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Section II - Exercise Physiology & Sports Medicine

Acute Physiological Responses to Ultra Short Race-Pace Training in Competitive Swimmers

by

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Ultra Short Race Pace training (USRPT) is an emerging training modality devised in 2011 to deviate from high-volume swimming training that is typically prescribed. USRPT aims to replicate the exact demands of racing, through its unique prescription of race-pace velocity sets with short rest intervals. It has been surmised, with little physiological evidence, that USRPT provides swimmers with the best opportunity to optimize the conditioning, technique, and psychology aspects of racing at the most specific velocity of the relevant event, with low blood lactate concentration. The aim of this study was to examine acute physiological responses of USRPT. Fourteen swimmers were recruited to perform a USRPT set: 20 x 25 m freestyle with a 35-s rest interval. Swimmers were required to maintain the velocity of their 100 m personal best time for each sprint. Sprint performance, blood lactate, heart rate and the RPE were measured. Blood lactate was taken before, during (after every 4 sprints) and 3 minutes after the USRPT protocol. Heart rate monitors were used to profile the heart rate. Athletes reported the RPE before- and after completion of the USRPT set. Sprint times increased by 3.3-10.8% when compared to the first sprint ($p < 0.01$). There was high blood lactate concentration (13.6 ± 3.1mmol/l), a significant change in the RPE from 8 ± 1.6 to 18 ± 1.6 ($p < 0.01$) and a substantially high heart rate profile with an average HR_{max} of 188 ± 9 BPM. The results show the maximal intensity nature of USRPT and portray it as an anaerobic style of training.

Key words: *swimming, high-intensity, heart-rate, blood-lactate, sprinting, and performance.*

Introduction

The world of swimming has long discussed and argued whether training faster or training longer would enhance performance results (Maglischo, 2003). This issue still exists in swimming and has now been formally classified as the ‘quality vs. quantity’ debate in scientific literature (Nugent et al., 2017b). The quality side of the debate argues that swimming programmes need to be based on low-volume training swum at high intensities, more generally known as High Intensity Training (HIT). Opposing, the quantity side of the debate argues that High-Volume Training (HVT) at low intensities, will better enhance swimming performance.

Traditionally, swimming coaches favour HVT and continually incorporate high-volume, low-intensity, aerobic training sets (Nugent et al., 2017a; Nugent et al., 2017b). Hibberd and Myers (2013) report HVT swimmers at youth level average 38 – 44 km a week, while, Pyne et al. (2001) report HVT elite swimmers cover 54 ± 19 km a week. It is now well established that reducing training volume and increasing high intensity swimming will not have a detrimental effect on swimming performance; thus, the rationale for large swimming distances is being questioned (Faude et al., 2008; Kilen et al., 2014; Pugliese et al., 2015; Sperlich et al., 2010; Termin and Pendergast, 2000). However, differences in training status and load prescription within these studies make it difficult to quantify the optimal HIT training load for elite athletes. The necessity for a more structured HIT protocol was identified and developed as a result.

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Rushall (2018) introduced Ultra Short Race-Pace Training (USRPT) as the swimming's newest specific HIT training modality for all populations. The USRPT training program has been designed and developed to incorporate the maximum amount of race-pace swimming possible during training sessions. It requires the athlete to repeatedly swim at a prescribed race-pace, over short distances, with short rest intervals; usually lasting no longer than 20 s. The swimmer must hold the prescribed race-pace for as long as possible. Competitive swimmers who have adopted the USRPT training method cover approximately 9 – 11 km per week (Stott, 2014). HIT training incorporates repeated bouts of high intensity exercise, from the maximal lactate steady state to supra-maximal exercise intensity, alternated with brief periods of low-intensity work or complete rest (Hawley et al., 1997). USRPT can therefore be classified as a type of HIT.

