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Impact of weekly swimming training distance on the ergogenicity of inspiratory muscle training in well trained youth swimmers

Inspiratory muscle training and swimming

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ABSTRACT

The aim of this study was to examine the impact of weekly swimming training distance upon the ergogenicity of inspiratory muscle training (IMT). Thirty-three youth swimmers were recruited and separated into a LOW and HIGH group based on weekly training distance ($\leq$ 31 km·wk^{-1} and > 41 km·wk^{-1}, respectively). The LOW and HIGH groups were further subdivided into control and IMT groups for a 6-week IMT intervention giving a total of four groups: LOW$_{con}$, LOW$_{IMT}$, HIGH$_{con}$, HIGH$_{IMT}$. Before and after the intervention period, swimmers completed maximal effort 100 m and 200 m front crawl swims, with maximal inspiratory and expiratory mouth pressures (PImax and PEmax, respectively) assessed before and after each swim. IMT increased PImax (but not PEmax) by 36% in LOW$_{IMT}$ and HIGH$_{IMT}$ groups ($P < 0.05$) but 100 m and 200 m swims were faster only in the LOW$_{IMT}$ group (3% and 7% respectively, $P < 0.05$). Performance benefits only occurred in those training up to 31 km·wk^{-1} and indicate that the ergogenicity of IMT is affected by weekly training distance. Consequently, training distances are important considerations, among others, when deciding whether or not to supplement swimming training with IMT.

Key words: breathing, training, adolescents

INTRODUCTION

The benefits of pressure-threshold inspiratory muscle training (IMT) upon sport performance are well documented and include improved cycling (17), running (33) and rowing (42) performance. In addition, dyspnea (34,42,43) and exercise blood lactate may be lower during both submaximal exercise (4,30,41) and volitional hyperpnea (3), while recovery time following high intensity repetitive sprint running is shortened (34) and oxygen uptake kinetics are accelerated (4).

Only a few studies have investigated the impact of inspiratory muscle training (IMT) or respiratory muscle training (RMT) on swimming performance (18,20,31,43). These studies employed strength based training protocols, which required swimmers to complete 30-36 training breaths per training session (18,31,43). In contrast only one RMT study (20) adopted an endurance based protocol whereby swimmers were required to complete 30 minutes of exhaustive breathing per session. It is surprising that so few studies have examined the role of breathing muscle training given that swimming presents some unique challenges to the breathing musculature (14), causing their functional weakening. For example, maximal inspiratory mouth pressure, a measure of inspiratory muscle strength, was significantly reduced following 100 m (1), 200 m (24,25), 300 m and 400 m (39) front crawl swimming, and 200 m back stroke, breast stroke and butterfly swimming (24).

Supplementing routine swimming training with 6-weeks of IMT or 8-weeks of RMT has been shown to increase inspiratory muscle strength and improve 50 m, 100 m and 200 m swimming time trial performance (18,20). However, the improvements reported in swimming time trial performance by Kilding et al. (18) and Lemaitre et al. (20), are not universal. Mickleborough, Stager, Chatham, Lindley and Ionescu (31) reported that 12-weeks IMT failed to improve respiratory muscle strength in National and International level swimmers undertaking at least 40 $km \cdot wk^{-1}$ of swimming training. Similarly, Wells et al. (43) reported that 12-weeks of RMT improved inspiratory muscle strength but not peak velocity or velocity at the lactate threshold in National standard swimmers completing in excess of 45 $km \cdot wk^{-1}$ of training.

