

ULRR

Ultra-short race-pace training (USRPT) In swimming: current perspectives

Item Type	Article
Authors	Nugent, Frank;Comyns, Thomas M.;Kearney, Philip E.;Warrington, Giles
Citation	Journal of Sports Medicine;10, 133-144
Publisher	Dove Medical Press
Download date	2026-06-08 01:56:09
Item License	https://creativecommons.org/licenses/by-nc-sa/1.0/
Link to Item	https://hdl.handle.net/10344/8244


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

This article was published in the following Dove Press journal:
Open Access Journal of Sports Medicine

Frank Nugent

Tom Comyns

Philip Kearney 

Giles Warrington 

Physical Education and Sport Sciences
Department, Faculty of Education and
Health Sciences, University of Limerick,
Limerick, Ireland

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

Correspondence: Frank Nugent
Physical Education and Sport Sciences
Department, Faculty of Education and
Health Sciences, University of Limerick,
Limerick, Ireland
Tel +353 61 00851506074
Email frank.nugent@ul.ie

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 al¹⁰ 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 Rushall¹² 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-Olof 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

Rushall¹² 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 USRPT¹² 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

Rushall³⁶ 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 Rushall⁴⁰ 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, Rushall⁴⁰ 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} Rushall⁴¹ 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

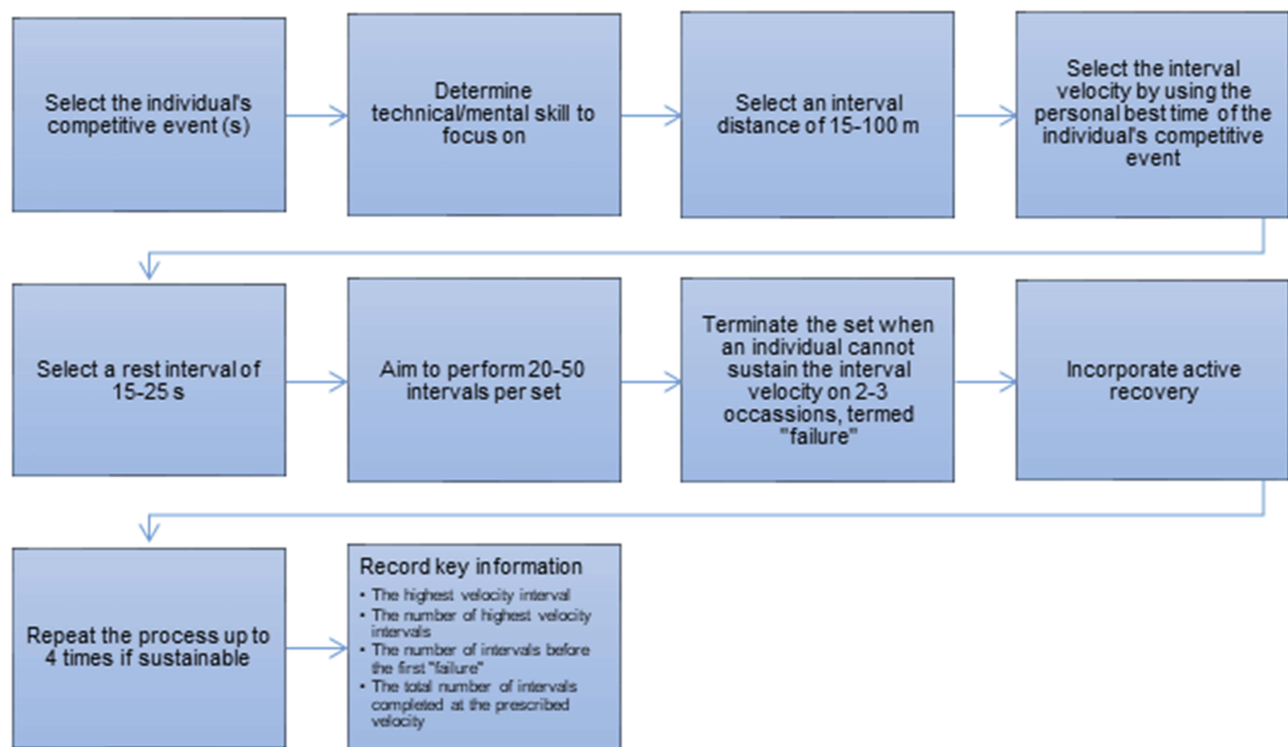


Figure 1 A proposed guideline for implementing a USRPT session.^{13,14}

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 Rushall⁴² 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 Rushall⁴⁴ 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). Rushall⁴⁴ 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

