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REVIEW

Ultra-Short Race-Pace Training (USRPT) In Swimming: Current Perspectives

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Abstract: The last decade has seen a dramatic rise in sports science research due to the ever-increasing professionalization of sport. As a result, many alternative training methodologies that challenge traditional training philosophies have emerged. In the sport of swimming, ultra-short race-pace training (USRPT) was recently proposed. The aim of this article was to provide current perspectives on USRPT in competitive swimming. A systematic review was conducted to determine the effects of USRPT on performance in competitive swimmers. Of the 1347 studies retrieved, 1332 were excluded. The full-texts of 15 studies were assessed for eligibility. However, all 15 studies were excluded as the intervention did not consist of USRPT. Consequently, there are concerns surrounding USRPT as it is not currently based on peer-reviewed published literature. In addition, the recommendations within USRPT to avoid resistance training, cross-training activities, training intensities less than race-pace velocity and part practice swimming drills are highly controversial and lack scientific evidence. There is evidence to suggest that USRPT is a derivative of high-intensity training (HIT) and there is peer-reviewed published literature available to support the effects of HIT on performance in competitive swimmers. Swimming coaches and sports scientists are advised to consider the applications of USRPT with caution. The authors suggest that USRPT is a training method, which may be incorporated within a holistic periodized training program that includes a variety of training methods and stimuli. Future research should involve a randomized controlled intervention of USRPT in competitive swimmers.

Keywords: high-intensity interval training, high volume training, quality and quantity

The Sport Of Swimming

Swimming is one of the largest Olympic sports, with 37 events ranging in distance from 50 to 10,000 m. Twenty-seven of the 37 (73%) Olympic swimming events are competed over a race distance of 200 m or less, for a typical duration of <2 mins 20 s. The physiological demands of all swimming events involve the alactic-anaerobic, lactic-anaerobic and aerobic energy system, with the specific contributions depending on the distance/duration of the event.[1] Swimming events <200 m (50 and 100 m) appear to be more dependent on alactic-anaerobic and lactic-anaerobic energy supply, as they are <75 s duration, while events of 200 m and above (200, 400, 800, 1500 and 10,000 m) are more dependent on aerobic energy supply.[2–4]

A number of studies have investigated the physiological and biomechanical determinants of swimming performance.[5–7] Peak oxygen consumption ($\dot{V}O_{2peak}$) has been found to determine 35.8–45.2% of 100 and 400 m swimming performance,[5,6] while biomechanical parameters such as stroke rate (SR), stroke length (SL) and stroke index (SI) determine 89.8–99% of 100, 200 and 400 m

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swimming performance.[5–7] Despite the fact that many of these studies involved youth swimmers, SL and SI have been found to be higher in elite swimmers when compared to lower caliber swimmers.[8,9] A recent review by Barbosa et al[10] suggests that a swimmer's biomechanics or technical skill is strongly related to their energy expenditure at a given velocity, which is in agreement with similar studies.[1,11] This research supports the suggestions within ultra-short race-pace training (USRPT) that swimming biomechanics or technical skill should be emphasized over the physiological adaptations of a swimmer.[12]

The Emergence Of USRPT

The term USRPT was first defined by Professor Brent Rushall in 2011 and involves performing repeated swimming intervals at a velocity that matches an individual's best competitive performance (i.e. their race-pace).[13] A USRPT session generally consists of a high number of intervals, from 20 to 50 repetitions, performed over short distances/durations of 15–100 m or 5–70 s, with brief rest periods of 15–25 s.[14] A typical example of a USRPT session is 20×50 m at 200 m race-pace velocity with 20 s rest.[12] Rushall[12] suggests that the concept of USRPT originates from some of the earliest published literature on interval training, which was undertaken by a group of Swedish physiologists, led by Per-Oløf Åstrand.[15–17] This early research demonstrated the benefits of performing short-distance/duration intervals with brief rest periods on performance.[15–17] However, USRPT has resulted in a large amount of controversy in the swimming community.[18–24] The training methodologies of elite swimming coaches typically involve prescribing a high-volume, low-intensity training (HVT) program which is defined as a training program that focuses on performing low-intensity training (<2 mM blood lactate) of longer duration,[25] also referred to as a "traditional or yardage program".[26] Training volumes of around 40 km or 16 hrs per week are common in competitive swimmers, even among youth cohorts.[27–29] In elite swimmers, training volumes may range up to 110 km or 29 hrs per week.[28] A large amount of evidence, both in the published literature[30,31] and in the applied setting,[32–34] suggest that a HVT program is a highly successful training methodology for competitive swimmers. However, recent reports suggest that one highly successful elite swimmer, who is widely known to perform a USRPT program, has a training volume of 9–11 km per week.[19]