Although Kilding et al. (18) did not report their swimmers average weekly training distance, those examined by Lemaitre et al. (20) swam between 14-34 km·wk^{-1}. Consequently, it is possible that differences in weekly training distance were responsible for the conflicting findings of these four studies. Indeed, an increase in training distance is one method recommended to improve performance in youth swimmers (28) and so it is likely that the natural inspiratory muscle conditioning effect induced by immersion and the horizontal body position will be accentuated with longer training distances (7,8). It is therefore possible that supplementing high weekly training distances in swimmers with strength-training IMT could fail to induce functional swimming benefits because the relatively high training distance could create a whole body training effect that IMT is unable to supplement. In support of this line of reasoning, both Williams et al. (44) and Sonetti et al. (38) have shown that supplementing routine whole body training with breathing muscle training in well trained runners and cyclists, fails to enhance exercise capacity or peak performance despite increasing respiratory muscle strength. This likely reflects saturation of the perceptual and cardiovascular mechanisms by which IMT is believed to enhance exercise performance (11). These mechanisms include a decrease in the oxygen cost of breathing, which can facilitate oxygen availability to the working muscles (40), a fall in blood lactate arising from an increase in the oxidative capacity of the inspiratory muscles (3,4), a drop in exercising heart rate (11) and a reduction in both breathing and leg discomfort (11,34,41).

The aim of this study was to determine the effect of weekly swimming training distance upon IMT ergogenicity. Specifically, we assessed the impact of IMT upon inspiratory and expiratory muscle strength and sprint swimming time trial performance in trained swimmers completing more than, or less than, 31 km·wk^{-1}. It was hypothesised that IMT would increase inspiratory muscle strength (but not expiratory muscle strength) regardless of weekly training distance, but that IMT would only enhance swimming time trial performance in those swimming up to 31 km·wk^{-1}.

METHODS

Experimental Approach to the Problem

It was our intention to address the impact of weekly training distance (on the basis that weekly session frequency and weekly training duration will dictate this) on the ergogenicity of IMT in well-trained youth swimmers. We did this by focusing on swimming performance time trial times and swimming kinematics in response to IMT in male and female swimmers with different training histories.

To do this trained swimmers undertaking different weekly training distances were recruited and separated into LOW and HIGH training distance groups. Swimmers were then further subdivided into IMT and control groups: thus each training distance permutation contained a control group. Training distance was kept consistent throughout the 6-week period with all LOW swimmers undertaking the same overall weekly training program and all HIGH groups undertaking the same overall weekly training program: this was confirmed by the respective coaches. It was not our intention to control how the swimming training distance was achieved as this would require selecting trained swimmers and changing their routine program (which would be unreflective of their actual training environment), or selecting untrained swim-able individuals and prescribing a swimming and IMT training program. Both of these approaches have the potential to confound swimming performance irrespective of IMT. Consequently, the approach we adopted, although not without limitation, was chosen to maximise ecological validity and provide swimmers and coaches with directly applicable information regarding the usefulness of IMT inclusion into routine swimming training.

Subjects

Thirty-three well trained youth swimmers (18 males, 15 females) volunteered for this study (including one asthmatic who did not require any medication for athma during the study). Swimmers were initially separated into two groups based upon their weekly training distance defined as either low (LOW) or high (HIGH): the selection of training distances were consistent with those reported in similar studies (20,31,43). Throughout the 6-week period the swimming coaches of the LOW and HIGH groups confirmed that the overall swimming training program was the same for both IMT and control swimmers. Descriptive data for the LOW and HIGH groups as a whole are in Table 1. Participants provided informed written consent after being informed of the benefits and risks of the study, and local Institutional ethical approval was obtained before the start of the study.

Table 1 about here

Study overview

Following a pulmonary and respiratory muscle familiarisation session, all participants completed a race-paced 100 m and 200 m front crawl swim (time trial tests) in their usual indoor training pool. The LOW and HIGH groups were then further separated with half the swimmers in the LOW and HIGH groups randomly assigned IMT (LOW_{IMT} n = 9; $HIGH_{IMT}$ n = 8) and the remaining swimmers serving as controls (LOW_{CON} n = 9; $HIGH_{CON}$ n = 7). Thus, there were a total of four experimental groups: LOW_{con}, LOW_{IMT}, $HIGH_{con}$ and $HIGH_{IMT}$. The IMT regimen was identical for both groups, see below.

Following the time trial tests, those in the LOW_{IMT} and $HIGH_{IMT}$ groups undertook their usual training plus 6-weeks of IMT. Those in the LOW_{con} and $HIGH_{con}$ continued with their usual training only. All swimmers then repeated the time trial and respiratory muscle function tests in the same indoor pool as their pre IMT time trial tests and following the same warm-up.