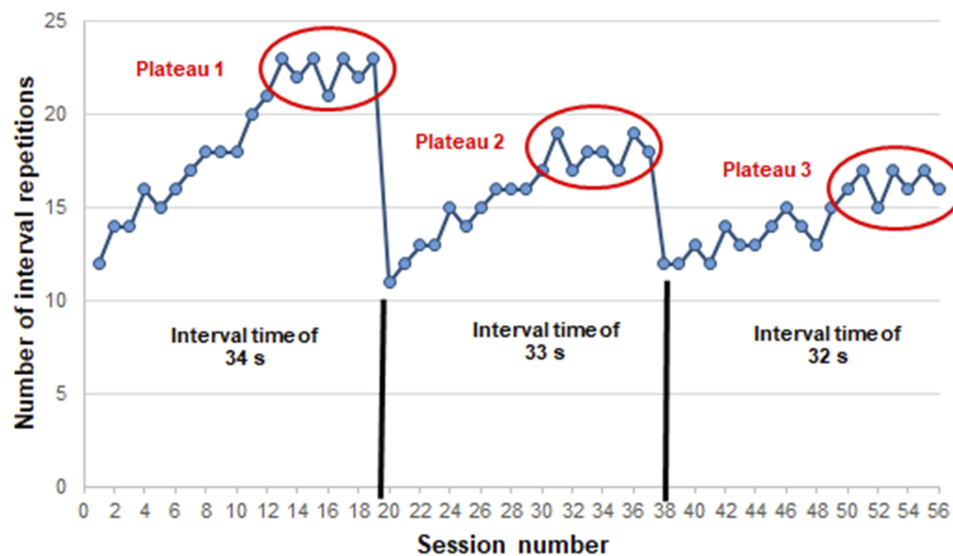


Figure 2 A suggested method of overloading a swimmer based on increasing the total number of interval repetitions prior to increasing the interval velocity, adapted with permission from Rushall BS.⁴¹

