rouillon, J., and Lonsdorfer, J., Interval training program on a wheelchair ergometer for paraplegic subjects. *Spinal Cord* 39(10):532, 2001.
- Keyser, R. E., Rasch, E. K., Finley, M., and Rodgers, M. M., Improved upper-body endurance following a 12-week home exercise program for manual wheelchair users. *J. Rehabil. Res. Dev.* 40(6):501, 2003.
- Lakomy, H. K., Campbell, I., and Williams, C., Treadmill performance and selected physiological characteristics of wheelchair athletes. *Br. J. Sports Med.* 21(3):130–133, 1987.
- Vinet, A., Le Gallais, D., Bouges, S., Bernard, P., Poulain, M., Varray, A. et al., Prediction of VO₂peak in wheelchair-dependent athletes from the adapted Leger and Boucher test. *Spinal Cord* 40(10):507, 2002.
- Suarez, V. J. C., Arroyo, Victor Eugenio Munoz Fernandez, Campo DR, Valdivielso FN, Rave JMG, Santos-Garcia DJ. Analysis of selected physiological performance determinants and muscle damage in a 24-hour ultra-endurance relay race: Brief clinical report. *Int. SportMed. J.* 12(4):179–186, 2011.
- Suarez, V. C., Valdivielso, F. N., and Rave, J. M. G., Changes in biochemical parameters after a 20-hour ultra-endurance kayak and cycling event. *Int. SportMed. J.* 12(1):1–6, 2011.
- Page, A. J., Reid, S. A., Speedy, D. B., Mulligan, G. P., and Thompson, J., Exercise-associated hyponatremia, renal function, and nonsteroidal antiinflammatory drug use in an ultraendurance mountain run. *Clin. J. Sport Med.* 17(1):43–48, 2007.
- Belinchon-deMiguel, P., and Clemente-Suárez, V. J., Psychophysiological, Body Composition, Biomechanical and Autonomic Modulation Analysis Procedures in an Ultraendurance Mountain Race. *J. Med. Syst.* 42(2):32, 2018.
- Clemente-Suárez, V. J., Psychophysiological response and energy balance during a 14-h ultraendurance mountain running event. *Appl. Physiol. Nutr. Metab.* 40(3):269–273, 2014.
- Neumayr, G., Ganzer, H., Stumm, W., Pfister, R., Mitterbauer, G., and Hortnagl, H., Physiological effects of an ultra-cycle ride in an amateur athlete - a case report. *J. Sports Sci. Med.* 1(1):20–26, 2002.
- Laursen, P. B., Rhodes, E. C., and Langill, R. H., The effects of 3000-m swimming on subsequent 3-h cycling performance: implications for ultraendurance triathletes. *Eur. J. Appl. Physiol.* 83(1):28–33, 2000.
- Schumacher, Y. O., Jankovits, R., Bültermann, D., Schmid, A., and Berg, A., Hematological indices in elite cyclists. *Scand. J. Med. Sci. Sports* 12(5):301–308, 2002.

18. Fallon, K. E., Sivyver, G., Sivyver, K., and Dare, A., The biochemistry of runners in a 1600 km ultramarathon. *Br. J. Sports Med.* 33(4): 264–269, 1999.
19. Warburton, D. E., Welsh, R. C., Haykowsky, M. J., Taylor, D. A., and Humen, D. P., Biochemical changes as a result of prolonged strenuous exercise. *Br. J. Sports Med.* 36(4):301–303, 2002.
20. Clemente-Suárez, V., Mielgo-Ayuso, J., Quiles, J., Varela-Lopez, A., and Aranda, P., Effect of α -tocopherol megadoses on hematologic parameters and antioxidant capacity of rats in an ultraendurance probe. *Physiol. Int.* 104(4):291–300, 2017.
