Does High Intensity Interval Training (HIIT), have an effect on young swimmers' performance?

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Abstract

Swimming in different high intensities and intervals (HIIT) is a type of exercise that can provide several improvements for swimming training. The aim of this review is to find out if HIIT swimming training is safe and beneficial for young swimmers. 43 studies from different HIIT's parameters were used to create this review. To be more specific, studies were used on HIIT's effects in human physiology, different types of rest protocols of HIIT, and other studies were carried out on the actual performance not only in swimming, but in other sports as well. The results showed us that HIIT can have a positive effect on the majority of physiological parameters including oxygen uptake, and muscle fibers. Moreover, the same positive effects can be found in the performance of soccer, rowing, kayak, cycling and in track athletes as the improvements reached from 6, 7 to 20%. These improvements also had effects on average recovery time between 60 to 120 seconds. To sum up, the HIIT technique showed us that it can provide benefits not only in young swimmers' performance but in most of the studies that were carried out. Importantly, we recommend that further studies on the HIIT's effects in young swimmers' performance must be continued so as to determine if this training method can continue producing improvements while reducing the training load.

Introduction

It is known that exercise helps the body adjust to new growth conditions via different mechanisms. Moreover, when a human exceeds the critical age of growth, exercise can aid the human body in order to continue physiological improvements while maintaining some of the benefits. The best time for a human to start exercising is in early age as a more athletic body is built up. Exercise in early age contributes to creating a better cardiovascular system, thus achieving a better quality of life.

The prevailing pedagogical movement states that exercise can be beneficial for both the physical and mental health of children, thus promoting health as well as fun (Hatzopoulos, 2012). On the contrary, there are many children that go through painful and exhausting training, being solely motivated by the desire of winning a medal or fame. Therefore, through this review we aim to find out whether High Intensity Interval Training (HIIT) should be applied by coaches on young swimmers or not. In conclusion, we will find out if low (pace - intensity) training is as beneficial as HIIT.

Methods

Forty three studies from different HIIT's parameters were used in order to create this review. Specifically, 18 studies were used on HIIT's physiology effects, 13 studies on the differences between recovery time in HIIT's trials, 10 studies on the performance effects in different sports, and 1 study relating to the effects of

HIIT's on swimming performance. As noted, only a single study relating to the effect of HIIT training on swimming was found. All referenced studies were found in the U.S. National Library of Medicine National Institutes of Health, Pubmed. The key words included: Repeated sprints, volume, intensity, swimmers and performance.

HIIT's physiological benefits

High interval and intensity training (HIIT) was introduced by Reindell and Roskamm in the 1950s (7). What this type of training was designed for is to train at high running velocities, similar race pace (7). Starting with this study, HIIT it is evident that it continues to be employed, with researchers reporting positive results for improving performance and physiological benefits (1, 36, 37).

HIIT has physiological benefits on anaerobic and aerobic energy supplying systems, lactate accumulation and on the resynthesis of PCr. Acevedo & Goldfarb, (1), analyzed the effects of increased intensity training on runners studying VO2max, plasma lactate, ventilator threshold and performance. These researchers documented an increase in performance and a decrease in lactate concentrations at sub maximal (85 – 90% of VO2max) volumes. On the contrary there were no positive or negative effects on VO2max and on the ventilation threshold.

Similar results regarding the effectiveness of physiological parameters via HIIT were presented from Tabata, Nishimura, Kouzaki, Hirai, Ogita, Miyachi et al.(36), Tabata, Irisawa, Kouzaki, Nishimura, Ogita & Miyachi,(37) and Buchheit, (8,12). They examined the effects of moderate intensity training versus high intensity training through repeated sprint and jump sequence respectively. Tabata et al. (36) used a 6 week program at 70% of VO2max versus a program at 170% VO2max. The results in the high intensity training showed an increased in VO2max 7 $ml.kg^{-1}.min^{-1}$ and in the anaerobic capacity 28%. Another study of Tabata et al. (37) examined the effects of two protocols. The first consisted of one set of 6 - 7 bouts of 20s exercise with an intensity of approximately 170% of the subject's VO2max and with a 10s rest between each effort. The second involved one set of 4 - 5 bouts of 30s exercise at an intensity of approximately 200% of the subject's VO2max with a 2min rest between each effort. Results presented an increase on the anaerobic and aerobic energy releasing systems for both of the protocols, with higher positive effects for the 170% of VO2max program. Buchheit (8) also studied selected physiological responses at repeated sprint and jump sequence in other two researches. In the first study he examined the running time, the rate of perceived exertion (RPE), pulmonary oxygen uptake ($V(O)_2$), blood lactate (La), and vastus lateralis deoxygenation (HHb).