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

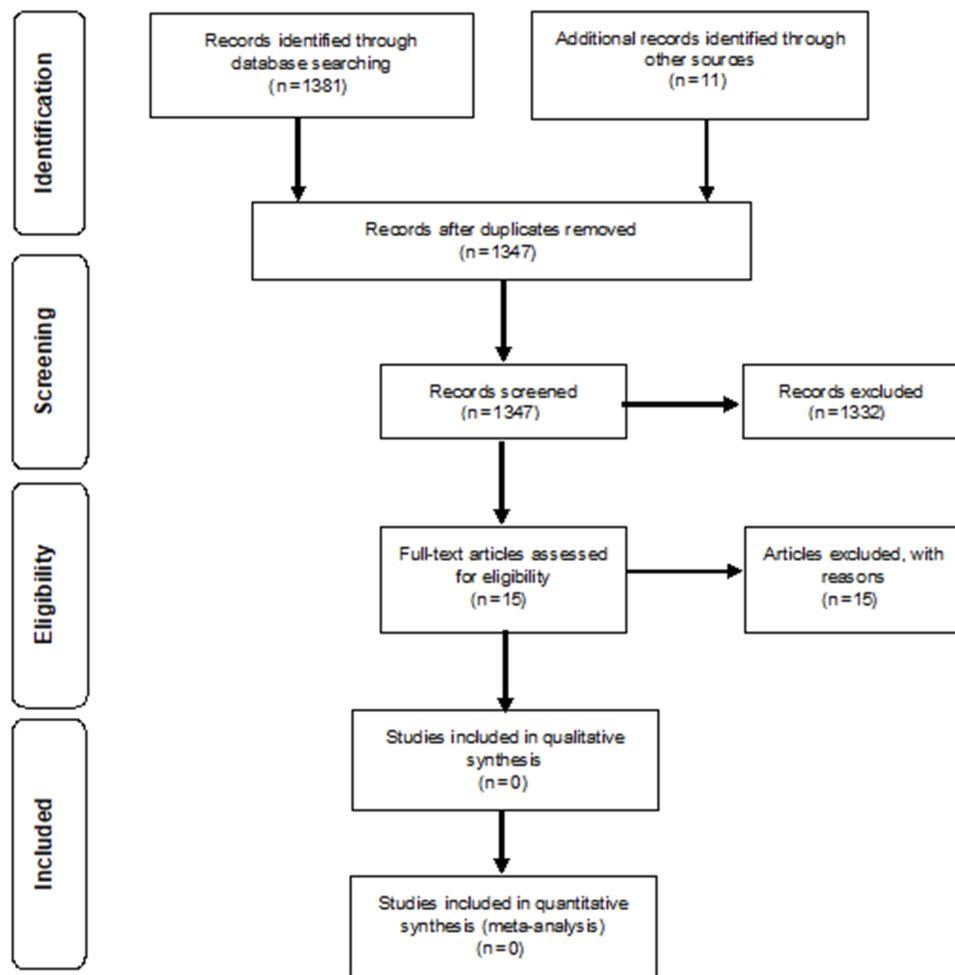


Figure 3 Preferred reporting items for systematic review and meta-analysis flowchart.

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, Rushall¹⁴ 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 al⁵⁸ 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 al⁶⁰ 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

Rushall⁴¹ 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 mM⁶⁹) 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 mM⁶⁹) 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 Jenkins⁷² suggests that the physiological adaptations 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 (LT₁ and LT₂).^{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 al⁷⁷ 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 USRPT¹³ 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 Ditroilo⁸² 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 capacity⁸⁵ 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 al²⁰ 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 al²² 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 theory⁹⁸ 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} Rushall¹⁴ 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). Rushall⁴⁴ 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

Rushall¹² 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 Noakes³⁵ 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 Rushall¹² 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. Rushall¹² 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 Rushall¹⁴ 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.

References

1. Pyne DB, Sharp RL. Physical and energy requirements of competitive swimming events. *Int J Sport Nutr Exerc Metab.* 2014;24(4):351–359. doi:10.1123/ijnsnem.2014-0047
2. Gastin PB. Energy system interaction and relative contribution during maximal exercise. *Sports Med.* 2001;31(10):725–741. doi:10.2165/00007256-200131100-00003
3. Laursen PB. Training for intense exercise performance: high-intensity or high-volume training? *Scand J Med Sci Sports.* 2010;20:1–10. doi:10.1111/j.1600-0838.2010.01184.x
4. Vandenbogaerde T, Derave W, Hellard P. Swimming. In: Laursen PB, Buchheit M, editors. *Science And Application Of High-intensity Interval Training: Solutions To The Programming Puzzle.* Champaign, IL: Human Kinetics; 2019:325–345.
5. Jürimäe J, Haljaste K, Cicchella A, et al. Analysis of swimming performance from physical, physiological, and biomechanical parameters in young swimmers. *Pediatr Exerc Sci.* 2007;19(1):70–81. doi:10.1123/pes.19.1.70
6. Lätt E, Jürimäe J, Mäestu J, et al. Physiological, biomechanical and anthropometrical predictors of sprint swimming performance in adolescent swimmers. *J Sports Sci Med.* 2010;9(3):398–404.