The Underlying Principles Of USRPT

Rushall[12] suggests that USRPT is based on three underlying principles: 1) race-specific technique instruction, 2) race-specific psychology and 3) race-specific conditioning. Race-specific technique instruction is the most important component of USRPT as swimming technique (or biomechanics) is specific to the velocity of swimming, and therefore as much swimming practice as possible should be performed at race-pace.[12] Race-specific psychology is the second most important component of USRPT[12] in order to optimize race strategies and to improve the role of cognitive activity in physiological responses during exercise, based on the seminal work of Noakes,[35] which will be discussed later in this article. Race-specific conditioning, or physiology, is the least important component of USRPT and is defined as training the energy demands associated with the technique used during race-pace.[12] Figure 1 displays a proposed guideline for implementing a USRPT session.[14]

Rushall[36] suggests that USRPT adheres to four fundamental principles of training: specificity, overload, recovery and individuality. The principles of training are commonly discussed in sports science literature.[37,38] The principle of specificity suggests that training adaptation is highly specific to the type of training undertaken.[37,39] Therefore, an athlete's training must be based on the dominant energy systems, technical skills and motor abilities of the sport.[37] Rushall[40] suggests that the more the training and competition activities differ, the less value the training activities have in improving performance. The principle of specificity appears to be evident in USRPT as training is performed at a velocity that matches the individual's best competitive performance (e.g. a 50 m freestyle swimmer will train using freestyle at the velocity of their best competitive performance in the 50 m freestyle). In addition, Rushall[40] proposes that USRPT programs should not include resistance training (RT), cross-training activities, training at slower than race-pace velocities or part practice drills (e.g. where parts of the stroke are performed in isolation), as these training activities do not improve competitive swimming performance. These controversial recommendations will be critically appraised later in this article.

The principle of overload is a key principle of training and is often viewed as a prerequisite to improving sports performance.[37,38] Rushall[41] suggests that when a swimmer undergoes a training stimulus that causes strain, the body will reorganize its capacities so that the next exposure to the

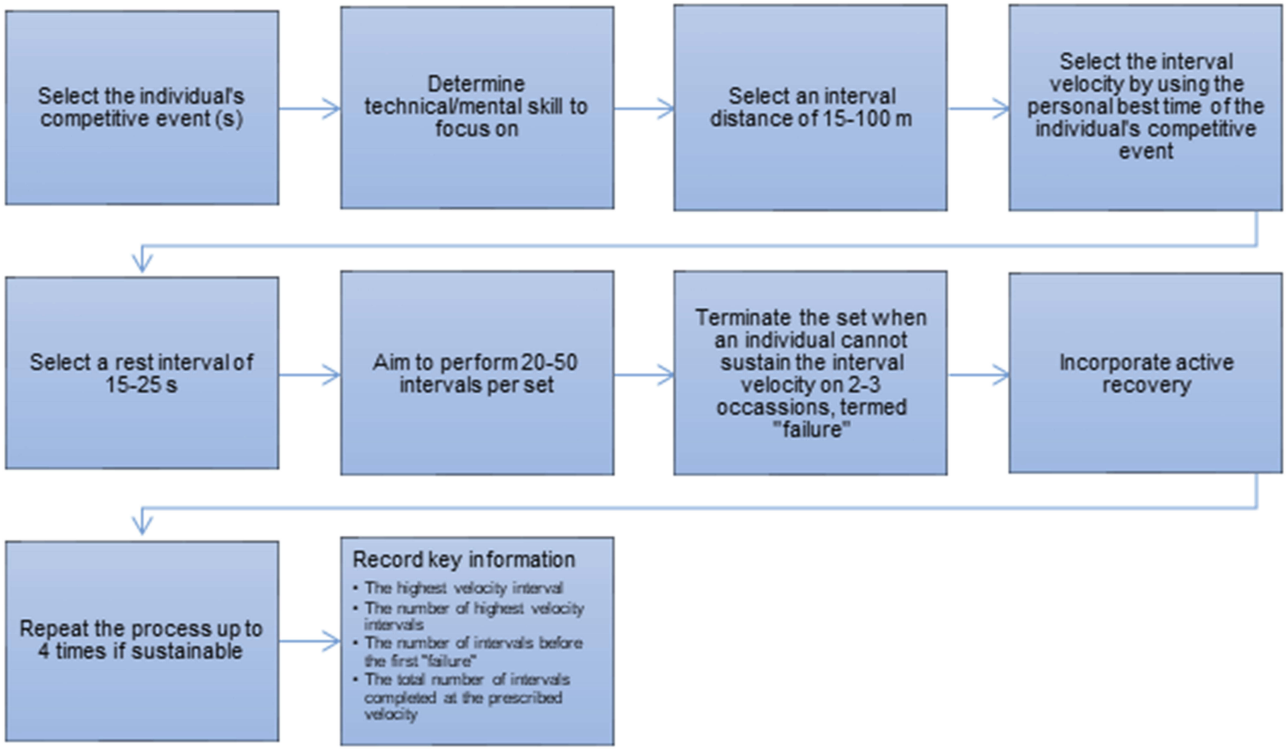

Figure 1 A proposed guideline for implementing a USRPT session.[13,14]