USRPT is gaining more attention among coaches, particularly with the ongoing success of Michael Andrew, an elite professional swimmer who utilises this type of swim-training (ISCA, 2015). Rushall (2018) states USRPT aims to better prepare athletes for the actual demands of racing in swimming. While traditional swimming training or HVT covers far more distance in metres, USRPT covers a much greater distance at the race-pace, which makes it highly specific to the athlete's event in competitive swimming. The concept behind swimming ultra-short distances at the race-pace, with short rest intervals, is to exploit Rushall's claimed physiological phenomenon. He asserts that training on such short intervals will allow swimmers to maintain low to no levels of blood lactate in conjunction with maintaining high levels of glycogen within the muscles, whilst repeatedly performing at maximal intensities (Rushall, 2018). Rushall goes on to state that traditional swimming training lacks the specific race-pace, and its style varies work-to-rest ratios, energy systems and strokes, which ultimately prevents skill-learning at a suitable velocity. He concludes that USRPT should replace traditional swimming, promoting it as the only style of swimming training that specifically replicates the demands of competitive swimming (Rushall, 2018).

Despite numerous articles describing the theoretical evidence appearing on Swimming Science Bulletin (Rushall, 2013, 2018), to the best of our knowledge there are no peer–reviewed published studies supporting the proposed physiological outcomes of USRPT. Very recently Nugent et al. (2019) published a review paper providing current perspectives of USRPT. Similarly, they found no reliable scientific evidence with ecologically valid data on USRPT and they stated the lack of peer reviewed published literature was a fundamental flaw of USRPT. Therefore, the aim of this study was to assess the acute physiological responses (blood lactate, heart rate and rate of perceived exertion - RPE) of USRPT among competitive swimmers.

Even though Rushall claims that blood lactate concentration during USRPT would be 'low to no levels' (Rushall, 2018), he does not specify an exact value. Previous literature on repeated sprint swimming reported average values of 12.1 mmol/L after 4 x 30 s sprint swimming with 30 s rest intervals in between (Peyrebrune et al., 2014) or up to 18.3 mmol/L after 4 x 50-yards of maximal front crawl swimming at intervals of 2 min (Toubekis et al., 2008). It was therefore hypothesised that the blood lactate concentration of participants in our study would be well above the traditional 4 mmol/L lactate threshold (Toubekis and Tokmakidis, 2013).

Methods

Participants

Fourteen (seven male, seven female) competitive swimmers (mean ± SD: age 20 ± 1.6 years; body height 184.6 ± 6.2 cm males and 171.0 ± 4.0 cm females; body mass 80.1 ±7.1 kg males and 62.9 ± 5.3 kg females) were recruited from the University College Dublin (UCD) swim team. Eight swimmers were members of the A team and considered to be elite level swimmers, regularly competing at the national and international level as well as training eight two-hour swimming sessions per week with each workout covering 3-6 km. The remaining six swimmers were members of the B team who were sub-elite level swimmers, regularly competing at the local level, sometimes at the national level and at the inter collegiate swimming competition as well as training four one and half hour sessions a week, covering 3 km per session. All participants were made aware of the potential risks and benefits associated with the study, and written informed consent was obtained from all participants. Ethical approval for all experimental procedures was granted by the University Research Ethics Committee.

Design and procedures

This investigation was designed as an acute intervention study in order to examine physiological outcomes in response to one session of USRPT. It was carried out in a 50 m swimming pool and temporary walls were placed at the 25 m mark to attain a 25 m set up.

Both the elite and sub-elite swimmers completed a standardised 400 m warm up, which was then followed by a USRPT set: 20 x 25 m freestyle with a 35 s rest interval holding a prescribed race pace. This particular set was chosen in accordance with the USRPT protocol as recommended by Rushall (2018). A set of 20 x 25 m was considered enough to profile a blood lactate comparison. Furthermore, it was considered a sufficient distance to standardise the research protocol, so each swimmer completed a suitable and comparable distance before experiencing fatigue. The race pace for each 25 m repetition was determined by one quarter of the swimmers' fastest 100 m freestyle time.