In the results, the usage of both repeated sprints and jumps provided more beneficial effects 82% at RPE, 80% at $V(O)_2$, 59% at La and 86% at HHb than, when the repeated sprints were solely used. In the second study, of Buchheit's et al. (12) investigated the effects on performance, cardiorespiratory variables, muscle deoxygenation post - exercise blood lactate [La] and vastus lateralis loads after a repeated - sprint running vs repeated shuttle sprints protocols. Results showed that there is a 70 – 90 % chance that repeated shuttle sprints may be a more effective training method than repeated sprints. This may have a greater systemic physiological load, but may not give a greater loading for vastus lateralis.

Another HIIT's effect is seen in skeletal muscles. Barstow, Jones, Nguyen & Casaburi (5) and Parolin, Chesley, Matsos, Spriet, Jones & Heigenhauser (32), examined the oxygen uptake in muscle fibers type I, II, glycogen phosphorylase (Phos) and pyruvate dehydrogenase (PDH) levels after high interval exercise. For the oxygen uptake examination in skeletal muscles the subjects pedaled at 45, 60, 75, and 90 rpm. The results showed that both of two type I and II muscle fibers were affect at VO2 and La concentrations, with no evidence of positive correlation in only type I muscle fibers (Barstow, 5).

In swimming, Deminice, Trindade, Degiovanni, Garlip, Portari, Teixeira et al., (16), tested blood lactate levels and modulations of oxidative stress biomarkers after a HIIT protocol. The results showed that HIIT may have a positive effect on physiological parameters like blood lactate but also that HIIT is a factor that may increase oxidative stress. The oxidative biomarkers were examined and showed an increase after the anaerobic training, CK from 206, 4 to 244,4 U/L, GSH from 0.52 to 0.62 mM, and ascorbic acid from 0.06 to 0.11±0.03 mg/dL.

With regard to the sources of energy used in high interval exercise Parolin (32), reported that after 3 bouts of 30s in maximal effort, phosphocreatine was rapidly activated up to 47% in the first 6s. Moreover the activation of pyruvate dehydrogenase (PDH) reached the 48% at 6 s and 95% at 15 s in the first bout. In the third bout, PDH was 42% at rest and activated rapidly. Progressively increases in Lactate accumulation were marked in the first bout from 2.7 to 76.1 mmol/ kg with no further increases in bout 3. Differences in physiological responses have also been in children and adolescents shown. Armstrong's & Barker's (3), provided a review that demonstrated that children have an enhanced potential for oxidative metabolism in the myocyte activity (do you mean "myocyte activity") compared with adults. Consequently, it will be of interest to study if it may be beneficial for children or adolescents to use HIIT in training via repeated sprints in different resting periods.

Recovery time in HIIT

Another important parameter when using HIIT is the recovery time, between the sets, as used by coaches in Interval Training. One method that is used to predict how much time is needed for athletes to recover is to establish a working capacity of 4 kcal. /min. as a limit between pauses. Another method is to count the heart rate, or pulse after the exercises (31).

Recovery time between sets is important for all athletes because it helps their physiological systems prepare for the next effort. Balsom, Seger, Sjödin & Ekblom (4) and Seiler, S. & Hetlelid (33), performed 15×40m sprints and six 4-min work bouts respectively. The rest time was 120, 60 and 30 seconds, respectively, for 15×40m between each sprint and 60, 120 and 240 s seconds, respectively for six 4-min work bouts. The results in both studies suggested that 120 seconds is the most beneficial rest time between maximal repetitions of exercise. Belfry, Paterson, Murias, Thomas (6), and Demarie, Koralsztein & Billat (15), showed different physiological oxygen demands between intermitted and continuous exercise. The authors suggested that intermitted exercises increase maximal aerobic power, allowing longer time for VO2max and obtaining higher

VO2peak with lower lactate accumulation. So, another parameter that studies examined is if intermitted exercise is better with active or passive recovery.