same training stimulus will produce less strain. A training adaptation occurs through a gradual development of the capacities required to tolerate the training stimulus.[41] In order to stimulate further adaptations, the training stimulus should be increased.[41] The principle of overload appears in USRPT as the ultra-short nature of the intervals (15–100 m or 5–70 s) is suggested to allow swimmers to complete a greater overall volume of distance/duration spent at race-pace velocity, thus increasing the training stimulus or overload within a session.[12] The USRPT format also aims to increase the total number of interval repetitions completed at race-pace until a plateau in performance is reached, which indicates that a maximal training adaptation has occurred and thus the swimmer should be able to increase the interval race-pace velocity for the next training cycle (see Figure 2).[41]

The principle of recovery suggests that an athlete's improvement is dependent upon the provision of adequate recovery so that training adaptation can be maximized.[42] Rushall[42] suggests that training programs should accommodate the recovery requirements of each individual swimmer. The USRPT format may help to accommodate individual differences in recovery rates as when a swimmer cannot maintain their prescribed interval velocity, termed a "failure"; the swimmer will be required to miss the next interval repetition, which therefore allows more recovery (see Figure 1).[14] A total of three failures or two consecutive failures in a USRPT set is suggested as the criteria for terminating a set, since a single failure could be a technical error (e.g. a slip on the wall in a turn).[14] In this way, USRPT accommodates each swimmer's individual ability to recover from a training stimulus as the recovery recommendations are in-built within each training set.[41]

The principle of individuality suggests that a coach needs to understand an athlete's needs (e.g. technical ability, physical characteristics, lifestyle, etc.) in order to develop a training program to meet those needs.[43] Rushall[44] suggests that the real strength of USRPT is accommodating individual swimmer's needs. For example, the number of interval repetitions to be completed during a USRPT set is not always strictly adhered to. Instead, swimmers perform as many interval repetitions as possible to the point of fatigue or "failure" (when a swimmer cannot maintain their race-pace). Rushall[44] suggests that day-to-day life stressors influence a swimmer's ability during training. This appears to be a form of autoregulation (AR),[45,46] which will be discussed later in this article. Thus, USRPT accommodates a swimmer's day-to-day fluctuations in accumulated life

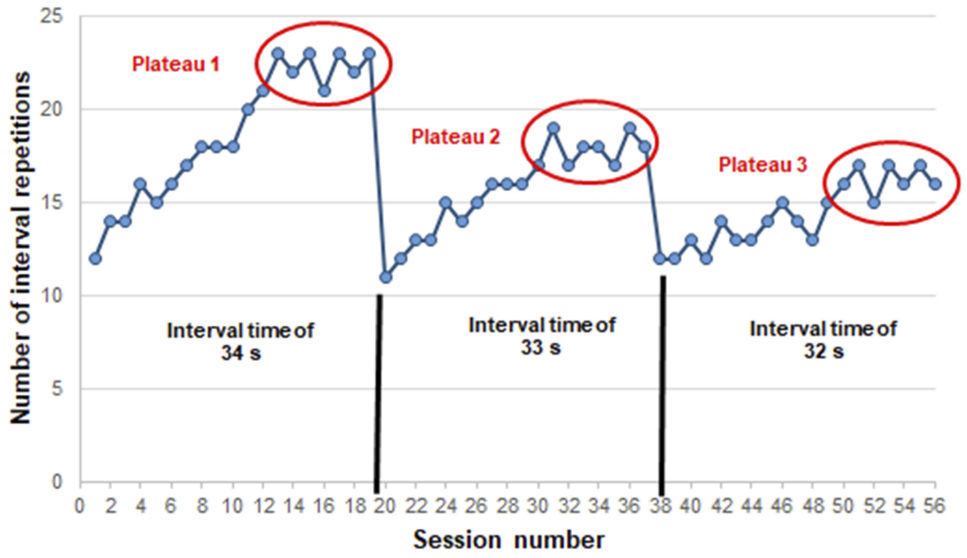

Figure 2 A suggested method of overloading a swimmer based on increasing the total number of interval repetitions prior to increasing the interval velocity, adapted with permission from Rushall BS.[41]

stressors in addition to the individual's preferred competitive event(s), physical characteristics and technical abilities. The next section in this article details a systematic review that aims to examine the current published literature to determine the effects of USRPT on performance parameters in competitive swimmers.