The study involved two separate pool visits for the swimmers, one session for familiarisation and the other for the actual testing procedure. Athletes were stimulated verbally throughout the USRPT set to ensure motivation and to inform them of their pace i.e. whether to maintain the same pace or swim faster. Each repetition and recovery period were timed using a stopwatch and saved on a timer app (Stopwatch & Timer v4.5.2 (81)). Swimmers were given a 10 s warning and a "3, 2, 1, GO" verbal command during every rest interval for the proceeding repetition. Capillary blood samples (0.5 μl) were taken from an ear prick, a painless procedure with minimal invasiveness. The blood was collected 7 times throughout the testing session; once before the start of the USRPT set, 5 times during (once after every four 25 m sprints i.e. 4, 8, 12, 16 and 20) and once again after 3 min of recovery. Blood lactate was measured using a Lactate Pro 2 LT-1730 (Arkray Inc, Kyoto, Japan). The rate of perceived exertion (RPE) was taken pre- and post the USRPT swim set. The RPE is considered the best practical, non-invasive, reliable and valid method for quantifying the internal training load in competitive swimmers (Wallace et al., 2009). The heart rate was measured continuously using a Polar V800 watch that was connected to a heart rate monitor strapped across the chest (Polar, Kempele, Finland). All swimmers wore a Rip Curl Aggrolite 2 mm short wetsuit during the testing session in order to standardise the conditions and to ensure the heart rate monitor chest strap was kept in place while swimming.

Statistical analysis

Data are presented as mean and standard deviation.

A repeated measures ANOVA was used to compare the performance time of each sprint across the 20 sprints. With regard to blood lactate, the average lactate measurement obtained across all 7-time points was compared to the 4 mmol/L lactate threshold using the one sample *t*-test. A Wilcoxon signed-rank test was used to detect if there was a statistically significant difference in the average pre- and post-RPE value. Statistical significance was set at $p < 0.05$ for all comparisons.

The heart rate of swimmers was calculated and profiled as the mean value during the 35-s rest interval after each sprint.

Results

A profile of sprint and resting time is presented in Figure 1. ANOVA displayed a significant difference between sprint time across the 20 sprints (F = 5.51, $p < 0.01$). When compared to sprint 1, performance time of each sprint was increased on average by 3.3-10.8%, which is evidence of fatigue occurring during the testing protocol.

All measures of blood lactate both during and 3 minutes post USRPT were significantly higher than the 4 mmol/L lactate value ($p < 0.01$). Figure 2 shows that after 4 sprints, the average blood lactate concentration was 7.7 ± 2.4 mmol/L. This increased to 13.6 ± 3.1 mmol/L after sprint 20 and blood lactate remained elevated at 11.3 ± 2.6 mmol/L 3 min into recovery.

Figure 3 shows the average heart rate (BPM) after each 35-s rest interval for 9 swimmers. It took 7 sprints for the profile to level. The average maximum heart rate (HR_{max}) observed between interval 7 and 20 was 188 ± 9 BPM. The absolute HR_{max} value recorded for one individual was 201 BPM.

There was a statistically significant difference between the RPE pre- and post USRPT (Figure 4). The average RPE pre-USRPT was 8±1.6 which increased to 18 ± 1.6 post USRPT ($p < 0.01$).

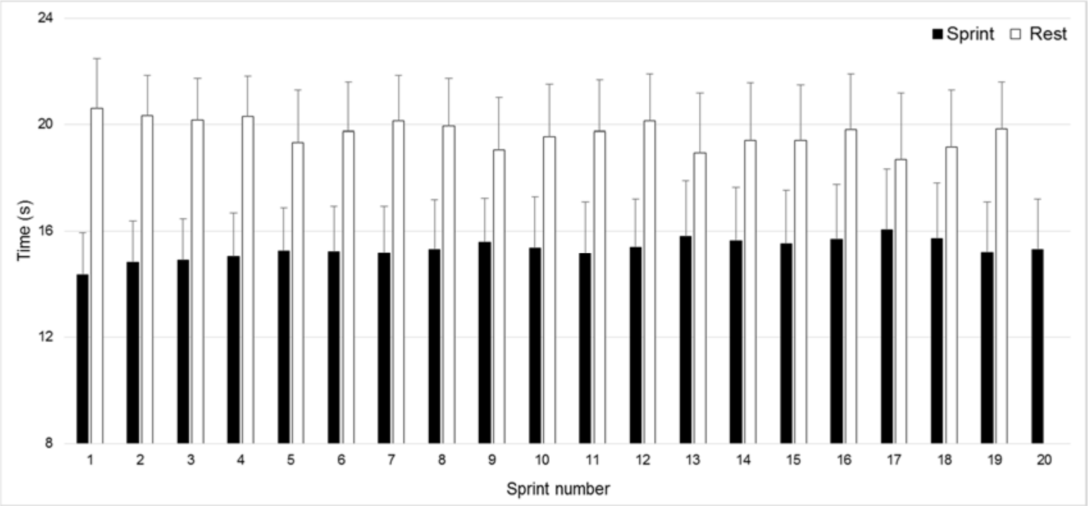

Figure 1

Bars show mean and SD of sprint and rest time.