21. Belinchon-Demiguel, P., and Clemente-Suarez, V. J., Nutrition, hydration and ergogenic aids strategies in ultraendurance mountain events. *J Sports Med Phys Fitness*, 2018. <https://doi.org/10.23736/S0022-4707.18.08920-X>.
22. Neumayr, G., Pfister, R., Mitterbauer, G., Gaenger, H., Sturm, W., and Hoertnagl, H., Heart rate response to ultraendurance cycling. *Br. J. Sports Med.* 37(1):89–90, 2003 Feb.
23. Gratzke, G., Rudnicki, R., Urban, W., Mayer, H., Schlogl, A., and Skrabal, F., Hemodynamic and autonomic changes induced by Ironman: prediction of competition time by blood pressure variability. *J. Appl. Physiol.* (1985) 99(5):1728–1735, 2005.
24. Jeukendrup, A. E., Moseley, L., Mainwaring, G. I., Samuels, S., Perry, S., and Mann, C. H., Exogenous carbohydrate oxidation during ultraendurance exercise. *J. Appl. Physiol.* 100(4):1134–1141, 2006.
25. Marteau, T. M., and Bekker, H., The development of a six-item short-form of the state scale of the Spielberger State–Trait Anxiety Inventory (STAI). *Br. J. Clin. Psychol.* 31(3):301–306, 1992.
26. Rotter, J. B., Internal versus external control of reinforcement: A case history of a variable. *Am. Psychol.* 45(4):489, 1990.
27. Remor, E., Psychometric properties of a European Spanish version of the Perceived Stress Scale (PSS). *Span. J. Psychol.* 9(1):86–93, 2006.
28. Simon, E., and Verboon, P., Psychological inflexibility and child anxiety. *J. Child Fam. Stud.* 25(12):3565–3573, 2016.
29. Scheier, M. F., Wrosch, C., Baum, A., Cohen, S., Martire, L. M., Matthews, K. A. et al., The life engagement test: Assessing purpose in life. *J. Behav. Med.* 29(3):291, 2006.
30. Freund, W., Weber, F., Billich, C., Birklein, F., Breimhorst, M., and Schuetz, U. H., Ultra-Marathon Runners Are Different: Investigations into Pain Tolerance and Personality Traits of Participants of the TransEurope FootRace 2009. *Pain Pract.* 13(7):524–532, 2013.
31. Schütz, U. H., Schmidt-Trucksäss, A., Knechtle, B., Machann, J., Wiedelbach, H., Ehrhardt, M. et al., The TransEurope Footrace Project: longitudinal data acquisition in a cluster randomized mobile MRI observational cohort study on 44 endurance runners at a 64-stage 4,486 km transcontinental ultramarathon. *BMC Med.* 10(1):78, 2012.
32. Steyn, B. J., Strategies used by South African non-elite athletes to cope with the environmental stressors associated with endurance events. *S. Afr. J. Res. Sport Phys. Educ. Recreation* 29(2):99–107, 2007.
33. Baker, J., Côté, J., and Deakin, J., Cognitive characteristics of expert, middle of the pack, and back of the pack ultra-endurance triathletes. *Psychol. Sport Exerc.* 6(5):551–558, 2005.
34. McCarthy, P., Barker, J., Jones, M., and Moran, A. P., *Single-case research methods in sport and exercise psychology*. London: Routledge, 2011.
35. Keegan, R. J., Schinke, R., Chirban, S., Durand-Bush, N., and Cotterill, S., Guidelines for writing applied case studies in sport and exercise psychology. *Rev. Psicol. Deporte*. 26(3):85–90, 2017.
36. Kinugasa, T., The application of single-case research designs to study elite athletes' conditioning: An update. *J. Appl. Sport Psychol.* 25(1):157–166, 2013.
37. Clemente-Suarez, V. J., and Robles-Pérez, J. J., Acute effects of caffeine supplementation on cortical arousal, anxiety, physiological response and marksmanship in close quarter combat. *Ergonomics* 58(11):1842–1850, 2015.
