

Abstract

Purpose: To assess the effects of a 7 week low-volume, high-intensity training (HIT) intervention on performance parameters in national level youth swimmers. **Methods:** Sixteen swimmers (age 15.8 ± 1.0 years, age at peak height velocity 12.9 ± 0.6 years, 100-m freestyle 61.4 ± 4.1 s) were randomly assigned to a HIT group or low-intensity, high-volume training (HVT) group which acted as a control. The HIT group reduced their weekly training volume of zone 1 (low-intensity) training by 50% but increased zone 3 (high-intensity) training by 200%. The HVT group performed training as normal. Pre to post-test measures of physiological performance (velocity at 2.5-mM and 4-mM blood lactate [velocity_{2.5mM} and velocity_{4mM}] and peak blood lactate), biomechanical performance (stroke rate [SR], stroke length [SL] and stroke index [SI] over a 50 and 400-m freestyle) and swimming performance (50-m, 200-m and 400-m freestyle) were assessed. **Results:** There was no significant three-way interactions between time, group and sex for all performance parameters ($P > .05$). There was a significant two-way interaction between time and group for velocity_{4mM} ($P = .02$, $\eta_p^2 = .40$), SL₅₀ ($P = .03$, $\eta_p^2 = .37$) and SI₅₀ ($P = .03$, $\eta_p^2 = .39$). Velocity_{4mM} decreased in the HIT group but increased in the HVT group while SL₅₀ and SI₅₀ decreased in the HVT group. **Conclusions:** A 7 week HIT intervention was neither beneficial nor detrimental to performance parameters however the HIT group completed 6 hours (17.0-km) swimming per week compared to 12 hours (33.4-km) per week for the HVT group.

Keywords: HIT, HVT, high-volume training, training organization, swimming

Introduction

Swimming is a cyclical sport with unique physiological and biomechanical demands due to the large variety of racing distances spread across multiple swimming stroke techniques. The gold medal winning times at the Rio 2016 Olympics ranged from 21.40 s for the 50-m event to 14 min 34.57 s for the 1500-m event. However twenty-six out of the thirty-two (81%) Olympic swimming events are competed over a race distance of 200-m or less, for a typical duration of less than 2 min 20 s. Despite the short duration of the majority of swimming events, the traditional training practices of competitive swimmers typically involve high training volumes (i.e. total training distance or duration) which are, in many cases, well in excess of other cyclical sports such as running, rowing and cycling.¹ This is particularly evident at youth level where training volumes may range from 11–20 hours per week spread across 6–11 training sessions.^{2,3}

Swimming performance is determined by a number of different physiological and biomechanical parameters.⁴⁻⁶ Biomechanical parameters such as stroke rate (number of swimming stroke cycles performed per minute), stroke length (distance the swimmer travels per stroke cycle) and stroke index (stroke length multiplied by swimming velocity; an indication of stroke efficiency) are among the best determinants of swimming performance.⁴⁻⁶ This is perhaps one of the incentives for undertaking high training volumes as swimming coaches suggest that large amounts of practice, typically around 11–20 hours per week, are required to develop efficient stroke mechanics.^{2,3,7} In recent years, a number of studies have investigated the effects of a low-volume, high-intensity training (HIT) programme versus a high-volume, low-intensity training (HVT) programme on swimming performance.^{2,8,9} A HIT training programme is defined as a lower volume programme which focuses on performing intervals of high-intensity training (zone 3, >4 mM blood lactate) to improve performance.¹⁰ A HVT training programme is defined as a higher volume programme which focuses on performing prolonged low-intensity training (zone 1, <2 mM blood lactate) to improve performance.¹⁰ A number of high profile international swimmers have had success using HIT programmes which are in contrast to more traditional HVT programmes, this has led to debate among the swimming community.^{11,12} Anecdotal evidence suggests that many of the best swimming coaches and athletes are advocates of HVT, hence the controversy.