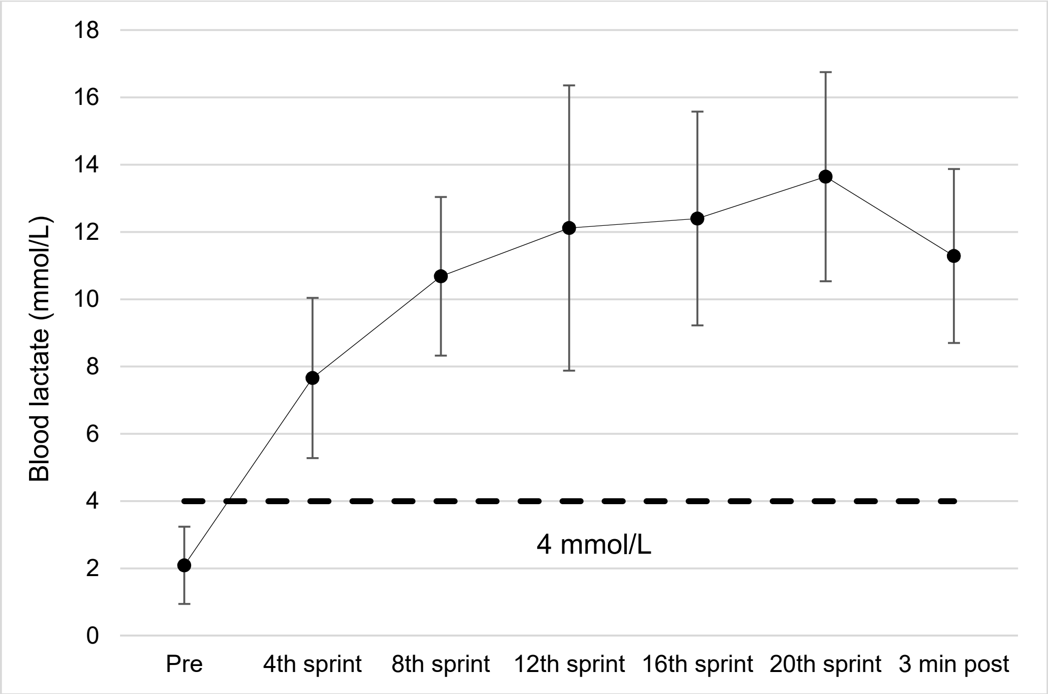

Figure 2

Average blood lactate concentration (± SD) vs. 4 mmol/L threshold.