Tardieu-Berger, Thevenet, Zouhal, Prioux (38), concluded that short intermittent exercise till exhaustion with active recovery at the 50% of VO2 max can also be beneficial for VO2max increases. Moreover, Thevenet, Tardieu-Berger, Berthoin, Prioux (40) and Dupont, Moalla, Matran, Berthoin (18), suggested that active recovery is more appropriate than passive recovery for energy sources after max volume exercise (95% of VO2max) in running and Wingate tests respectively. The same results were demonstrated by Thevenet, Leclair, Tardieu – Berger, Berthoin, Regueme (39). They concluded that active recovery between 50% and 67% of maximal aerobic velocity can be beneficial for the cardiorespiratory system. On the other hand Spencer, Dawson, Goodman, Dascombe &Bishop (35), supported that moderate and low intensity active recovery showed 3, 4 - 6,0% reductions in peak power cycle test. Moreover, active recovery was inferior in recreation of triphosphate and phosphocreatine compared with passive recovery respectively.

In swimming and recovery, Elbe, Rasmussen, Nielsen & Nordsborg (19), indicated that HIT helps swimmers to increase their recovery levels. The results concluded that after a 12 week program when training intensity was increased and volume training was reduced, the stress and recovery levels decreased 16.6% and improved 6.5% respectively.

Another point of focus in swimming is the type of recovery. Toubekis, Adam, Douda, Antoniou, Douroundos, Tokmakidis (41), examined the effects of active and passive recovery in a high intensity swimming protocol. As far as the results are concerned they indicated that active recovery is better to be avoided especially in exercise intensities higher than 40% of the swimmer's 100 meter best time. Furthermore, passive recovery and active recovery at 40% of 100 meter best time is more beneficial in lactate parameters.

Similar results were demonstrated from Buchheit, Al Haddad, Chivot, Leprêtre, Ahmaidi, Laursen (9). They concluded that after six repetitions of 50m freestyle at maximum velocity with active and passive recovery, repeated sprint performance and heart rate recovery were significantly lower in the passive than in the active recovery. These results indicated that active recovery is more beneficial than passive, but passive can also be used in training for intramuscular energy status improvement.

Effect of HIIT training in performance

It may be evident that HIIT training is beneficial to for improving the majority physiological and performance responses through a wide range of training. These results were found by the surveys of Helgerud, Engen, Wisloff & Hoff (24), Laursen & Jenkins (27), Buchheit, Millet, Parisy, Pourchez, Laursen & Ahmaidi (10), Mosey (30), Laursen (28). Their surveys showed significant differences between the parameters that were studied. Specifically, endurance performance, peak oxygen uptake, maximal oxygen uptake, running economy and distance covered, had a statistically significant improvement, with values between 6, 7% and 20%. Most of the investigations refer to soccer, track athletes, rowing, kayak and cycling.

HIIT is a training method for both male and female athletes, and can be used with excellent results in physiological parameters including maximal oxygen uptake, running economy, heart rate and perceived exertion (21, 13). Moreover, HIIT may also be used with pre-pubertal athletes, with beneficial effects in speed performance between training protocols with maximal sprinting and aerobic speeds (29).

It is interesting however to note that the study of football players by Buchheit, Simpson, Mendez – Villaneuva (12), noted that not all young footballers are affected by the repeated sprints, because of the different physical position demands that are needed in a match. Similar results showed by Dellal, Varliette, Owen, Chirico & Pialoux (14), between HIIT and small side games after a six week program with 5.1 and 6.6%, improvement in Vameval test respectively. Moreover aerobic and recovery capacity improved too. Closing, Ferrari Bravo, Impellizzeri, Rampinini, Castagna, Bishop, Wisloff (20), supports that repeated sprint training in footballers is more beneficial than interval training with greater effects in the Yo Yo test and in the ability repeated sprint. Specifically, after the repeated sprint training they run from 1917m to 2455m and with interval training they run from 1846m to 2077m.