Procedures

Forced vital capacity (FVC) and forced expired volume in one second (FEV_1) were measured (MicroLab MK8 digital spirometer, CareFusion, Kent, UK), in a seated position and from total lung capacity pre IMT for descriptive purposes of lung function (Table 1). Maximal inspiratory and expiratory mouth pressures (PImax and PEmax, respectively) were measured upright with the nose occluded on poolside using a hand-held respiratory pressure metre (RPM, Micro Medical, Rochester, UK). PImax and PEmax were measured pre (before the warm-up) and post each performance test from residual volume and total lung capacity respectively.

Each swimmer completed a maximum effort 100 m and 200 m front crawl swim from a dive start, in a counterbalanced order and on separate occasions within one week of each other. Swimming time was recorded per swim using a stop watch, and in the case of the 200 m swim, per 100 m partial also. Clean swimming velocity and stroke rate (SR) were recorded per 100 m and 200 m swim (Finis stop watch with base count 3 function) using a 12.5 m central pool zone, and expressed per 100 m partial of the 200 m swims. Stroke rate was converted from total stroke cycles to cycles per second (Hz) using achieved velocity ($m{\cdot}s^{-1}$) and then multiplied by 60 to achieve cycles per minute ($cycles{\cdot}min^{-1}$) (6,21). Stroke length (SL: $m{\cdot}cycle^{-1}$) was then calculated as achieved velocity divided by SR in Hz (5,6).

IMT was performed (POWERbreathe, POWERbreathe International Ltd, UK; Power Lung, Power Lung, USA) twice daily, 7 $d{\cdot}wk^{-1}$ for 6-weeks. Each session consisted of 30 breaths at an intensity equivalent to 50% PImax (11,16,18,33). After the initial setting of training loads , participants were instructed by an investigator to increase periodically the load on the inspiratory muscle trainer so that 30 breaths could only just be completed (18). Those assigned to the control condition undertook their usual (coach prescribed) training only.

Statistical Analyses

Baseline (i.e. pre-IMT) descriptive data (age, mass, stature, FVC, FEV_1, FEV_1/FVC, PImax, PEmax, 100 m and 200 m swimming time trial times) were first assessed for normality and then compared between LOW (pooled LOW_{con} and LOW_{IMT}) and HIGH (pooled $HIGH_{con}$ and $HIGH_{IMT}$) groups as a whole using independent samples t-tests and a Mann Whitney U test for age. Baseline and post IMT PImax and PEmax were recoded as the highest value regardless of time trial test.

Mixed model repeated measures ANOVAs were used to assess for differences in PImax, inspiratory muscle fatigue (IMF), expiratory muscle fatigue (EMF), PEmax, swimming time, velocity, SR and SL per 100 m and 200 m swim in LOW_{con}, LOW_{IMT}, $HIGH_{con}$ and $HIGH_{IMT}$ groups. In the case of the 200 m swim, this was also extended to per 100 m partial. IMF and EMF were defined by the transient reduction (cmH_2O) in mouth pressure pre- (before the warm-up) vs post- exercise.

Post hoc, repeated measures ANOVAs with Bonferroni adjustments were used to assess differences in swimming time, velocity, SR and SL for all groups, per 200 m swim. Paired and independent samples t-tests assessed differences in swimming time, velocity and SR for the 100 m swim pre and post IMT. Between groups ANOVA's with Bonferroni adjustments and independent t-tests were used to assess for differences in the highest recorded PImax and PEmax values pre and post IMT between groups.

P was set at 0.05 and analyses were undertaken using IBM SPSS statistics version 22. Effect sizes were calculated using Cohen's *d* for parametric data with an effect size of 0.2 deemed small, 0.6 moderate, 1.2 large, 2.0 very large and 4.0 extremely large (15). For non-parametric data, r was used, whereby r is the z score divided by the square root of the total number of observations. A value of 0.1 is deemed small, 0.3 medium and 0.5 and above large (12). Data are presented as mean and standard deviation (SD) unless otherwise stated.