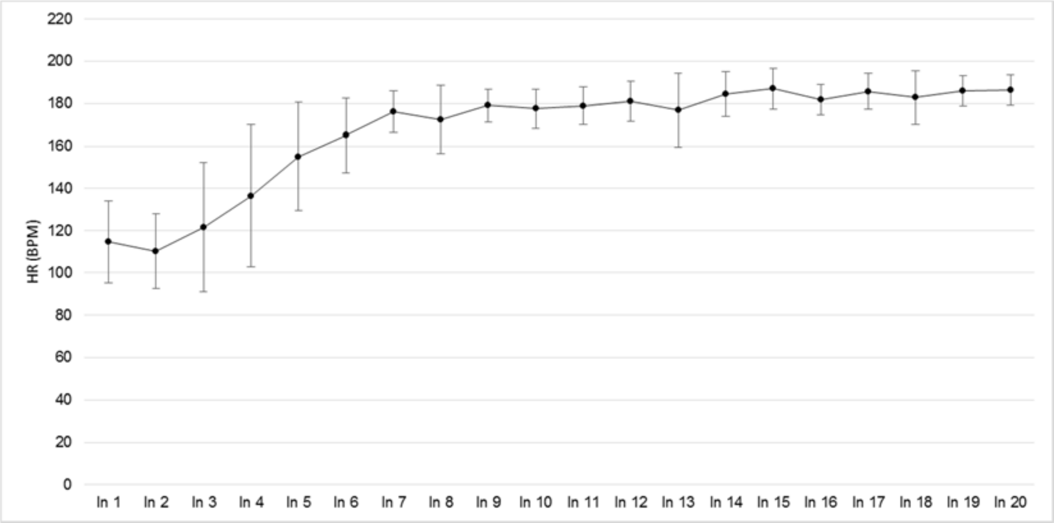

Figure 3

Average heart rate (± SD) after 35 s rest interval after each sprint. In = interval

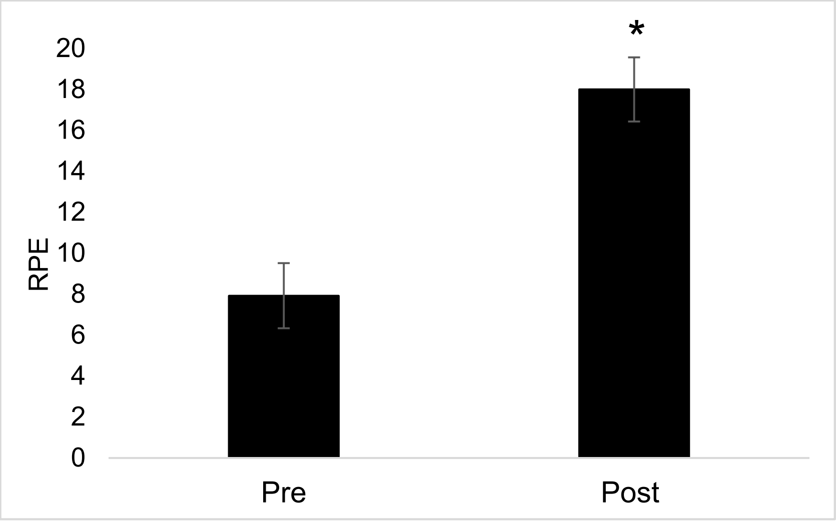

Figure 4

RPE (mean and SD) Pre & Post USRPT swim.
** Significantly increased from Pre (p < 0.01)*

Discussion

The aim of this study was to assess the acute physiological responses of USRPT among both elite and sub-elite competitive swimmers. The main results show that: a) sprint time increased significantly across the 20 sprints; b) blood lactate concentration was significantly higher than the 4 mmol/L lactate threshold; c) the heart rate and RPE values obtained indicated a very high training intensity for USRPT.

It has been shown that the nature of maximal race-pace training will decline with subsequent bouts of performance (Girard et al., 2011). Our results reveal that sprint times increased by 3.3-10.8% in comparison to the first sprint ($p < 0.01$). During repeated sprint type training, rest intervals should allow the majority of PCr to be replenished while being short enough to induce general fatigue to stimulate a training adaptation of quicker PCr recovery (Little and Williams, 2007). An exercise to the rest ratio of 1:6 has been recommended to best develop the phosphagen system (Bangsbo, 1994). USRPT is performed with an exercise ratio of 1:1-2. This may account for the small increase in sprint times but the ultra-short distance (25 m) likely prevented excessive fatigue among swimmers. It must be noted that swimmers held their prescribed velocity, and external variables such as delayed lactate testing and wetsuits may have added some additional unexpected time. Alternatively, fatigue may also arise from limitations in energy supply (including energy available from phosphocreatine hydrolysis, anaerobic glycolysis and oxidative metabolism) and intramuscular accumulation of metabolic bi-products e.g. hydrogen ions (Girard et al., 2011).