A Systematic Review Of USRPT Interventions

The methodology outlined in the PRISMA-P document was used.[47] A search of the MEDLINE, SPORTDiscus and Web of Science databases was conducted on 4 April 2019. The search strategy comprised of swim* AND (ultra-short race-pace training OR USRPT OR high-intensity training OR interval training OR HIT). The search was limited to the English language and human participants. In addition to database searching, manual searches were performed among the references from the Biomechanics and Medicine in Swimming Conference (volume 1, 1970–volume 13, 2018), the Journal of Swimming Research and among the reference lists of identified studies. Studies were deemed eligible if they met the following inclusion criteria:

- Competitive swimmers (male or female)
- Intervention consisted of USRPT
- Outcome measures of physiological, biomechanical, psychological or swimming performance
- All experimental study designs

The first stage involved two reviewers (FN and GW) independently screening the literature titles and abstracts before comparing results. The second stage involved the reviewers retrieving and screening full-text studies; the results were then compared to determine inclusion in the systematic review. A final decision on the inclusion of the full-text studies was reached through consensus. No studies met the inclusion criteria for the systematic review. The PRISMA flowchart of the study selection process is summarized in Figure 3.

The Concerns Surrounding USRPT

A Lack Of Peer-Reviewed Published Literature

Based on the findings of the systematic review, there is currently no peer-reviewed published literature of USRPT interventions in competitive swimmers. This is despite the strong suggestions by Rushall:[12] "USRPT is completely steeped in scientific research". The lack of published literature to support USRPT has been previously highlighted by numerous critics.[20,48,49] A large amount of USRPT literature was found on the Swimming Science Journal, the personal website of Professor Brent Rushall; however, this literature was nonpeer reviewed, largely anecdotal and heavily biased. The use of peers to assess the work of fellow scientists has been a foundation of the publication process for at least 200 years.[50] The principal functions of the peer review process are to filter out incorrect or inadequate literature and improve the accuracy and clarity of