RESULTS

Respiratory muscle strength

Baseline PImax and PEmax were similar between all groups. PEmax was unaffected by IMT, but PImax did increase (F = 105.142, $P < 0.001$) after IMT. The biggest improvement in PImax was seen in the $\mathrm{LOW_{IMT}}$ (98 ± 4% IMT compliance) and $\mathrm{HIGH_{IMT}}$ (91 ± 3% IMT compliance) groups (F = 16.355, $P < 0.001$, $d = 0.97\text{-}1.29$) (figure 1).

Figure 1 about here

IMF was highly variable amongst swimmers (Figure 2). These differences in IMF magnitude were not significant and were unaffected by IMT. There was no evidence of EMF.

Figure 2 about here

Swimming time and velocity

Pre IMT 100 m and 200 m swimming times were on average 14% faster (9.1 s and 20.8 s, respectively) ($P < 0.001$) in the HIGH (pooled HIGH_{con} and HIGH_{IMT}) compared with LOW (pooled LOW_{con} and LOW_{IMT}) group swimmers (Table 1). IMT improved 100 m (F = 14.455, $P < 0.001$, power = 0.954) and 200 m (F = 21.108, $P < 0.001$, power = 0.993) swimming times (and hence velocity) in the LOW_{IMT} group (100 m: $d = 0.32$; 200 m: $d = 0.64$) but not the HIGH_{IMT}, LOW_{con} or HIGH_{con} groups (Table 2). 100 m and 200 m swimming times were slower following IMT in HIGH_{IMT} and HIGH_{con} respectively ($P < 0.05$; 100 m: $d = 0.65$; 200 m: $d = 0.59$).

The 1st and 2nd 100 m partials of the 200 m differed between the HIGH and LOW groups (F = 10.844, $P = 0.003$, power = 0.889). The 1st 100 m ($d = 0.39$) and 2nd 100 m ($d = 0.24$) partials were faster after IMT in the LOW_{IMT} group ($P < 0.05$). The 1st 100 m ($d = -0.58$) and 2nd 100 m ($d = -0.58$) partials were slower ($P < 0.05$) after the intervention in the HIGH_{con} group (Table 2).

The improvement in PImax post IMT in the LOW_{IMT} group was not correlated with the change in 100 m or 200 m swimming times pre and post IMT ($P > 0.05$).

Table 2 about here

Stroke rate and length

100 m (F = 8.298, $P = 0.008$, power = 0.789) and 200 m (F = 35.578, $P < 0.001$, power = 1.000) SR was higher in the HIGH_{con} and HIGH_{IMT} groups than the LOW_{con} and LOW_{IMT} groups pre and post IMT (Table 2). No differences were observed between partials ($P > 0.05$) although SR was lower in HIGH_{con} per partial (1st 100 m: $d = 0.84$; 2nd 100 m: $d = 0.75$) following IMT, and was lower in the 2nd 100 m

partial for the $HIGH_{IMT}$ group regardless of whether assessed pre or post IMT (pre IMT: $d = 0.78$; post IMT: $d = 0.67$) ($F = 18.257$, $P < 0.001$, power = 1.000, Table 2).

100 m SL was unaffected by IMT status ($P > 0.05$). Although SL was similar in the $HIGH_{IMT}$ and LOW_{IMT} groups the tendency for SL to be lower in the $HIGH_{con}$ group compared with the LOW_{con} group pre and post IMT (d = 0.40-0.52) just missed statistical significance ($F = 4.096$, $P = 0.054$, power = 0.493). SL in the 2nd 100 m partial of the 200 m was consistently shorter than the 1st 100 m partial in all groups ($F = 23.748$, $P < 0.001$, power = 0.997, d = 0.12-0.36). However, IMT did not affect SL and no differences were observed between the LOW and HIGH groups ($P > 0.05$; Table 2).

DISCUSSION

The aim of this study was to investigate the effect of weekly training distance upon the ergogenicity (100 m and 200 m swimming time trial tests) of 6-weeks pressure threshold IMT. The main findings were that IMT increased PImax, but swimming time (and hence velocity) were only improved when swimming training distance was no greater than 31 $km \cdot wk^{-1}$.