38. Clemente-Suárez, V. J., and Arroyo-Toledo, J., Use of biotechnology devices to analyze fatigue process in swimming training. *J. Med. Syst.* 41(6):94, 2017.
39. Saito, S., Does fatigue exist in a quantitative measurement of eye movements? *Ergonomics* 35(5–6):607–615, 1992.
40. Clemente-Suárez, V. J., de la Vega, R., Robles-Pérez, J. J., Lautenschlaeger, M., and Fernández-Lucas, J., Experience modulates the psychophysiological response of airborne warfighters during a tactical combat parachute jump. *Int. J. Psychophysiol.* 110: 212–216, 2016.
41. Clemente-Suarez, V. J., and Robles-Perez, J. J., Mechanical, physical, and physiological analysis of symmetrical and asymmetrical combat. *J. Strength Cond. Res.* 27(9):2420–2426, 2013.
42. Beltrán-Velasco, A. I., Bellido-Esteban, A., Ruisoto-Palomera, P., and Clemente-Suárez, V. J., Use of Portable Digital Devices to Analyze Autonomic Stress Response in Psychology Objective Structured Clinical Examination. *J. Med. Syst.* 42(2):35, 2018.
43. Clemente-Suárez, V. J., Robles-Pérez, J. J., and Fernández-Lucas, J., Psycho-physiological response in an automatic parachute jump. *J. Sports Sci.* 35(19):1872–1878, 2017.
44. Fox, S. I., Agud Aparicio, L. J., *Fisiología humana*, 2003.
45. Lippi, G., Brocco, G., Franchini, M., Schena, F., and Guidi, G., Comparison of serum creatinine, uric acid, albumin and glucose in male professional endurance athletes compared with healthy controls. *Clin. Chem. Lab. Med.* 42(6):644–647, 2004.
46. Langberg, H., Bjørn, C., Boushel, R., Hellsten, Y., and Kjaer, M., Exercise-induced increase in interstitial bradykinin and adenosine concentrations in skeletal muscle and peritendinous tissue in humans. *J. Physiol.* 542(3):977–983, 2002.
47. Clemente-Suárez, V. J., The application of cortical arousal assessment to control neuromuscular fatigue during strength training. *J. Mot. Behav.* 49(4):429–434, 2017.
48. Clemente-Suárez, V. J., Cortical arousal and central nervous system fatigue after a mountain marathon. (Activación cortical y fatiga del sistema nervioso después de una maratón de montaña). *CCD.* 12(35):143–148, 2017. <https://doi.org/10.12800/ccd.v12i35.886>.
49. Vallverdú, M., Ruiz-Muñoz, A., Roca, E., Caminal, P., Rodríguez, F. A., Irurtia, A., and Perera, A., Assessment of Heart Rate Variability during an Endurance Mountain Trail Race by Multi-Scale Entropy Analysis. *Entropy* 19(12):658, 2017.
50. Clemente-Suárez, V. J., and Arroyo-Toledo, J. J., The Use of Autonomic Modulation Device to Control Training Performance after High-Intensity Interval Training Program. *J. Med. Syst.* 42(3):47, 2018.
51. Hormeño-Holgado, A. J., Perez-Martinez, M. A., and Clemente-Suárez, V. J., Psychophysiological response of air mobile protection teams in an air accident manoeuvre. *Physiol. Behav.* 199:79–83, 2019.
52. Clemente-Suarez, V. J., Periodized training archive better autonomic modulation and aerobic performance than non periodized training. *J. Sports Med. Phys. Fitness* 58(11):1559–1564, 2018. <https://doi.org/10.23736/S0022-4707.17.07582-X>.
53. Clemente-Suárez, V. J., Dalamitros, A., Ribeiro, J., Sousa, A., Fernandes, R. J., and Vilas-Boas, J. P., The effects of two different swimming training periodization on physiological parameters at various exercise intensities. *Eur. J. Sport Sci.* 17(4):425–432, 2017.