7. Mezzaroba PV, Machado FA. Effect of age, anthropometry, and distance in stroke parameters of young swimmers. *Int J Sports Physiol Perform.* 2014;9(4):702–706. doi:10.1123/ijsp.2013-0278
8. Sánchez J, Arellano R Stroke index values according to level, gender, swimming style and event race distance. Paper presented at: International Society of Biomechanics in Sports; 2002; Spain.
9. Smith DJ, Norris SR, Hogg JM. Performance evaluation of swimmers: scientific tools. *Sports Med.* 2002;32(9):539–554. doi:10.2165/00007256-200232090-00001
10. Barbosa TM, Bragada JA, Reis VM, Marinho DA, Carvalho C, Silva AJ. Energetics and biomechanics as determining factors of swimming performance: updating the state of the art. *J Sci Med Sport.* 2010;13(2):262–269. doi:10.1016/j.jsams.2009.01.003
11. Toussaint HM, Beek PJ. Biomechanics of competitive front crawl swimming. *Sports Med.* 1992;13(1):8–24. doi:10.2165/00007256-199213010-00002
12. Rushall BS. USRPT defined: after two years USRPT comes of age. *Swimming Sci Bull.* 2016;49:1–17.
13. Rushall BS. Swimming energy training in the 21st century: the justification for radical changes. *Swimming Sci Bull.* 2011;39:1–59.
14. Rushall BS Step-by-step USRPT planning and decision-making processes and examples of USRPT training sessions, microcycles, macrocycles, and technique instruction. *Swimming Sci Bull.* 2018;47:1–67.
15. Åstrand I, Åstrand PO, Christensen EH, Hedman R. Intermittent muscular work. *Acta Psychiatr Scand.* 1960;48(3–4):448–453. doi:10.1111/j.1748-1716.1960.tb01879.x
16. Christensen EH, Hedman R, Saltin B. Intermittent and continuous running (A further contribution to the physiology of intermittent work.). *Acta Psychiatr Scand.* 1960;50(3–4):269–286. doi:10.1111/j.1748-1716.1960.tb00181.x
17. Åstrand I, Åstrand PO, Christensen EH, Hedman R. Circulatory and respiratory adaptation to severe muscular work. *Acta Psychiatr Scand.* 1960;50(3–4):254–258. doi:10.1111/j.1748-1716.1960.tb00179.x
18. Stott MJ. The case for less volume. In: *Swimming World Magazine.* March ed. Phoenix, AZ: Sports Publications Inc; 2012:29–30.
19. Stott MJ. A new way to train. In: *Swimming World Magazine.* June ed. Phoenix, AZ: Sports Publications Inc; 2014:25–29.
20. Nugent FJ, Comyns TM, Burrows E, Warrington GD. Effects of low-volume, high-intensity training on performance in competitive swimmers: a systematic review. *J Strength Cond Res.* 2016;31(3):837–847. doi:10.1519/JSC.0000000000001583
21. Nugent FJ, Comyns TM, Warrington GD. Quality versus quantity debate in swimming: perceptions and training practices of expert swimming coaches. *J Hum Kinet.* 2017;57:147–158. doi:10.1515/hukin-2017-0056
22. Nugent F, Comyns T, Nevill A, Warrington GD. The effects of low-volume, high-intensity training on performance parameters in competitive youth swimmers. *Int J Sports Physiol Perform.* 2019;14(2):203–208. doi:10.1123/ijsp.2018-0110
23. Goldsmith W. The distance debate: how much swim training should we be doing? In: *Swimming World Magazine.* May ed. Phoenix, AZ: Sports Publications Inc; 2016. Available from: <https://www.swimmingworldmagazine.com/news/swim-training/>. Accessed March 6, 2017
24. Goldsmith W. How much is enough? In: *Swimming World Magazine.* January ed. Phoenix, AZ: Sports Publications Inc; 2017:34–36.
25. Stoggl TL, Sperlich B. The training intensity distribution among well-trained and elite endurance athletes. *Front Physiol.* 2015;6:295. doi:10.3389/fphys.2015.00295