A recent systematic review by Nugent et al⁸ investigated the effects of a HIT intervention on performance in competitive swimmers. Seven studies met the inclusion criteria, ranging in

duration from 4 weeks to 4 years and were conducted on youth, university, masters and elite swimmers. Six out of the 7 studies found that HIT resulted in improvements to performance measures such as maximal rate of oxygen consumption and swim velocity at fixed blood lactate values. Four of the 7 studies found that HIT resulted in improvements to performance in events from 50 to 2000-m, whilst none of the 7 studies resulted in a reduction in performance. The review concluded that the applications of HIT may be limited as a number of the controlled studies were only 4 to 5 weeks duration therefore more research is required.

To the best of the authors' knowledge, the effects of HIT on biomechanical parameters in competitive swimmers have not been investigated. Swimming coaches have suggested that HIT programmes may be detrimental to technical development as swimming technique is best practiced at low-intensities;^{2,7} this topic warrants further investigation. In addition, none of the previous HIT studies have accurately quantified the training completed by the HIT and HVT groups using measures such as heart rate, blood lactate, rating of perceived exertion etc.^{13,14} This is important during swimming interventions as different stroke techniques (e.g. butterfly) and technical exercises (e.g. kicking drills) can result in varied metabolic responses.^{15,16} The current study aimed to address this methodological flaw by assessing physiological, biomechanical and perceptual responses to individual HIT and HVT sessions. The main purpose of this study is to assess the effects of a 7 week HIT intervention on physiological, biomechanical and swimming performance parameters in national level youth swimmers. Due to the competition schedule it was not possible to conduct an intervention of longer duration.

Methods

Subjects

Sixteen swimmers from the senior team of a local swimming club volunteered to partake in this study (Table 1). The swimmers were all competing at the top tier national level in 50–400 m events, consistently completed 6–7 swim sessions and 2–3 gym sessions per week, and had a mean swimming volume of 35-km (12 hours) per week. The study was approved by the university ethics committee and procedures were in accordance with the Declaration of Helsinki. All subjects and their parents/guardians signed an informed consent form prior to participation.

Insert Table 1 about here

Study Design

The study was a randomised controlled design. The swimmers were matched for sex (male or female) and randomly allocated into either a HIT group or control (HVT) group (Table 1). The study was conducted during the third preparation training phase (week 36–43 of a 48 week season). Prior to the study, the swimmers trained as normal which was a HVT programme based on the results of pilot testing that was conducted during the previous and current season, indicating that ~95% of the training volume was in zone 1 with ~5% performed in zone 2–3.¹⁷

In order to investigate the effects of a HIT intervention, the swimming coach (21 years experience, Swim Ireland level 3 coach, multiple international medallists) of the team was asked to reduce mean weekly training volume by 50% and to increase mean weekly zone 3 training volume by 200%, based on previous studies.^{9,18,19} The control group trained as normal using a HVT programme. The lead author was present during every session. In order to ensure that the training volume distributions for both groups were valid, the swimming coaches training prescriptions were analysed on a daily basis (Table 2). In addition, physiological, biomechanical and perceptual data was collected during 10 random training sessions for both groups (Table 3).

Insert Table 2 about here

The HIT group swam completed a mean of 1 hour (2.8-km) per session and the HVT group swam as normal for a mean of 2 hours (5.6-km) per session. Each session was divided into a warm up, main session and cool down. The warm up consisted of zone 1 training for both groups which was performed using a variety of technical drills, kicking and pulling exercises. During the main session, the HIT group performed zone 3 training as 25–100 m intervals at an individualised race pace velocity for 50–400 m events across all swimming strokes. This was performed three days per week and zone 1 training was performed on alternative days. The HVT group trained as normal which primarily involved zone 1 training across all swimming strokes. The cool down consisted of zone 1 training for both groups. Training volume and zone distribution during the 7 week intervention for the HIT and HVT group are summarised in Figure 1.