As expected, the blood lactate concentrations were well above 4 mmol/L. Rushall (2013, 2018) promoted USRPT as an evidence-based aerobic training protocol that can elicit maximal effort swimming without a successive build-up of blood lactate. The results show that as early as 4 sprints swimmers reached lactate concentration of 7.7± 2.4 mmol/L. This value increased to an average of 13.6 ± 3.1 mmol/L after the final sprint. Additionally, swimmers still presented high lactate concentration (11.3 ± 2.6 mmol/L) three minutes after USRPT. It is known that during intense exercise with short rest intervals, lactate and H+ accumulate in the contracting muscle (Juel et al., 2004) and are a major determinant of fatigue (Monedero and Donne, 2000). Lactate removal is dependent on the peripheral capacity of the working musculature to utilise any available oxygen (Jacobs, 1986). Thus, lactate production is associated with a lack of muscle oxygenation (van Hall, 2010). It appears the maximal intensity nature of USRPT generates high blood lactate levels and that the typical rest interval of 20 s is not sufficient to clear and restore such a large concentration of lactate. The results from this study better portray USRPT as an anaerobic style of training.

The heart rate is traditionally a physiological variable that is measured amongst athletes to monitor training intensity during exercise (Zavorsky, 2000). Typically, the maximum heart rate is calculated by the (220 – age) equation (Tanaka et al., 2001). There was an average heart rate of 188 BPM and one absolute value of 201 BPM was observed. These values indicate that USRPT is a highly intense training modality. Sweetenham and Atkinson (2003) derived heart rate values as beats below maximum (BBM) to describe the training zone and energy system being utilized. Any form of training that elicits a heart rate ranging from 0 to 15 BBM is classified as anaerobic. The average heart rate of 188 BPM when subtracted from the average heart rate maximum (220-average age) lies within 0-15 BBM. Therefore, based on the Sweetenham's classification model, the heart rate profile shows USRPT is an anaerobic training modality. This may further support why high blood lactate values were observed.

Although this study dispels Rushall's concept of a low lactate training program, his rationale for implementing USRPT is still highly plausible and still needs to be considered as a training modality. Swimming is a major Olympic sport with 32 pool events ranging from 50 to 1500 m. Nugent et al. (2017a) mention 26 of 32 or 81% of these Olympic events are 200 m or less in distance, typically lasting no more than 2 min 20 s. Therefore, the mantra of 'train fast to compete fast' is logical. However, given the physiological outcomes obtained from this USRPT set, overtraining, fatigue and subsequent injury possibilities cannot be ruled out of HIT type sessions. The RPE of 8 pre- to 18 post swim indicates USRPT is a highly intense protocol for swimmers. Rushall (2018) argues that this training protocol should be used consistently as an ongoing training method. Again, the heart rate and blood lactate profile observed further quantify the intensity of this style of training. It is widely documented that irrespective of the benefits, high intensity exercise can result in overtraining which reduces health benefits, impairs immunity and increases the risk of both illness and injury (Friery, 2008). Thus, the sustainability of HIT as a full-time modality is still unknown.

The existing scientific literature displays both pros and cons to HIT and HVT modalities in swimming (Laursen, 2010). This is certainly a grey area with great promise for future research. USRPT seems highly specific, but future research should look to build on these findings and assess both its physiological outcomes and performance measures over time in all populations, to truly understand its transfer to performance.

Some limitations of the present study are acknowledged. Swimmers had not been accustomed to this style of training over time. Also, more evidence about acute responses to this type of training needs to be gathered before it can be used routinely. The swimming times increased by 3 – 10%. While this may indicate that swimmers did not maintain their pace, it must be noted that they had to wear wetsuits to hold the heart rate monitors steady. This precaution may have slowed swimmers slightly. Secondly, some lactate measurements delayed swimmers after 'GO' which also occasionally resulted in a slower time. Conversely, some swimmers exceeded their race-pace in some situations. While this sounds ideal, there is no information on whether they should be instructed to maintain a faster pace or whether they should be instructed to slow down which may have led to subsequent sprint fatigue.

Conclusion

The findings of this paper do not rule USRPT out as a training protocol. They simply elucidate the acute physiological responses to this type of training. Based on the high intensity nature of USRPT, a polarized approach with USRPT sets may be optimal, where training progresses from high-volume sets to USRPT sets approaching competition. The specificity of USRPT in terms of technique, psychology and conditioning performed at race-relevant velocities would be desirable approaching competition. Until USRPT is assessed long-term, in terms of its physiological outcomes with all populations, it could be a potential risk to recommend USRPT as a full-time training programme, considering the acute physiological responses we observed in our study. Future research should isolate gender specific populations with competitive swimmers of the same training status.

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