26. Rushall BS. Swimming Energy Training in the 21st Century: The Justification for Radical Changes. *Swimming Sci Bull.* 2018;39:1–59.
27. Faude O, Meyer T, Scharhag J, Weins F, Urhausen A, Kindermann W. Volume vs. intensity in the training of competitive swimmers. *Int J Sports Med.* 2008;29(11):906–912. doi:10.1055/s-2008-1038377
28. Sein ML, Walton J, Linklater J, et al. Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. *Br J Sports Med.* 2010;44(2):105–113. doi:10.1136/bjsm.2008.047282
29. Hibberd EE, Myers JB. Practice habits and attitudes and behaviors concerning shoulder pain in high school competitive club swimmers. *Clin J Sport Med.* 2013;23(6):450–455. doi:10.1097/JSM.0b013e31829aa8ff
30. Hellard P, Avalos-Fernandes M, Lefort G, et al. Elite swimmers' training patterns in the 25 weeks prior to their season's best performances: insights into periodization from a 20-year cohort. *Front Physiol.* 2019;10(363):1–16.
31. Nugent FJ, Comyns TM, Warrington GD. Effects of increased training volume during a ten-day training camp on competitive performance in national level youth swimmers. *J Sports Med Phys Fitness.* 2018;58(12):1728–1734. doi:10.23736/S0022-4707.17.07838-0
32. Maglischo EW. Training for different events. In: *Swimming Fastest: The Essential Reference On Technique, Training, And Program Design.* Champaign, IL: Human Kinetics; 2003:485–540.
33. Sweetenham B, Atkinson J. Training systems. In: *Championship Swim Training.* Champaign, IL: Human Kinetics; 2003:3–16.
34. Stott MJ. The case for volume. In: *Swimming World Magazine.* February ed. Phoenix, AZ: Sports Publications Inc; 2012:26–27.
35. Noakes TD. Fatigue is a brain-derived emotion that regulates the exercise behavior to ensure the protection of whole body homeostasis. *Front Physiol.* 2012;3:82. doi:10.3389/fphys.2012.00082
36. Rushall BS. Understanding a USRPT set. *Swimming Sci Bull.* 2013;45e:1–4.
37. Bompa TO, Haff G. *Periodization: Theory and Methodology of Training.* 5th ed. Champaign, IL: Human Kinetics; 2009.
38. Stone MH, Stone M, Sands WA. Introduction: definitions, objectives, tasks and principles of training. In: *Principles And Practice Of Resistance Training.* Champaign, IL: Human Kinetics; 2007:1–14.
39. Maglischo EW. Principles of training. In: *Swimming Fastest: The Essential Reference On Technique, Training, And Program Design.* Champaign, IL: Human Kinetics; 2003:395–416.
40. Rushall BS. USRPT and training theory V: the specificity principle. *Swimming Sci Bull.* 2017;60e:1–39.
41. Rushall BS. USRPT and training theory II: the overload principle. *Swimming Sci Bull.* 2016;60b:1–20.
42. Rushall BS. USRPT and training theory IV: the recovery principle. *Swimming Sci Bull.* 2016;60d:1–21..
43. Bompa TO, Haff G. Principles of training. In: *Periodization: Theory And Methodology Of Training.* 5 ed. Champaign IL: Human Kinetics; 2009:31–55.
44. Rushall BS. USRPT and training theory VI: the individuality principle. *Swimming Sci Bull.* 2017;60f:1–16.
45. Graham T, Cleather DJ. Autoregulation by "repetitions in reserve" leads to greater improvements in strength over a 12-week training program than fixed loading. *J Strength Cond Res.* in press;2019.
46. Sanchez-Medina L, Gonzalez-Badillo J. Velocity loss as an indicator of neuromuscular fatigue during resistance training. *Med Sci Sports Exerc.* 2011;43(9):1725–1734. doi:10.1249/MSS.0b013e318213f880
47. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ.* 2015;349:g7647. doi:10.1136/bmj.g7647