Past studies have shown that PImax of trained swimmers varies between 83-146 cmH_2O in those aged 13-17 years (20,24,27,35,39,43) and between 123-148 cmH_2O in individuals aged 19-30 years (1,16, 22,25,26); although one study reported substantially higher pressures of 182 ± 27 cmH_2O in swimmers aged 18.2 ± 1.6 years (31). Our baseline PImax data (Table 1) is therefore consistent with that of youth swimmers, and substantially greater than their age-predicted PImax: 144 ± 29% for LOW (pooled LOW_{con}, LOW_{IMT}) and 142 ± 25% for HIGH (pooled $HIGH_{con}$, $HIGH_{IMT}$) groups (45).

IMT has been shown to increase PImax by 9-17% following only 6-weeks of IMT (18) or RMT (43), by ~40% following 8-weeks of RMT (20) and by as much as 64% following 12-weeks of RMT (43). We observed a 36% improvement in PImax following 6-weeks of IMT. However, as the LOW_{con} and $HIGH_{con}$ groups collectively improved PImax by 9%, which most likely reflects a learning effect, we cannot rule out the possibility that the $\mathrm{LOW_{IMT}}$ and $\mathrm{HIGH_{IMT}}$ groups experienced a similar phenomenon.

The 100 m and 200 m performance tests were 3% and 7% faster ($P < 0.05$) following IMT in the $\mathrm{LOW_{IMT}}$ group, which represented a lower standard group of swimmers However, these improvements were not correlated with the increase in PImax ($P > 0.05$). We are not the first to observe such a disconnect and evidence in cycling and running suggests that improved performance following acute or chronic improvements in PImax is not due to PImax *per se* (10,11,17). Rather, it seems likely that the improved 100 m and 200 m swimming times of the $\mathrm{LOW_{IMT}}$ group following IMT reflects a number of mechanistic changes secondary to the IMT-induced structural and functional changes occurring in the inspiratory muscles (11,17,34). These might include an increase in the oxidative capacity of the inspiratory muscles including enhanced lactate kinetics (3,4), and a fall in the oxygen cost of breathing. The latter would facilitate oxygen availability to the working muscles (40) and potentially reduce the perception of both breathlessness and limb muscle discomfort (11,34,41). Furthermore, given that the magnitude of increase in PImax does not dictate the magnitude of exercise improvement, this might partly explain why IMF is not necessarily reduced after IMT (11) or correlated with performance following RMT (42). In support of this we found that IMT had no impact on the magnitude of IMF experienced by swimmers. However, it should also be noted that while IMF did occur in some swimmers, it was highly variable (Figure 2).

Our swim time and velocity data suggest that training distance is a key factor in determining the ergogenecity of IMT. Our data also supports the contradictory observations reported in the literature. For example, Kilding et al. (18) and Lemaitre et al. (20) found that 50 m, 100 m and 200 m time trial swims were 1.7% to 4% faster following 6-weeks IMT or 8-weeks RMT, whereas Wells et al. (43) found that IMT did not enhance peak swimming velocity when training distance was 45-88 $\mathrm{km{\cdot}wk^{-1}}$. The swimmers recruited by Wells and colleagues (43) were of National standard, whereas Kilding et al. (18) and Lemaitre et al. (20) examined club-level and well-trained swimmers, respectively. Although Kilding et al. (18) did not provide details of their swimmers weekly training distance, Lemaitre et al. (20) reported that their swimmers completed 14-34 $\mathrm{km{\cdot}wk^{-1}}$, which was substantially lower than that reported by Wells et al. (43) and is consistent with the distances completed by the LOW_{con} and LOW_{IMT} groups of the present study. Furthermore, it is interesting to note that pre IMT/RMT 200 m and 100 m swimming times were around 130-133 s and 64 s respectively in the studies of Kilding et al. (18) and Lemaitre et al. (20), which are faster than the 200 m and 100 m swimming times of LOW_{con} and LOW_{IMT} groups, but slower than the $HIGH_{con}$ and $HIGH_{IMT}$ groups (Table 2). However, based on our findings it would be unwise to attribute the inability of IMT to improve performance in the $HIGH_{IMT}$ group to an absolute training distance threshold phenomenon that once exceeded means that IMT is unable to enhance performance. Because both the $HIGH_{IMT}$ and $HIGH_{con}$ groups tended to swim more slowly after the 6 week intervention (Table 2), we cannot exclude the possibility that swim training volume *per se* resulted in a state of holistic fatigue or overreaching compared with the LOW groups. Although LOW and HIGH group swimmers were in endurance and high volume focused periods at the time of testing (preparatory for the LOW groups and specific preparatory for the HIGH groups), HIGH group swimmers completed an additional 66-246 km than LOW group swimmers over the 6 week intervention. Indeed, Gonzάlez-Boto et al. (13) found that increasing training distance from 28-32 km to 45 km or greater in Regional standard swimmers (age 15.5 ± 7.5 years) over a 6 week period significantly increased the signs of overreaching (diminished recovery and elevated stress). These signs only reversed when training distance was reduced to 39 km or less. Thus, it is possible that the administration of IMT in the $HIGH_{IMT}$ group coincided with a period of overreaching masking any potential IMT mediated benefits.