Insert Figure 1 about here

Methodology

Performance tests were conducted over a two day period in the week prior to and after the intervention. All subjects were familiar with the performance tests having performed them

previously. The testing was conducted during normal training hours in a 50-m indoor pool (depth: 2.4-m and temperature: 27–28°C). Dietary intake, prior exercise up to 48 hours and warm up procedures were standardized during testing.

Physiological performance. On day 1 of testing, physiological performance was assessed using the 7 × 200 m incremental test outlined by Pyne et al²⁰. The test involves performing seven 200-m freestyle swims on a 5 minute interval at graded intensities from easy to maximal. The seventh and final swim was a maximal effort and served as a measure of 200-m swimming performance. The swimmers were instructed to maintain an “even pace” during each 200-m interval and an auditory signal was provided at the end of each 100-m to ensure swimmers were pacing correctly. Immediately after completion of each 200-m interval, heart rate (HR) was measured using the Cardio Swim system (Freelap, Switzerland) which measured beat-by-beat HR during swimming, a rating of perceived exertion (RPE) was assessed using the Borg 6–20 Scale²¹ and a blood lactate sample was taken from the earlobe using a Lactate Pro 2 analyser (ARKRAY Europe, Netherlands). In order to determine a peak blood lactate (BLa_{peak}) value, lactate was collected immediately after completion of the seventh 200-m, at 2 and 5 minutes post 200-m swim. The lactate-velocity curve was plotted using Lactate-e software²² for determination of velocity at fixed blood lactate markers of 2.5-mM and 4-mM which are commonly utilised indicators of the lactate and anaerobic threshold, respectively.²² The reliability values for velocity at fixed blood lactate markers (ICC = .85–.96, CV = 0.7–1.1%) and BLa_{peak} (ICC = .81, CV = 11.3%) have been shown to be acceptable.²³

Biomechanical performance. On day 2 of testing, biomechanical performance was assessed using the methods outlined by Smith et al²⁴ to calculate swimming velocity (SV), stroke rate (SR), stroke length (SL) and stroke index (SI) over a 50 and 400-m freestyle time trial. A 20-m mid-pool section was used to measure these parameters in order to exclude the influence of the start (0–15 m) and the turn (5–7.5 m from the wall). A video camera (JVC Everio, Model GZ-MG130EK, USA) sampling at 50 Hz was placed in an elevated position at the 25-m mark of the 50-m pool. The recording was later analysed using Sportscode 11.0 software (Hudl, Agile Sports Technologies) in order to calculate SV, SR, SL and SI over the 20-m mid-pool section. Swimming velocity (SV) was calculated to the nearest 0.01 m/s using the formula: SV (m/s) = 20 ÷ 20-m time (s). Stroke rate (SR) was calculated by timing three stroke cycles using a Finis chronometer (Model 3X-300M, USA). Stroke rate was measured three times over the 20-m mid-pool section and the median value was used for

analysis. Stroke length (SL) was calculated as follows: SL (m/stroke) = SV (m/s) ÷ SR (strokes/s). Stroke index (SI) was calculated as follows: SI = SV (m/s) × SL (m/stroke). The mean value of SR, SL and SI over every 50-m of the 400-m time trial was used for analysis. The reliability of SR, SL and SI has been shown to be moderate to excellent (ICC = .78–.98, CV = 2.4–4.9%).²⁵

Swimming performance. On day 2 of testing, swimming performance was assessed using a 50 and 400-m freestyle time trial from starting blocks. The time trials were performed as a mock competition by matching swimmers, based on previous performance times, thus ensuring a maximal effort. There was a 20 minute active recovery interval between time trials. The times were recorded by an experienced swim coach (>7 years' experience) using a Finis chronometer (Model 3X-300M, USA) and to the nearest 0.01 s.