48. Beliaev S. Ultra-short race-pace training – breakthrough or a phantom from the past? In: Bob Ingram, editor. *Swimming Technique Magazine*. February ed. Phoenix, AZ: Sports Publications Inc; 2015:5–7.
49. McGinnis E The pros, cons and misconceptions of ultra short race pace training (USRPT); 2015. Available from: <https://swimswam.com/the-pros-cons-and-misconceptions-of-ultra-short-race-pace-training-usrpt/>. Accessed December 19, 2015.
50. Kronick DA. Peer review in 18th-century scientific journalism. *JAMA*. 1990;263(10):1321–1322. doi:10.1001/jama.1990.03440100021002
51. Jefferson T, Alderson P, Wager E, Davidoff F. Effects of editorial peer review: a systematic review. *JAMA*. 2002;287(21):2784–2786. doi:10.1001/jama.287.21.2784
52. Smith R. Peer review: a flawed process at the heart of science and journals. *J R Soc Med*. 2006;99(4):178–182. doi:10.1177/014107680609900414
53. Mahoney MJ. Publication prejudices: an experimental study of confirmatory bias in the peer review system. *Cognit Ther Res*. 1977;1(2):161–175. doi:10.1007/BF01173636
54. Rushall BS. USRPT training of a club squad at a UK midlands ASA swimming club – update. *Swimming Sci Bull*. 2017;63:1–11.
55. Rushall BS. USRPT training of a club squad at a UK midlands ASA swimming club. *Swimming Sci Bull*. 2017;61:1–12.
56. Murad MH, Asi N, Alsawas M, Alahdab F. New evidence pyramid. *BMJ Evid Based Med*. 2016;21(4):125–127. doi:10.1136/bmed-2016-110401
57. Willholt T. Bias and values in scientific research. *Stud Hist Philos Sci A*. 2009;40(1):92–101. doi:10.1016/j.shpsa.2008.12.005
58. Crowley E, Harrison AJ, Lyons M. The impact of resistance training on swimming performance: a systematic review. *Sports Med*. 2017;47(11):2285–2307. doi:10.1007/s40279-017-0730-2
59. Aspenes ST, Karlsen T. Exercise-training intervention studies in competitive swimming. *Sports Med*. 2012;42(6):527–543. doi:10.2165/11630760-000000000-00000
60. Suchomel TJ, Nimphius S, Stone MH. The importance of muscular strength in athletic performance. *Sports Med*. 2016;46(10):1419–1449. doi:10.1007/s40279-016-0486-0
61. Faigenbaum AD, Lloyd RS, MacDonald J, Myer GD. Citius, altius, fortius: beneficial effects of resistance training for young athletes. *Br J Sports Med*. 2016;50(1):3–7. doi:10.1136/bjsports-2015-094621
62. Faigenbaum AD, Meadors L. A coach's dozen: an update on building healthy, strong and resilient athletes. *Strength Cond J*. 2017;39(2):27–33. doi:10.1519/SSC.0000000000000282
63. Jayanthi N, Pinkham C, Dugas L, Patrick B, Labella C. Sports specialization in young athletes: evidence-based recommendations. *Sports Health*. 2013;5(3):251–257. doi:10.1177/1941738112464626
64. Fraser-Thomas J, Côté J, Deakin J. Examining adolescent sport dropout and prolonged engagement from a developmental perspective. *J Appl Sport Psychol*. 2008;20(3):318–333. doi:10.1080/10413200802163549
65. Larson HK, Young BW, TLF M, Rodgers WM. Markers of early specialization and their relationships with burnout and dropout in swimming. *J Sport Exerc Psychol*. 2019;41(1):46–54. doi:10.1123/jsep.2018-0305
66. Mostafavifar AM, Best TM, Myer GD. Early sport specialisation, does it lead to long-term problems? *Br J Sports Med*. 2013;47:1060–1061. doi:10.1136/bjsports-2012-092005
67. Huxley DJ, O'Connor D, Healey PA. An examination of the training profiles and injuries in elite youth track and field athletes. *Eur J Sport Sci*. 2014;14(2):185–192. doi:10.1080/17461391.2013.809153
68. Nugent FJ, Comyns TM, Warrington GD. Strength and conditioning considerations for youth swimmers. *Strength Cond J*. 2018;40(2):31–39. doi:10.1519/SSC.0000000000000368