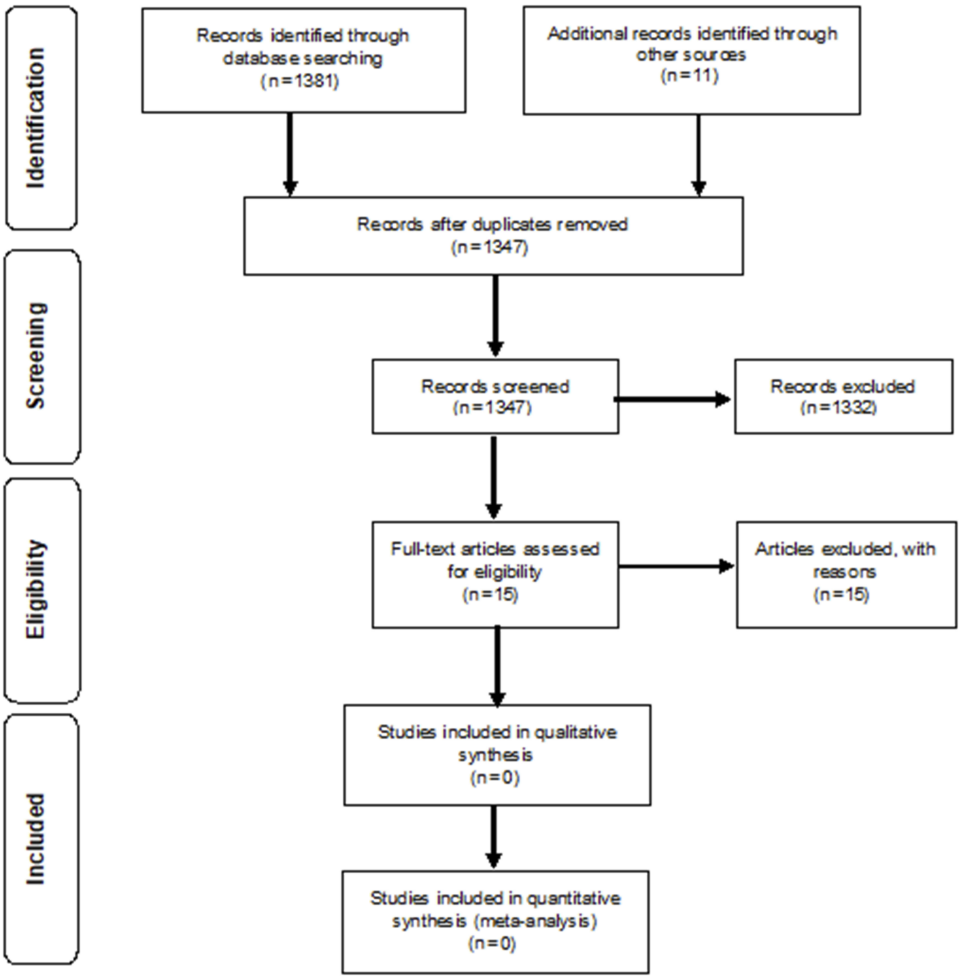

Figure 3 Preferred reporting items for systematic review and meta-analysis flowchart.

published literature.[51] Scientific journals acknowledge that there are limitations associated with the peer review process;[52,53] however, it is still a fundamental flaw of Professor Brent Rushall to avoid publishing USRPT literature in peer-reviewed scientific journals. The Swimming Science Journal contains articles that detail anecdotal evidence of USRPT in competitive swimmers.[14,54,55] For example, Rushall[14] provides training records of the highly successful American swimmer, Michael Andrews, who is widely known as an advocate of USRPT. To date, Michael Andrews has broken over 100 American national age group records, won 9 medals (4 Gold) at the World Junior Championships and won 6 medals (5 Gold) at the World Senior Short Course Championships. While anecdotal evidence should not be undervalued, particularly in the area of sports science, statistical evidence as provided through a randomized controlled intervention is the strongest form of research evidence.[56] Finally, the articles in the Swimming Science Journal are heavily biased. Bias in scientific research refers to cases in which research results seem to directly reflect the preferences and interests of certain individuals involved in the research process.[57] For example: "There are many benefits that USRPT has over traditional training. When they are reviewed it is a wonder that anyone would ever try traditional training again".[26] In addition, there are concerns surrounding the USRPT recommendations to avoid RT, cross-training activities, slower than race-pace training velocities and part practice drills.[26]

RT, Cross-Training Activities And Risk Of Early Specialization

The effects of RT on swimming performance are a frequently debated topic.[58,59] A recent systematic review by Crowley et al[58] suggests that RT can improve swimming

performance; however, more longitudinal studies are needed. RT also plays a vital role in reducing the occurrence of injuries,[60] particularly in youth athletes.[61,62] Swimming is a repetitive, overhead sport where HVT is common, and subsequently, there is a risk of overuse injuries of the shoulder.[28,29] A recent systematic review by Suchomel et al[60] suggests that RT may reduce the occurrence of injuries. In addition, RT and other cross-training activities (e.g. participation in additional sports) can help to combat the effects of early specialization (ES) in youth swimmers. ES is defined as intensive year-round training in a single sport at the exclusion of other sports.[63] In swimming, ES is common[64,65] and may have many negative effects, such as burnout or early dropout from sport.[63,66,67] Research suggests that youths should avoid ES as regular participation in multiple sports or activities enhances motor skill development, improves athletic capacity and increases the opportunity for a youth to discover the sport(s) that he/she enjoys and can possibly excel in.[63,66] Based on the current peer-reviewed published literature, it is clear that RT and cross-training activities should not be excluded from swimming programs, particularly for youth swimmers,[60–62,68] despite the recommendations of USRPT.[12,26,40]

Training Intensities Less Than Race-Pace Velocity

Rushall[41] suggests that training intensities less than race-pace velocity are "a waste of time" for well-trained swimmers. In cyclical sports, well-trained athletes are widely known to complete large amounts of low-intensity training (LIT – defined as continuous training performed below the first ventilatory/lactate threshold, or at stable blood lactate [BLa] concentrations of <2 mM[69]) and moderate-intensity training (MIT – defined as training performed between the first ventilatory/lactate threshold and second ventilatory/lactate threshold or at BLa concentrations of 2–4 mM[69]) during both the preparation and competition phases of the season.[25,69,70] National and international level swimmers competing in sprint to distance events have been found to perform 86–90% of their training as LIT and MIT.[30,71] The training adaptations that occur at intensities less than race-pace velocity (LIT and MIT) are multifactorial in nature and result in profound changes to physiological and neuromuscular systems within the body.[3] A review by Laursen and Jenkins[72] suggests that the physiological adaptions that occur include increased blood/plasma volume, increased cardiac output, changes in muscle capillary density and mitochondrial volume. As a consequence, a number of performance-related physiological adaptations have been reported in well-trained athletes such as increased $\dot{V}O_{2peak}$,[73,74] improved exercise economy,[75] increased velocity at $\dot{V}O_{2peak}$[74] and increased velocity at the first and second lactate threshold (LT_1 and LT_2).[73,74,76] These performance adaptations are the result of increased oxygen delivery and extraction in working muscles; thus, efficiency improves and consequently physical work capacity increases.[72]