Statistical analysis

All data was analysed with SPSS 21.0 software (SPSS Inc, Chicago, Illinois, USA). The level of significance was set at $P < .05$. The data was checked for normality using visual inspection and the Shapiro-Wilk test. Independent-samples t -tests were conducted to determine if there were differences between the groups demographics at baseline, compliance rate, and individual responses (physiological, biomechanical and perceptual) to the HIT and HVT group training sessions. A 3-way analysis of variance (ANOVA) with repeated measures was conducted to determine the effects of time, group and sex on performance parameters. The within-subject factor was time (pre-test vs post-test). The two between-subject factors were group (HIT vs HVT) and sex (male vs female). The Levene's test was used to check for homogeneity of variances. Effect sizes are described using partial eta squared (η_p^2) and were interpreted as follows: small ($\geq .01$), medium ($\geq .06$) and large ($\geq .15$).²⁶

Results

One swimmer in the HIT group did not complete post-testing due to an injury and therefore their data was excluded from the final analysis. No differences were observed between the groups demographics at baseline ($P > .05$), nor were there differences in the compliance rate for the HIT group ($87.8 \pm 6.2\%$) and HVT group ($93.2 \pm 5.6\%$, $P = .10$) during the study. The mean training volume for the HIT group was 17.0 ± 2.2 -km per week and 33.4 ± 3.2 -km per week for the HVT group. The total training volume across the 7 week intervention was 119.2-km for the HIT group and 233.7-km for the HVT group. There were significant differences in physiological,

biomechanical and perceptual responses to the HIT and HVT group training sessions (all $P < .001$, Table 3).

Descriptive statistics of the physiological, biomechanical and swimming performance tests for the HIT and HVT group are provided in Table 4. There were no significant three-way interactions between time, group and sex for physiological performance (velocity_{2.5mM}, velocity_{4mM}, BL_{peak}), biomechanical performance (SR₅₀, SL₅₀, SI₅₀, SR₄₀₀, SL₄₀₀, SI₄₀₀) and swimming performance (50_{freestyle}, 200_{freestyle} and 400_{freestyle}) ($P > .05$ for all; Table 4). There was a significant two-way interaction between time and group for velocity_{4mM} ($F_{1,11} = 7.34$, $P = .02$, $\eta_p^2 = .40$, Figure 2), SL₅₀ ($F_{1,10} = 5.99$, $P = .03$, $\eta_p^2 = .37$, Figure 2) and SI₅₀ ($F_{1,10} = 6.49$, $P = .03$, $\eta_p^2 = .39$, Figure 2). All other two-way interactions were not significant ($P > .05$). There was a significant main effect of time for 50_{freestyle} ($F_{1,11} = 5.16$, $P = .04$, $\eta_p^2 = .32$, Table 4) while the main effect of time for 200_{freestyle} was borderline significant ($F_{1,11} = 4.31$, $P = .06$, $\eta_p^2 = .28$, Table 4).

Insert Table 3 about here

Insert Table 4 about here

Insert Figure 2 about here

Discussion

The purpose of this study was to assess the effects of a 7 week HIT intervention on performance parameters in national level youth swimmers. The main finding of this study was that a 7 week HIT intervention resulted in a decrease to velocity_{4mM} in the HIT group and an increase in the HVT group while both SL₅₀ and SI₅₀ decreased in the HVT group (Figure 2). The only performance parameter that was found to decrease in the HIT group was velocity_{4mM} while all other swimming and biomechanical performance parameters remained unchanged. This suggests that a 7 week HIT intervention was neither beneficial nor detrimental to the majority of performance parameters however the HIT group only completed a mean of 6 hours (17.0-km) swimming per week compared to 12 hours (33.4-km) per week for the HVT group. Therefore the HIT programme was more time efficient as it involved 50% less training time and distance.