HIIT's training effects in young swimmers.

Most of the studies in other sports and especially in soccer showed that HIIT used with different exercise protocols improves the performance and the physiological parameters like oxygen uptake, endurance, heart rate and muscle energy sources (14). These improvements are also related to both adults and pre-pubertal athletes. Swimming involves a large number of athletes in different ages, especially children and adolescents, and therefore is an excellent sport to investigate the effects of HIIT training.

The study by Sperlich, Zinner, Heilemann, Kjendlie, Holmberg & Mester (35), examined the effects of a 5-week HIT program versus high volume training in 9 to 11 year old swimmers. The results from test protocols before and after the 5 week program were 100 and 2,000m freestyle time. The parameters calculated, were VO (2peak) and rate of maximal lactate accumulation. Between the two programs, the 2,000m time performance, lactate and the VO (2peak) increased following HIIT. On the contrary, no changes showed at 100m time. All these improvements were achieved with two hours less training than the high volume training.

On the other hand Kilen, Larsson, Jørgensen, Johansen, Jørgensen, Nordsborg (25) examined the effects of HIIT including reduced volume and high intensity training, versus the control group that followed high volume and low intensity. The results in adolescent high level swimmers showed that performance, oxygen uptake and body fat were less improved in HIIT training than in the control group.

Discussion

Investigations showed that many of HIIT has many positive effects in physiological and performance parameters. Moreover HIIT can be used in different protocols and recovery times. Starting with physiological positive effects Acevedo, (1); Tabata et al., (36) ; Tabata et al., (37) ; Buchheit, (8), proved that HIIT training

used by athletes training in different sports, showed a number of positive effects. These physiological parameters include increases in oxygen uptake, VO2max, muscle energy sources and blood lactate. These positive effects were also found in swimming. The only difference was the increase of oxidative stress via increasing oxidative stress biomarkers (16). The explanation for this is that high intensity training loads leads the body adjusting to greater training loads. A mechanism that prepares the body for successive training bouts.

These increases in physiological parameters come from maximal and submaximal training volume set, especially with active recovery (38, 40, 18, 39). All these authors reason that active recovery in 40–50% of maximum volume is the most beneficial way to recover. In swimming, the most beneficial way to recover is through active recovery, providing greater results than passive recovery (19, 41, 9). The explanation for this is that the blood flow during active recovery helps to remove the oxidative stress remarks and assists blood lactate to transfer faster from the muscles to the liver. Recovery at 40 – 50% may help the body to prepare for the next training try.

The majority of the studies reviewed showed improvements in performance after HIIT versus repeated sprints training. (12,13,21,24,28,29,30). The difference between two types of training is that HIIT includes big duration in high intensity tries with big rest time. On the other hand repeated sprints training includes maximal intensities with big rest time too but with small duration tries. In swimming the study by Sperlich at al., (35), determined that HIIT is a better way to improve swimming performance than high volume training. This is an important point because it is very common for children to be trained like adolescents, the excessive workloads and time in the water often resulting in them giving up on swimming. Sperlich et al., (35), proved that with two hours less training per week the results in children performance can be improved. The only drawback is the lack of studies because this citation the only one about HIIT and young swimmers. In contrast, the study by Kilen et al., (25), is the only one that showed opposing results regarding the beneficial effects of HIIT. This researcher reported no differences in swimmers performance that used HIIT versus the swimmers who followed the main program.

By way of explanation between the two studies, there was a basic difference in the age and level of the participating swimmers. This means that in high level swimmers the HIIT's duration period may need to be longer to achieve more adaptions. Concluding, it is logical for children to show improvements after HIIT because this type of training motivates them to work on bigger intensities for longer periods and as a result boosts their physiology adaptions. Furthermore, it has been reported that the metabolic pathways of children favor aerobic sources of energy and oxidation muscle fibers in contrast with adolescents and adult swimmers, that use anaerobic sources of energy and glycolytic muscle fibers (17). These findings, once again, call for further research in the coaching of young swimmers.

Applications in sport

From this review it is concluded that different ways of training improve children's performances. Moreover it was found that HIIT training is beneficial and can be used by coaches working with young athletes. However, care must be taken to adjust both volume and intensity of the training.

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