69. Seiler S. What is best practice for training intensity and duration distribution in endurance athletes? *Int J Sports Physiol Perform*. 2010;5(3):276–291. doi:10.1123/ijsp.5.3.276
70. Plews DJ, Laursen PB, Kilding AE, Buchheit M. Heart-rate variability and training-intensity distribution in elite rowers. *Int J Sports Physiol Perform*. 2014;9(6):1026–1032. doi:10.1123/ijsp.2013-0497
71. Mujika I, Chatard JC, Busso T, Geysant A, Barale F, Lacoste L. Effects of training on performance in competitive swimming. *Can J Appl Physiol*. 1995;20(4):395–406. doi:10.1139/h95-031
72. Laursen PB, Jenkins DG. The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Med*. 2002;32(1):53–73. doi:10.2165/00007256-200232010-00003
73. Pugliese L, Porcelli S, Bonato M, et al. Effects of manipulating volume and intensity training in masters swimmers. *Int J Sports Physiol Perform*. 2015;10(7):907–912. doi:10.1123/ijsp.2014-0171
74. Ingham SA, Carter H, Whyte GP, Doust JH. Physiological and performance effects of low- versus mixed-intensity rowing training. *Med Sci Sports Exerc*. 2008;40(3):579–584. doi:10.1249/MSS.0b013e31815ecc6a
75. Enoksen E, Shalfawi SA, Tønnessen E. The effect of high-vs. low-intensity training on aerobic capacity in well-trained male middle-distance runners. *J Strength Cond Res*. 2011;25(3):812–818. doi:10.1519/JSC.0b013e3181cc2291
76. Ni Cheilleachair NJ, Harrison AJ, Warrington GD. HIIT enhances endurance performance and aerobic characteristics more than high-volume training in trained rowers. *J Sports Sci*. 2017;35(11):1052–1058. doi:10.1080/02640414.2016.1209539
77. Elliott MC, Wagner PP, Chiu L. Power athletes and distance training. *Sports Med*. 2007;37(1):47–57. doi:10.2165/00007256-200737010-00004
78. Greyson I, Kelly S, Peyrebrune M, Furniss B. Interpreting and implementing the long-term athlete development model: english swimming coaches' views on the (swimming) LTAD in practice. A commentary. *Int J Sports Sci Coach*. 2010;5(3):403–406. doi:10.1260/1747-9541.5.3.403
79. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: part II: anaerobic energy, neuromuscular load and practical applications. *Sports Med*. 2013;43(10):927–954. doi:10.1007/s40279-013-0066-5
80. Hydren JR, Cohen BS. Current scientific evidence for a polarized cardiovascular endurance training model. *J Strength Cond Res*. 2015;29(12):3523–3530. doi:10.1519/JSC.0000000000001197
81. Maglischo EW. Sprint, race-pace and recovery training. In: *Swimming Fastest: The Essential Reference On Technique, Training, And Program Design*. Champaign, IL: Human Kinetics; 2003:451–483.
82. Williamson D, Ditroilo M. *The Physiological Outcomes of Ultra Short Race Pace Training (USRPT) in Elite and Sub-elite Swimmers*. Dublin: School of Public Health, Physiotherapy and Sport Science, University College Dublin; 2018.
83. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: part I: cardiopulmonary emphasis. *Sports Med*. 2013;43(5):313–338. doi:10.1007/s40279-013-0029-x
84. Westgarth-Taylor C, Hawley JA, Rickard S, Myburgh KH, Noakes TD, Dennis SC. Metabolic and performance adaptations to interval training in endurance-trained cyclists. *Eur J Appl Physiol Occup Physiol*. 1997;75(4):298–304. doi:10.1007/s004210050164
85. Weston AR, Myburgh KH, Lindsay FH, Dennis SC, Noakes TD, Hawley JA. Skeletal muscle buffering capacity and endurance performance after high-intensity interval training by well-trained cyclists. *Eur J Appl Physiol Occup Physiol*. 1996;75(1):7–13. doi:10.1007/s004210050119