The present findings are similar to those of previous studies.^{9,27} Faude et al⁹ compared the effect of a 4 week HIT and HVT intervention on performance in regional to national level swimmers (16.6 ± 1.4 years). The HIT and HVT groups both experienced significant increases in velocity at anaerobic threshold (velocity_{threshold}), however there was no change to swimming performance over 100 and 400-m in either group. The findings of our study indicate that velocity_{4mM}, a similar

measure to velocity_{threshold}, decreased in the HIT group and increased in the HVT group (Figure 2). However the decrease in velocity_{4mM} in the HIT group did not result in an improvement in 50, 200 or 400-m swimming performance. This is an interesting finding as velocity_{4mM} is an indicator of aerobic capacity which is important for the more aerobic dependent 200 and 400-m swimming events.²⁸ Similarly the increase in velocity_{4mM} in the HVT group did not result in an increase in swimming performance. Perhaps if the present study and the study by Faude et al⁹ was of a longer duration, the changes to velocity_{4mM} may have influenced swimming performance. However previous studies have found varied responses of velocity_{4mM} and velocity_{threshold} to HIT and HVT interventions.^{10,17,29}

Sperlich et al²⁷ compared the effect of a 5 week HIT and HVT intervention on performance in regional swimmers (10.5 ± 1.4 years). The HIT and HVT groups both experienced large and similar increases in performance parameters such as $\text{VO}_{2\text{peak}}$, BLa_{peak} and swim performance across 50 to 2000-m events. The results indicate that both the HIT and HVT programmes had similar effects however the HIT group performed 50% less training volume per week, similar to our study. In the present study, a main effect of time for 50_{freestyle} was observed which suggests there was a difference over time if the group the participants were in and the sex of participants were accounted for. In addition, a borderline main effect of time for 200_{freestyle} was found. However no significant three or two-way interactions were found for 50_{freestyle} and 200_{freestyle}. The improvements found in both groups of the Sperlich et al²⁷ study could be expected in a very young cohort (10.5 ± 1.4 years) with limited training experience (~4 swim sessions per week). The cohort of youth swimmers in our study were older (15.8 ± 1.0 years), had higher training experience (~6–7 swim sessions per week) and were all competing at national level. Therefore it could be anticipated that improving performance over a relatively short period of time would be more challenging particularly during the third preparation training phase of the season.

To the best of the authors' knowledge, this study is the first to investigate the effects of a HIT intervention on biomechanical performance in competitive swimmers. The findings indicate both SL_{50} and SI_{50} decreased in the HVT group (Figure 2). Stroke length and SI have been found to be one of the best determinants of swimming performance in youth swimmers,⁴⁻⁶ therefore optimising the development of these parameters is crucial. In addition, the findings are in contrast to the recommendations of expert swimming coaches who suggest HVT programmes optimise stroke mechanics.^{2,7} These results

were slightly unexpected as the HVT group trained as normal so the authors anticipated no change in biomechanical performance. However medium to large effect sizes ($\eta_p^2 = \geq .06$ and $\geq .15$ respectively, Table 4) were found in the time by group interactions for the remaining biomechanical parameters (SR₅₀, SR₄₀₀, SL₄₀₀, SI₄₀₀), in combination with no significant changes. This suggests that a greater sample size may have provided more significant findings and thus a clearer picture.

While this study has added to the current literature on this topic, a number of limitations must be noted. Firstly, accurately quantifying the distribution of training volume in different training zones is challenging particularly in an aquatic sport due to the difficulties associated with recording HR underwater and varied metabolic responses to different strokes and technical drills.^{15,16} In order to reduce any error associated with training zone prescriptions, the lead author was present during all sessions and detailed individual responses to 10 random training sessions were collected for each group (Table 3). The measurement of individual responses to HIT and HVT training sessions has not been conducted in previous swimming HIT studies.^{9,18,19} Secondly, there may be the possibility of parallax error due to the use of a single-camera analysis system during pre-post biomechanical performance testing. However a multi-camera analysis system was not available during testing and the more widely utilised single-camera analysis system has been shown to be as accurate.³⁰ Thirdly, the short duration of this study is a limitation. A systematic review of this topic by Nugent et al⁸ identified two longitudinal studies of 1 year and 4 years duration which found that HIT improved performance in competitive swimmers. However, there are numerous methodological flaws associated with both studies such as the lack of an appropriate control group.