Unfortunately the current study is unable to identify how 100 m and 200 m velocities increased after IMT in the LOW_{IMT} swimmers. Swimming velocity is the product of SR and distance travelled i.e. SL and at faster velocities typically increases by increasing SR and decreasing SL (9,36,37). The faster swimming 100 m and 200 m velocities observed in the HIGH compared with LOW groups were consistent with this (Table 2). However, the increase in 100 m and 200 m velocities after IMT in the LOW_{IMT} group were not associated with an increase in SR. Because of the relationship between SR and SL, velocity will increase if the force exerted per stroke, and hence distance travelled, increases without an accompanying rise in SR (9). But SL was also unchanged in the LOW_{IMT} group after IMT (Table 2). Our findings are therefore difficult to explain. It is possible that the non-significant increase in SR (d = -0.24) lead to an increase in 100 m mean velocity, but this does not explain the increased mean 200 m velocity. Indeed, the increase in velocity was mainly due to improvements observed in the 1st 100 m partial ($P < 0.05$, $d = -0.30$), yet SR and SL were unchanged following IMT. Only during the 2nd 100 m partial did SL exhibit a tendency to increase after IMT ($P > 0.05$, $d = -0.10$). We have no satisfactory explanation for this and unfortunately no other swimming IMT/RMT studies have examined the impact of IMT/RMT on SR or SL. It is conceivable that the measurement methods adopted were simply not sensitive enough to detect IMT-induced changes or partition the effect of IMT-induced, from swim-training induced, changes. Indeed, there was a non-significant tendency for swim time to improve in the LOW_{con} group after IMT. This might indicate that IMT in the LOW_{IMT} group supplemented the swim-training induced changes making them statistically significant. Given that SR, SL and velocity provide no information about technique or arm coordination measures (36,37), analysis of arm coordination parameters (e.g. entry, pull, push and recovery phases) might prove more revealing than simply SR and SL when investigating the impact of IMT on stroke characteristics and in-turn velocity.

In conclusion, as 100 m and 200 m swimming times, and hence velocity, improved after IMT only when swim-training distance did not exceed 31 $km \cdot wk^{-1}$, our data indicate that IMT should not be advocated as a blanket training adjunct to all swimmers. Even though swimming performance did not improve once training distance exceeded 41 $km \cdot wk^{-1}$, this training distance is unlikely to reflect a fixed threshold value in determining the ergogenicity of IMT. Rather, the independent effects of the competitive level of swimmers, training volume, training cycle phase and other routine training considerations more likely, and collectively, dictate the ergogenicity of IMT.

Furthermore, it is important to reiterate that the swimmers in the current study were adolescent and therefore unlikely to have reached physically maturity at the time of testing (19,28). Caution is therefore advised if applying our findings to Senior and Masters swimmers who are likely to be fully mature and better able to cope with the physiological, biomechanical and psychological demands associated with the greater weekly training distances routinely undertaken (28).