In addition to the physiological and performance adaptations to LIT and MIT, there are also numerous practical applications. A review article by Elliott et al[77] suggests LIT enhances recovery from HIT, improves body composition and helps to prepare musculoskeletal structures for more intense training. The proposed mechanisms behind LIT improving recovery are that the increases to muscle capillarization provided by LIT may help to improve the delivery of oxygen to working muscles and thus increase the removal of metabolic by-products.[77] This is an important factor to consider if recovery during and after HIT/race-pace sessions or competitions is to be optimized,[3,21,78] particularly in a sport like swimming where athletes typically compete in numerous events across multi-day competitions.

The Potential Benefits Of USRPT

USRPT And HIT: The Similarities

HIT is defined as training performed above the second ventilatory/lactate threshold or at BLa concentrations of >4 mM.[69] HIT is usually performed in low volumes using an interval training format involving repeated short (<45 s) to long (2–4 mins) bouts of exercise interspersed with active or passive recovery periods.[79] The recovery periods are generally fixed work-recovery ratios (e.g. 1:1, 1:2 or 2:1).[72] Typical heart rate (HR) values for prescribing HIT are ≥88% of maximal HR,[69] while rating of perceived exertion (RPE) values of ≥17 has been suggested.[80] In swimming, HIT is often described using a variety of terms, for example, aerobic overload, lactate production, lactate tolerance, race-pace or sprint training.[33,81] The definition of USRPT[13] appears to classify it as a derivative of HIT. However, being that there is currently no peer-reviewed published literature of USRPT interventions, it is difficult to establish the demands of a USRPT session.

A recent unpublished master's thesis by Williamson and Ditroilo[82] investigated the physiological and perceptual demands of a USRPT session in 14 university swimmers (7 males and 7 females, age 20±1.6 years, 100 m freestyle personal best time 60.35±7.95 s). The USRPT session involved 20×25 m intervals at 100 m race-pace velocity with a 20 s rest period. The physiological outcome measures that were assessed during the USRPT session were BLa (measured after every fourth interval), HR (measured after every interval) and RPE (measured post-session). Descriptive data of the USRPT session were as follows: mean interval duration was 15.32±1.77 s, mean BLa was 11.4±3.7 mM, mean HR was 188±9 beats per minute and post-session RPE was 18.0±1.6. These findings indicate that the physiological and perceptual demands of a typical USRPT session are similar to HIT: BLa of >4 mM, work-recovery ratios of around 1:1, ≥88% of maximal HR and RPE values of ≥17.[69,72,80]

Physiological, Biomechanical And Performance Adaptations

Despite the lack of peer-reviewed published literature on USRPT, there is a large amount of published literature investigating the effects of HIT on performance in cyclical sports.[3,72,79,83] The physiological and performance adaptations that occur due to HIT appear to be similar to both LIT and MIT but occur more rapidly and to a greater degree, particularly for athletes who have not previously performed HIT.[69] Physiological adaptations to HIT in well-trained athletes include increased skeletal muscle lipid oxidation,[84] increased skeletal muscle buffering capacity[85] and increased ability to engage a greater volume of muscle mass.[86,87] In addition, numerous performance adaptations to HIT have been found to occur, such as increased maximal oxygen uptake ($\dot{V}O_{2max}$),[76,86,88,89] velocity at $\dot{V}O_{2max}$[84–86] and velocity at LT_1 and LT_2.[76,89] Consequently, HIT has been found to improve performance in events from 30 s to 40 min duration.[76,84,85,89] The physiological and performance adaptations of HIT, and potentially USRPT, could have even greater applications in a non-weightbearing sport such as swimming as the eccentric demands on the musculoskeletal system appear to be minimal. This means that swimmers could potentially perform greater volumes of HIT and thus promote greater physiological and performance adaptations.