Practical Applications

The main findings of this study could be of use to coaches and sport scientists who are working with youth athletes that may have limited training time due to school timetables, participation in multiple sports or the commonly restricted training hours for competitive swimming clubs in public facilities. In addition, the lower training volume of a HIT programme may potentially help to reduce the risk of overuse injury. The findings demonstrate that a 7 week HIT intervention involving a 50% reduction in zone 1 training volume and a 200% increase in zone 3 training volume had neither a beneficial nor detrimental effect on the majority of performance parameters compared to a traditional HVT programme. The HIT programme was more time efficient involving a mean training volume of 6 hours (17.0-km) per

week whereas the HVT programme had a mean training volume of 12 hours (33.4-km) per week.

Conclusions

A 7 week HIT intervention was neither beneficial nor detrimental to the majority of performance parameters compared to a traditional HVT program. Velocity_{4mM} decreased in the HIT group and increased in the HVT group while both SL₅₀ and SI₅₀ decreased in the HVT group. Therefore the only performance parameter that was found to decrease in the HIT group was velocity_{4mM} while all other parameters remained unchanged. The decreases in SL₅₀ and SI₅₀ in the HVT group are of concern and appear to suggest that a HIT programme may be a better option to optimise biomechanical performance. Despite this, more research is needed in this area. Future studies should be of >12 weeks duration with larger sample sizes and should investigate the effect of HIT and HVT on similar performance parameters.

Acknowledgements

The study was part-funded by the National Aquatic Centre Swimming Club, Dublin. The authors would like to thank the swimming coaches – David Malone and Hayley Burke who made this study possible. In addition, the authors would like to thank Ciara Sinnott O'Connor for her help during pre-testing, Alan Swanton for his advice on biomechanical analysis and the reviewers for their detailed comments.

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Table 1 Anthropometric and performance characteristics for the HIT and HVT group

Variables	HIT (n = 8)	HVT (n = 8)
Sex (n, male/female)	3/5	3/5
Age (years)	16.0 ± 1.1	15.6 ± 0.9
Body mass (kg)	66.3 ± 10.6	65.3 ± 12.5
Height (cm)	174.9 ± 9.3	172.3 ± 10.0
Age at peak height velocity (years)	12.9 ± 0.5	13.0 ± 0.6
100-m freestyle personal best time (s)	61.1 ± 3.8	61.6 ± 4.6

Table 2 The swimming coaches' distribution of total training volume during the 7 week intervention

Training zone	Descriptors	Example training sets	HIT (km)	% of total	HVT (km)	% of total
1	Low-intensity training: <2 mM blood lactate, <80% HR _{max} , session-RPE ≤4	3 × 300 m warm up (changing each 50 m–swim, drill, swim), rest 20 s	97.4	81.7	223.9	95.8
2	Moderate-intensity training: 2–4 mM blood lactate, 80–87% HR _{max} , session-RPE 5–6	10 × 100 m threshold kick, rest 20 s	2.2	1.9	2.9	1.2
3	High-intensity training: >4 mM blood lactate, >87% HR _{max} , session-RPE ≥7	20 × 50 m at individualised 400-m race pace, rest 20 s	19.6	16.4	6.9	3.0

Descriptors based on the recommendations of Seiler.¹⁴

Table 3 Physiological, biomechanical and perceptual responses to the HIT and HVT group training sessions during the 7 week intervention (n = 15)