86. Creer AR, Ricard MD, Conlee RK, Hoyt GL, Parcell AC. Neural, metabolic and performance adaptations to four weeks of high intensity sprint-interval training in trained cyclists. *Int J Sports Med.* 2004;25(2):92–98. doi:10.1055/s-2004-819945
87. Enoka RM, Duchateau J. Muscle fatigue: what, why and how it influences muscle function. *J Physiol.* 2008;586(1):11–23. doi:10.1113/jphysiol.2007.139477
88. Laursen PB, Shing CM, Peake JM, Coombes JS, Jenkins DG. Interval training program optimization in highly trained endurance cyclists. *Med Sci Sports Exerc.* 2002;34(11):1801–1807. doi:10.1097/00005768-200211000-00017
89. Driller MW, Fell JW, Gregory JR, Shing CM, Williams AD. The effects of high-intensity interval training in well-trained rowers. *Int J Sports Physiol Perform.* 2009;4(1):110–121. doi:10.1123/ijspp.4.1.110
90. Sperlich B, Zinner C, Heilemann I, Kjendlie PL, Holmberg HC, Mester J. High-intensity interval training improves VO₂peak, maximal lactate accumulation, time trial and competition performance in 9–11 year old swimmers. *Eur J Appl Physiol.* 2010;110(5):1029–1036. doi:10.1007/s00421-010-1586-4
91. Kilen A, Larsson TH, Jørgensen M, Johansen L, Jørgensen S, Nordborg NB. Effects of 12 weeks high-intensity & reduced-volume training in elite athletes. *PLoS One.* 2014;9(4):e95025. doi:10.1371/journal.pone.0095025
92. Houston ME, Wilson DM, Green HJ, Thomson JA, Ranney DA. Physiological and muscle enzyme adaptations to two different intensities of swim training. *Eur J Appl Physiol.* 1981;46(3):283–291. doi:10.1007/BF00423404
93. Kame VD, Pendergast DR, Termin B. Physiologic responses to high intensity training in competitive university swimmers. *J Swim Res.* 1990;6(4):5–8.
94. Termin B, Pendergast DR. Training using the stroke frequency-velocity relationship to combine biomechanical and metabolic paradigms. *J Swim Res.* 2000;14:9–17.
95. Barbosa TM, De Jesus K, Abraldes JA, et al. Effects of protocol step length on biomechanical measures in swimming. *Int J Sports Physiol Perform.* 2015;10(2):211–218. doi:10.1123/ijspp.2014-0108
96. De Jesus K, Sanders R, De Jesus K, et al. The effect of intensity on 3-dimensional kinematics and coordination in front-crawl swimming. *Int J Sports Physiol Perform.* 2016;11(6):768–775. doi:10.1123/ijspp.2015-0465
97. Oliveira MF, Caputo F, Lucas RD, Denadai BS, Greco CC. Physiological and stroke parameters to assess aerobic capacity in swimming. *Int J Sports Physiol Perform.* 2012;7(3):218–223. doi:10.1123/ijspp.7.3.218
98. Naylor J, Briggs G. Effects of task complexity and task organization on the relative efficiency of part and whole training methods. *J Exp Psychol.* 1963;65(3):217–224. doi:10.1037/h0041060
99. Magill RA, Anderson D. *Motor Learning and Control.* 11 ed. Boston, MA: McGraw-Hill; 2016.
100. Chollet D, Chabies S, Chatard JC. A new index of coordination for the crawl: description and usefulness. *Int J Sports Med.* 2000;21(1):54–59. doi:10.1055/s-2000-8855
101. Potdevin F, Bril B, Sidney M, Pelayo P. Stroke frequency and arm coordination in front crawl swimming. *Int J Sports Med.* 2006;27(3):193–198. doi:10.1055/s-2005-837545
102. Counsilman JE. *The Science of Swimming.* Englewood Cliffs, NJ: Prentice Hall; 1968.
103. Davids K, Kingsbury D, Bennett S, Handford C. Information-movement coupling: implications for the organization of research and practice during acquisition of self-paced extrinsic timing skills. *J Sports Sci.* 2001;19(2):117–127. doi:10.1080/026404101300036316
104. Konstantaki M, Winter EM, Swaine IL. The effects of arms- or legs-only training on indices of swimming performance and dry-land endurance in swimmers. In: Keskinen K, Komi P, Hollander P, editors. *Biomechanics And Medicine In Swimming.* Vol. 8. Jyväskylä, Finland: University of Jyväskylä; 1999:391–395.
105. Konstantaki M, Winter EM. The effectiveness of a leg-kicking training program on performance and physiological measures of competitive swimmers. *Int J Sports Sci Coach.* 2007;2(1):37–48. doi:10.1260/174795407780367140
106. Fontana FE, Jr O F, Mazzardo O, Gallagher JD. Whole and part practice: a meta-analysis. *Percept Mot Skills.* 2009;109(2):517–530. doi:10.2466/pms.109.2.517-530
107. Wickens CD, Hutchins S, Carolan T, Cumming J. Effectiveness of part-task training and increasing-difficulty training strategies: a meta-analysis approach. *Hum Factors.* 2013;55(2):461–470. doi:10.1177/0018720812451994
108. Christian E, Kearney P. Coaching tools for adventure sports. In: Berry M, Hodgson C, Lomax J, editors. *Adventure Sports Coaching.* London: Routledge; 2015:102–123.
109. Carson HJ, Collins D. Refining and regaining skills in fixation/diversification stage performers: the Five-A Model. *Int Rev Sport Exerc Psychol.* 2011;4(2):146–167. doi:10.1080/1750984X.2011.613682
110. Hanin Y, Hanina M. Optimization of performance in top-level athletes: an action-focused coping approach. *Int J Sports Sci Coach.* 2009;4(1):47–91. doi:10.1260/1747-9541.4.1.47
111. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psych Rev.* 1993;100(3):363–406. doi:10.1037/0033-295X.100.3.363
112. Baker J, Young B. 20 years later: deliberate practice and the development of expertise in sport. *Int J Sport Exerc Psychol.* 2014;7(1):135–157. doi:10.1080/1750984X.2014.896024
113. Hambrick DZ, Macnamara BN, Campitelli G, Ullén F, Mosing MA. Beyond born versus made: a new look at expertise. In: Ross BH, editor. *Psychology Of Learning And Motivation.* Vol. 64. Academic Press; 2016:1–55.
114. Maglisco EW. Quality versus quantity. In: *Swimming Fastest: The Essential Reference On Technique, Training, And Program Design.* Champaign, IL: Human Kinetics; 2003:414–415.
115. Stewart M NBAC coach bob bowman comments on usrpt – video interview; 2014. Available from: <https://swimswam.com/nbac-coach-bob-bowman-comments-usrpt/>. Accessed December 14, 2014.

Open Access Journal of Sports Medicine

Publish your work in this journal

Open Access Journal of Sports Medicine is an international, peer-reviewed, open access journal publishing original research, reports, reviews and commentaries on all areas of sports medicine. The

Submit your manuscript here: <http://www.dovepress.com/open-access-journal-of-sports-medicine-journal>

manuscript management system is completely online and includes a very quick and fair peer-review system. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Dovepress