A complete psychophysiological profile of a Paralympic athlete in a ultraendurance. A case study

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ABSTRACT

Psychophysiological response of athletes with spinal cord injury has not been reported yet in scientific literature. The aim of this study is to analyze the specific psychophysiological response in a 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 hours and 44 minutes mountain ultraendurance event. An increase in sympathetic autonomous nervous system, heart rate, lactate, muscular pain and rated of perceived exertion and a decrease in cortical arousal and hand strength and inspiratory muscle fatigue. These results are consistent with the expected response during a highly stressful situation and consistent with previous findings in athletes without spinal cord injury.

CCS Concepts

• **Applied computing~Health care information systems** •
• **Computer systems organization~Special purpose systems** •
• **Hardware~Emerging tools and methodologies** •
• **Hardware~Biology-related information processing**

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Keywords

Strength; Rate of perceived exertion; Lactate; Cortical Arousal; Spinal cord Injury.

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1 INTRODUCTION

Previous researches in athletes with spinal cord injuries (SCI) were focused on the analysis of strength, ergometry and psychological well-being, showing that long-term and short-term physical training is feasible, improving physical and psychological well-being [1-3]. Specifically, in Paralympic athletes, previous studies were focused 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 has also been investigated the physical condition of wheelchair athletes attending to different levels of functional classification, determining 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 races, such as the Ironman, 100-km or longer races performed in several days and mountain marathons [10-14]. A number of biochemical blood parameters have been analyzed in ultraendurance athletes such as creatinine kinase and urea, showing an increase in muscle destruction and catabolic status of athletes [15]; lactate, showing how the ultraendurance runs are performed with a blood lactate

concentration below the anaerobic threshold [16]; hemoglobin, maintenance of hemoglobin values due to increased erythropoiesis to compensate for exercise-induced hemolysis [17]; triglycerides, an increase in the consumption of triglycerides as energetic substrate [18]; creatinine, shows normal renal function that evaluates creatinine parameters and creatinine clearance [19]. In this line, novel studies tried to improve performance with the use of vitamin E megadosis [20], although more studies are necessary to delimit the best ergogenic aids in this field. Another study analyzed athletes heart rate (HR) response during a 21-hour ultraendurance event, measuring how the race was performed at 71% of maximum heart rate (HRmax) [21]. They also analyzed heart rate variability (HRV) after an Ironman race and found an increase in sympathetic modulation of the autonomic nervous system indicated by a decrease in high frequency values and an increase in the low frequency [22]. In addition, a parameter of subjective perception of intensity as is, the rating of perceived effort (RPE), showed values between 13 and 14 points on the 6-20 RPE scale [23]. 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 [24-28]. Previous studies have seen that low perception of pain may predispose a person to become a long-distance athlete [29], examining a greater automatic suggestibility of ultraendurance athlete's behavior than normal population [30]. These ultraendurance athletes perceived problems and challenges as a positive experience, assuming them as a challenge to test their own abilities [30,31], showing the expert athletes more proactive cognitions than novices [32]. The unique case research, in the field of sports psychology, has steadily increased in recent years [33] 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 [34]. 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 [35]. 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 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.

2 METHODS

2.1. Participants

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.

2.2. Ultraendurance Probe

The probe consisted in an ultraendurance race defined by the following parameters: length: 11,5 kilometers, height of 1640 meters (ascension of Abantos in Madrid, Spain), accumulative altitude change of 1240 meters and 620 meters uphill. The participant completed the of in a time of 11 h and 44 min in a proposed mountain handbike prototype (Figure 1).

2.3. 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 [24]; Rotter locus of Control, internal versus external control of reinforcement, often referred to as locus of control, is currently one of the most studied variables in psychology and social sciences [25]; the Perceived Stress Scale (PSS), that evaluate the degree of which people find that life is unpredictable, uncontrollable, or overloaded [26]; the AFQ-8 to study the relationship between psychological inflexibility [27]; 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 [28].

Figure 1 Hand bike prototype used during the ultraendurance mountain event

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 µl of capillary finger blood using a portable analyser (One Touch Basic, LifeScan Inc. Madrid)
- Blood lactate concentration taking a sample of 5 ul capillary blood from a finger of subjects and analysed 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 12021) following the procedures conducted in previous studies [36,37]. 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 [38].

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 [39,40]. In addition, the participant wore a polar v800 heart rate monitor (Polar Electro

Oy, Finland) validated to analyse RR function to analyse heart rate variability (HRV) and used by previous researchers [1,42]. We analysed (i) 20 minutes 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 analyse 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.

3 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 very 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 [24-28].

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 6h), possibly due to a poor nutritional strategy planning [23], fact that occasioned discomfort, headache and dizziness to the athlete. Despite this fluctuation and taking into consideration the normal glucose limits [43], she did not presented hypoglycemia, remarking her lower glucose values as professional athletes, being both lowers than healthy sedentary population [44].

Table 1. Changes in physiological measurements during the ultraendurance event

Parameter	unity	Previous day	pre	3:35	6:12	8:00	11:44	post 10 h	post 15 h	post 21 h
BOS	%	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				

BOS: 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.

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 modality) or after a 3 and 5 hours cycloergometer tests [16,23]. The cortical accumulation of adenosine in neurons due to the high consumption of ATP during the event may have produced these high RPE values [45]. 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 [29]. Also, this low value could be explained since the higher increases of CreatinKinase, enzyme related with muscle destruction, occurs after 24h 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 [46]. 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, this 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. This fact is related with the decrease in hand strength that showed the athlete at the end of the race [47]. Also, is important to remark the similar response in cortical arousal and hand strength, following the same increases and decreases tendencies during the race.

The HR (figure 2) shown a low basal HR explained by the high training status of the Paralympic athlete as well as professional athletes [21]. 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 tranche the HR is higher and in the recovery phases

does not decrease as in the first tranche, clearly seeing the effect of fatigue. Therefore, the results obtained are 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 [48], and it has been identified as an efficiency tool to control workload during training as well [49].

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 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 [50].

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 [51,52].

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

4 CONCLUSIONS

An increase in sympathetic autonomous nervous system, heart rate, lactate, muscular pain and rated of perceived exertion and a decrease in cortical arousal and hand strength and inspiratory muscle fatigue in a spinal cord injury female athlete during an ultraendurance mountain event. These results are consistent with the expected response during a highly stressful situation and consistent with previous findings in athletes without spinal cord injury.

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