Variables	HIT (n = 7)	HVT (n = 8)
Mean HR (beats/min)	181 ± 7	152 ± 9*
Peak HR (beats/min)	192 ± 8	180 ± 11*
Blood lactate (mM)	6.7 ± 2.7	1.9 ± 0.8*
Mean velocity (m/s)	1.43 ± 0.15	1.10 ± 0.09*
Peak velocity (m/s)	1.56 ± 0.18	1.37 ± 0.10*
Mean SR (strokes/min)	39 ± 6	26 ± 4*
Mean RPE (6–20)	17.4 ± 1.9	11.9 ± 1.4*
Session-RPE (1–10)	7.8 ± 1.4	3.7 ± 1.2*

All values are calculated as the mean ± SD of 10 random training sessions for the HIT group (45 individual data sets) and HVT group (43 individual data sets).

HR and velocity values are the mean and peak of the main session (i.e. excluding warm up and cool downs).

Blood lactate values were obtained at least 2 times during the second half of each main session.

Stroke rate and RPE values were obtained 3 times over the main session and a mean was calculated.

Session-RPE was recorded at least 30 minutes after each session.

*Independent samples t-test. Both group variables were significantly different from each other ($P < .001$).

HR: heart rate, RPE: rating of perceived exertion, SR: stroke rate.

Table 4 Descriptive statistics of the physiological, biomechanical and swimming performance tests for the HIT and HVT group (n = 15)

Variables	HIT (n = 7)		HVT (n = 8)		ANOVA P Values and Effect Sizes (η_p^2)	
	Pre	Post	Pre	Post	Time	Time × Group
Velocity _{2.5mM} (m/s)	1.24 ± 0.09	1.24 ± 0.05	1.25 ± 0.07	1.28 ± 0.08	.50 (.04)	.20 (.15)
Velocity _{4mM} (m/s)	1.32 ± 0.07	1.30 ± 0.07	1.31 ± 0.07	1.33 ± 0.07	.86 (.00)	.02 (.40)
BLa _{peak} (mM)	9.3 ± 4.4	9.7 ± 3.0	9.7 ± 2.6	10.0 ± 2.2	.90 (.00)	.99 (.00)
SR ₅₀ (strokes/min)	49.9 ± 8.0	49.1 ± 8.1	49.1 ± 4.3	49.2 ± 4.7	.29 (.11)	.22 (.14)
SL ₅₀ (m/stroke)	1.98 ± 0.22	1.98 ± 0.25	2.03 ± 0.25	1.96 ± 0.27	.11 (.23)	.03 (.37)
SI ₅₀	3.22 ± 0.45	3.17 ± 0.49	3.34 ± 0.59	3.12 ± 0.60	.01 (.53)	.03 (.39)
SR ₄₀₀ (strokes/min)	34.7 ± 2.6	34.5 ± 2.6	34.7 ± 3.2	35.5 ± 3.7	.28 (.14)	.20 (.16)
SL ₄₀₀ (m/stroke)	2.18 ± 0.15	2.20 ± 0.16	2.22 ± 0.31	2.21 ± 0.30	.85 (.00)	.18 (.19)
SI ₄₀₀	2.72 ± 0.30	2.77 ± 0.33	2.90 ± 0.56	2.86 ± 0.50	.72 (.02)	.12 (.25)
50 _{freestyle} (m/s)	1.72 ± 0.16	1.70 ± 0.15	1.71 ± 0.12	1.69 ± 0.11	.04 (.32)	.56 (.03)
200 _{freestyle} (m/s)	1.36 ± 0.08	1.37 ± 0.09	1.37 ± 0.07	1.39 ± 0.07	.06 (.28)	.59 (.03)
400 _{freestyle} (m/s)	1.31 ± 0.09	1.31 ± 0.09	1.33 ± 0.08	1.33 ± 0.07	.62 (.03)	.87 (.00)