Nugent et al[20] conducted a systematic review investigating the effects of HIT on performance in competitive swimmers. The seven eligible studies that were found during the review extended to a wide range of competitive swimmers and included youth swimmers,[27,90] elite swimmers,[91] university swimmers[92–94] and master swimmers.[73] The studies ranged in duration from 4 weeks to 4 years. Six of the 7 studies found that HIT resulted in significant improvements to outcome measures of physiological performance, both aerobic[27,73,90,92–94] and anaerobic.[90,94] Four of the 7 studies found that HIT resulted in significant improvements to swimming performance in events from 50 to 2000,[73,90,93,94] whilst none of the seven studies resulted in a reduction in physiological or swimming performance. The systematic review concluded that the application of these findings to the long-term development of a competitive swimmer might be limited as four of the controlled studies are short at only 4 to 6.5 weeks.[27,73,90,92] In addition, the majority of eligible studies did not investigate the effects of HIT on biomechanical parameters related to swimming technique.[73,90–92] Biomechanical parameters such as SR, SL and SI have been consistently found to be among the strongest determinants of swimming performance.[5–7] Studies have found that as swimming intensity increases, SR increases[95,96] and SL decreases[95,96] while SI remains stable.[95,97] The most prominent biomechanical modifications to swimming technique occurred at swimming intensities above LT_2;[96] therefore HIT may be a valuable tool to optimize swimming biomechanics. This is in line with the recommendations of Rushall.[12]

A recently published randomized controlled study by Nugent et al[22] investigated the effects of a 7-week HIT intervention on physiological, biomechanical and swimming performance variables in 16 national level youth swimmers (6 males and 10 females, age 15.8±1.0 years, 100 m freestyle personal best time 61.4±4.1 s). The swimmers were randomly assigned to a HIT group or HVT group, which acted as a control. The HIT group reduced their weekly training volume of LIT by 50% but increased HIT by 200%. The HVT group performed training as normal. The study concluded that a 7-week HIT intervention was neither beneficial nor detrimental to performance parameters; however, the HIT group completed a mean of 6 hrs (17.0 km) of swimming per week compared to 12 hrs (33.4 km) per week for the HVT group. The findings of the studies by Nugent et al[20,22] could be of use to coaches and sport scientists who are working with swimmers that may have limited training time. However, training

intensities less than race-pace velocity (LIT and MIT) should remain a priority where possible, particularly for youth swimmers.[3,21,25,30,69–78]

USRPT And Skill Acquisition

Swimming skills are both highly complex (i.e. there are a large number of active body parts) and highly organized (i.e. the actions of one body part influence the actions of other body parts).[98,99] Consequently, when attempting to develop a swimmer's technique, coaches often resort to some form of part practice such as simplification (e.g. training intensities less than race-pace velocity) or fractionization (e.g. isolating the kicking action).[21,32,78] USRPT largely rejects this part practice approach, especially for well-trained swimmers, on the basis of the principle of specificity.[40] In support of the general USRPT position, swimming at differing velocities has been shown to produce distinct movement patterns,[100,101] while an isolated part of a technique is not performed in the same manner as when integrated into the whole movement[102,103] as each action is influenced by preceding and concurrent actions. Furthermore, intervention studies examining the relative effectiveness of whole versus fractionation part practice approaches for well-trained swimmers, whilst being rare, have consistently supported the benefits of whole practice;[104,105] a finding that is in line with both theory[98] and a meta-analysis of whole/part practice across a range of skills.[106]

While rejecting fractionization, USRPT does advocate an alternative method of part practice:[14] variable priority training (VPT).[107] During VPT, the swimmer completes the whole action, but pays particular attention to (and judges success based upon) part of the action.[107,108] Rushall[14] describes VPT when stating:

> swimmers should be directed to practice concentrating on every stroke in a repetition after an explanation of a technique feature. (e.g. "keep the head down so that a film of water breaks over the top of the swimming cap").

The available evidence points toward the effectiveness of VPT for enhancing learning,[107] especially when supplemented by "exaggeration" – the purposeful use of contrasting or exaggerated positions to enhance a learner's awareness of their actions.[109,110] An example of exaggeration is provided by Rushall:[14] "Every odd repetition, swim with new head and body alignment. Every even repetition exaggerate the changes being attempted to the head and shoulder positions to elevate the hips and legs".

The description of VPT provided by Rushall:[14] "For a swimmer to take a stroke without some directed mental activity is a stroke wasted", is also consistent with the concept of deliberate practice,[111,112] where the performer focuses their attention on a limiting element of their performance during practice and monitors their performance carefully, potentially with the aid of a coach, to ensure that they receive accurate feedback on their progress. Such deliberate practice is challenging, effortful and may not be inherently enjoyable, but is regarded as a key component in the development of high-performance athletes.[112,113] Thus, in limiting the use of part practice methods, in exploiting exaggeration to enhance athlete awareness, and in the promotion of deliberate practice, USRPT does appear to contain guidelines for developing technical skills which are consistent with core principles within the skill acquisition literature.[99]