PRACTICAL APPLICATIONS

6-weeks of pressure threshold IMT significantly increased PImax in well-trained youth swimmers although this did not automatically translate into improved swimming time trial performance. 100 m and 200 m swim times following IMT improved only in adolescent swimmers who undertook no more than 31 $km{\cdot}wk^{-1}$ of swim training. However, the merits of supplementing swimming training with IMT should not be based on weekly training distance in isolation but rather on a combination of the competitive level of swimmers, swim-training and IMT.

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Figure 1. Highest PImax before and after IMT

Note. Filled bars = pre IMT; open bars = post IMT. *($P < 0.05$) different to pre IMT within group; §§($P < 0.01$) §($P < 0.05$) pre and post IMT delta change different to HIGH_{IMT}; $^{⌠}$($P < 0.05$) pre and post IMT delta change different to LOW_{IMT}

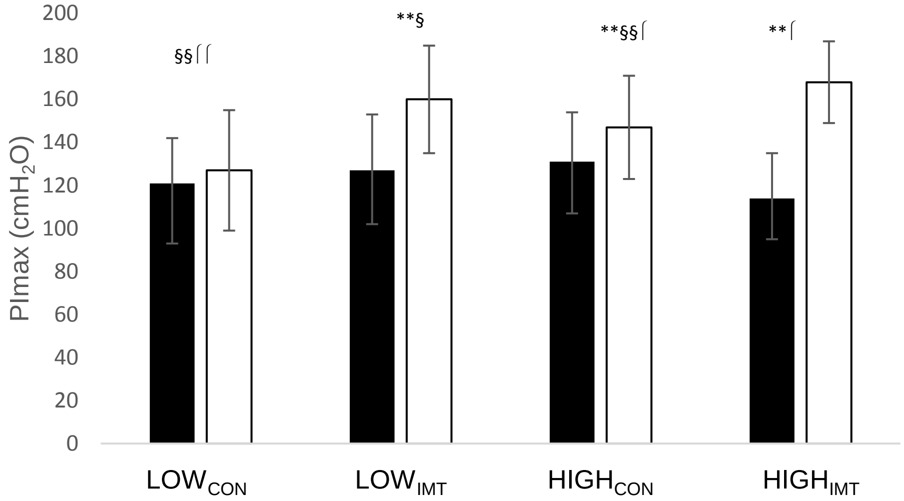
200
180
160
140
120
100
80
60
40
20
0
PImax (cmH_2O)
§§⌠⌠
**§
**§§⌠
**⌠
LOW_{CON}
LOW_{IMT}
$HIGH_{CON}$
$HIGH_{IMT}$

Figure 2. IMF following 100 m (A) and 200 m (B) swimming time trial tests before and after IMT