Values are mean ± SD

BLa: blood lactate, SR: stroke rate, SL: stroke length, SI: stroke index

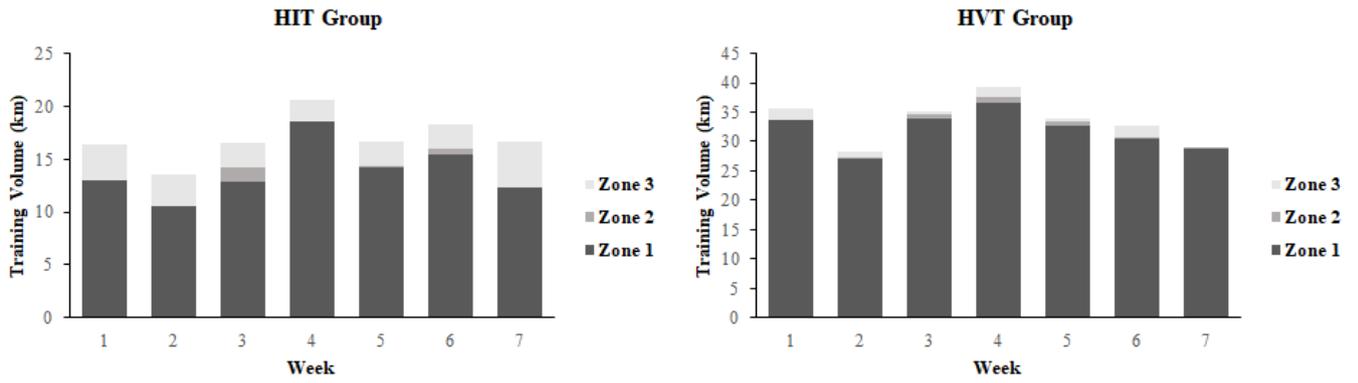


Figure 1 – Training volume and zone distribution during the 7 week intervention for the HIT and HVT group.

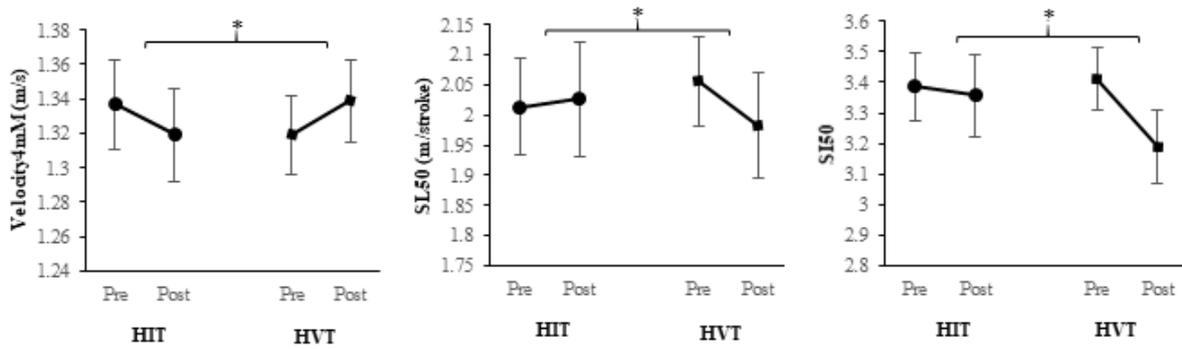


Figure 2 – A significant two-way interaction between time and group for velocity_{4mM} ($P = .02$, $\eta_p^2 = .40$), SL₅₀ ($P = .03$, $\eta_p^2 = .37$) and SI₅₀ ($P = .03$, $\eta_p^2 = .39$). Abbreviations: * indicates a significant interaction ($P < .05$); Velocity_{4mM} indicates swim velocity (m/s) at a fixed blood lactate of 4-mM; SL₅₀ indicates stroke length (m/stroke) over the 50-m freestyle time trial; SI₅₀ indicates stroke index over the 50-m freestyle time trial.