Autoregulation In USRPT

The use of autoregulation (AR) in USRPT is an interesting feature. AR is defined as the adjustment of an individual's program based on their readiness to train on a daily basis.[45] This is a popular topic in designing RT programs and a number of studies have demonstrated greater improvements in an AR group when compared to a fixed group (a group that does not adjust an individual's program).[45,46] A common method of AR in RT is to use a predetermined reduction in barbell velocity, measured using a linear position transducer attached to the barbell, as a means of establishing the volume of repetitions or sets within a training session.[46] This is similar to AR within a USRPT set, for example: "a set is terminated when an individual cannot sustain the prescribed swimming interval velocity on 2–3 occasions" (see Figure 1). Rushall[44] suggests that day-to-day life stressors influence a swimmer's ability during training. Thus, the inclusion of AR within USRPT may help to accommodate a swimmer's day-to-day fluctuations in accumulated life stressors.

The Role Of Cognitive Activity In Physiological Responses During Exercise

Rushall[12] suggests that improving race-specific psychology is the second most important component of USRPT in order to optimize the role of cognitive activity in physiological responses during exercise. This is based on the seminal work of Noakes[35] who proposed the "Central Governor Model" (CGM). The CGM suggests that the brain regulates exercise performance by continuously modifying the number

of motor units that are recruited in the exercising limbs.[35] The brain uses the unpleasant (but illusory) sensations of fatigue to ensure that the exercise intensity and duration are always within the exerciser's physiological capacity, therefore maintaining homeostasis.[35] The CGM proposes that the greatest performances are achieved by athletes who control the progression of these illusory symptoms during exercise.[35] Rushall[12] suggests that as swimmers become increasingly willing to extend the threat that exercise efforts bring to their bodies' homeostasis, so will fatigue-dominated performances improve. Rushall[12] suggests that improving these cognitive elements through using USRPT to increase a swimmers' tolerance of fatigue in training and races will lead to a "breakthrough" in swimming standards. The authors agree that this may have a role to play.

Conclusion

The emergence of USRPT as a new and alternative training methodology has resulted in a large amount of controversy in the swimming community.[18–24] The notion that low-volume training at high intensities (USRPT or HIT) may be a more beneficial training methodology than HVT, often coined – the "Quality versus Quantity" debate, is a long-standing topic of discussion among swimming coaches.[18,23,114] While there are potential benefits to USRPT, the findings of the systematic review indicate that there is currently no peer-reviewed published literature of USRPT interventions on competitive swimmers. This is a fundamental flaw of USRPT. There is evidence to suggest that USRPT is a derivative of HIT,[69,82] and there is peer-reviewed published literature to support the benefits of HIT in competitive swimmers.[22,27,73,90–94] However, national and international level swimmers competing in sprint to distance events have been found to perform around 6–16% of their training as HIT[30,71] which is similar to the training patterns of other cyclical sports.[25,69,70] The remainder of their training comprises a variety of stimuli: LIT, MIT, RT and cross-training activities, of which there is a large amount of published literature to support.[3,4,21,25,30,60,69–71,73–76,78]

In youth swimmers, the recommendations by Rushall[14] to perform 3–7 sessions of USRPT per week for 8–12 years old and 8–9 sessions per week for ≥14 years old may be harmful to this cohort. USRPT and HIT are highly stressful training stimuli (e.g. BLa of >4 mM, ≥88% of maximal HR and RPE values of ≥17); therefore, high volumes of this form of training could constitute ES which may lead to a higher risk of burn out or early dropout from sport, particularly in youth athletes.[67] In addition, the 50 m and 100 m events are the only events that are primarily dependent on alactic-anaerobic and lactic-anaerobic energy supply, as they are <75 s duration.[2,3,4] Therefore, high volumes of USRPT or HIT for youth swimmers may not be the most effective training methodology in order to meet the aerobic demands of the majority of swimming events (200, 400, 800, 1500 and 10,000 m).

Swimming coaches and sports scientists are advised to consider the applications of USRPT with caution regardless of the small number of anecdotal reports.[14,19,54,55] The authors suggest that USRPT should be viewed as a training method to incorporate within a periodized training program that consists of a variety of training methods and stimuli, particularly for youth swimmers. This is similar to the suggestions of Bob Bowman, coach of 38 Olympic swimming medals, who recently provided his opinion of USRPT:

> It's good. It's like spinach, it's really good for you but I'm not going to eat spinach every day. It needs to be a variety for me and everything must work holistically. We have done something relatively similar, but we mix it with other things which I feel are really important. I don't think you can do only one thing. I think there must be a variety of stimuli.[115]

Future research should involve a randomized controlled intervention of USRPT in competitive swimmers with outcome measures of physiological, biomechanical, psychological or swimming performance.

Disclosure

The authors report no conflicts of interest in this work.

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