Note. Filled bars = pre IMT; open bars = post IMT

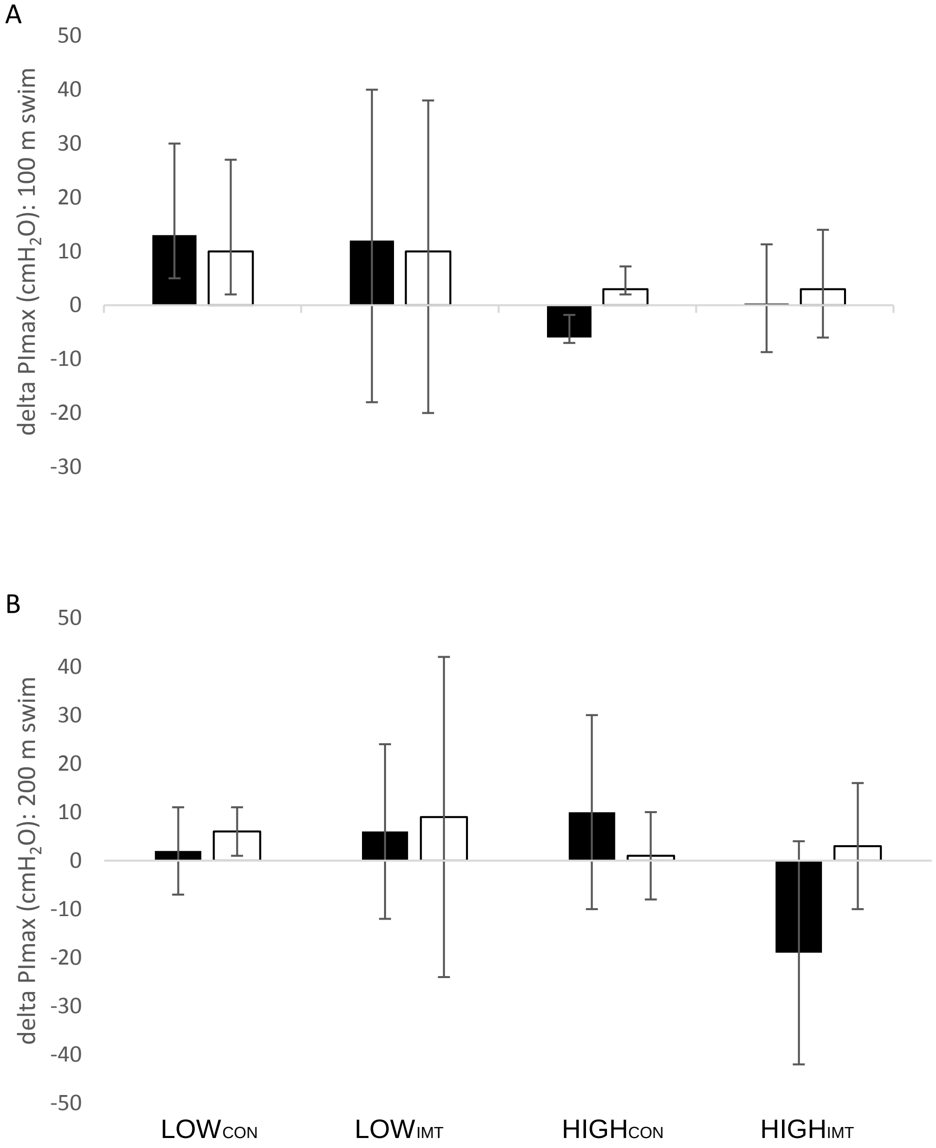
A
50
40
30
20
10
0
-10
-20
-30
delta PImax (cmH$_2$O): 100 m swim
B
50
40
30
20
10
0
-10
-20
-30
-40
-50
delta PImax (cmH$_2$O): 200 m swim
LOW$_{CON}$
LOW$_{IMT}$
HIGH$_{CON}$
HIGH$_{IMT}$

Table 1. Baseline participant and swimming descriptive data for LOW and HIGH group swimmers: mean ± SD

Parameter	LOW	HIGH	*P*	d or *r*
n	18	15	/	/
Males (number)	11	7	/	/
Weekly training distance (km)	15-31	42-56	/	/
Weekly training duration (hours)	10.5	14-19	/	/
Weekly session frequency	6	8-9	/	/
Competitive experience (years)	5-8	3-4	/	/
Standard	National	International	/	/
Training period	Preparatory	Specific preparatory	/	/
100 m swimming time (s)	66.4 ± 6.6	57.3 ± 4.1	<.001	large effect
200 m swimming time (s)	146.5 ± 13.8	125.7 ± 8.1	<.001	large effect
Age (years)	16 ± 3	16 ± 1	.957	*no effect*
Mass (kg)	65.9 ± 13.7	65.2 ± 8.3	.851	no effect
Stature (m)	1.76 ± 0.12	1.75 ± 0.11	.828	no effect
PImax (cmH_2O)	124 ± 22	123 ± 24	.893	no effect
PEmax (cmH_2O)	135 ± 42	133 ± 28	.845	no effect
FVC (l)	5.23 ± 1.22	4.48 ± 1.25	.090	moderate effect
FEV_1 ($l \cdot s^{-1}$)	4.40 ± 1.14	3.94 ± 1.08	.243	small/moderate effect
FEV_1/FVC (%)	84 ± 8	88 ± 6	.123	moderate effect

Note. Italic = non-parametric analyses. Highest PImax and PEmax regardless of trial. T and U = independent t-test and Mann Whitney U test, respectively between LOW and HIGH groups. *d* and *r* = effect sizes. See text for abbreviations.