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Section III – Sports Training

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Effects of Concurrent Strength and High-Intensity Interval Training on Fitness and Match Performance in Water-Polo Players

by

Petros G. Botonis[1], Argyris G. Toubekis[1,2], Gerasimos D. Terzis[2], Nickos D. Geladas[3], Theodoros I. Platanou[1]

The purpose of the study was to examine changes in performance and match-induced fatigue over a 27-week training period. Eight national-level water-polo players performed a 5 x 200 m swimming test to calculate velocities corresponding to blood lactate concentration of 4.0, 5.0 and 10.0 mmol·l^{-1} at three testing periods: i) baseline, ii) end of the pre-season (8 weeks of 4 x 4 min swimming bouts), iii) end of the in-season (8 weeks of 8 x 20 m swimming sprints). During each testing period, four competitive matches were played and repeated sprints (8 x 20 m), 400 m swimming, and shooting accuracy were evaluated at the pre- and post-match. Repeated sprint tests were also conducted at mid-game. Analysis of variance for repeated measures was used to detect changes among training periods and within games. Swimming velocities corresponding to 4.0, 5.0 and 10.0 mmol·l^{-1} were increased after the pre-season by 9%, 7.7%, and 6.7% ($p < 0.01$) and decreased following the in-season compared to the pre-season by 8.9%, 7.0% and 3.3% ($p < 0.01$), respectively. Pre-match repeated sprints and 400 m performance were improved after the pre-season by 4.3% and 3.8% ($p < 0.01$) and decreased by ~3% after the in-season compared to the pre-season ($p < 0.01$). Mid- and post-match repeated sprint performance was improved after the pre-season by 4.8 ± 1.4% and 4.4 ± 1.1% and remained unchanged after the in-season compared to the pre-season. Post-match 400 m speed was improved by 3.2% after the pre-season ($p < 0.01$) and decreased by 2.8% after the in-season ($p = 0.04$).Pre-season training improved players' aerobic endurance and performance. Intensified in-season training decreased aerobic power, endurance, and pre-match performance while maintaining match repeated sprint performance.

Key words: *team-sports, physical fitness, match-induced fatigue.*

Introduction

Successful playing a team sport requires the development of players' physical, technical and tactical skills with appropriately year-round planned training periodization including pre-season and in-season periods (Mujika, 2009). In water-polo, daily sessions of pre-season training usually include a high-volume of continuous and/or interval training, together with strength and specific water-polo training. On the other hand, in-season training consists of lower-volume, high-intensity training maintaining physical fitness benefits obtained within the pre-season period and enhancing players' tactical efficiency.

High-intensity interval training (HIT) is defined as either repeated short (<45 s) or long (2-4 min) bouts of rather high- but not maximal

[1] - *Division of Aquatic Sports, School of Physical Education and Sports Science, National and Kapodistrian University of Athens, Athens, Greece.*
[2] - *Sports Performance Laboratory, School of Physical Education and Sports Science, National and Kapodistrian University of Athens, Athens, Greece.*
[3] - *Division of Sport Medicine and Biology of Exercise, School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Athens, Greece.*

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intensity exercise or repeated sprint sequences interspersed with recovery periods (Buchheit and Laursen, 2013). HIT such as 4 x 4 min and sufficient 3-min rest intervals between efforts (HIT_{4x4}) has been widely used at in the pre-season period increasing exercise performance variables in already trained water-polo players (Botonis et al., 2016a). In particular, Botonis et al. (2016a) showed important increments in variables depicting aerobic and anaerobic potential such as swimming velocity corresponding to 4.0, 5.0 and 10.0 mmol·l^{-1} (V4, V5, V10) after HIT_{4x4} concurrently performed with strength and specific water-polo training. Additionally, HIT with repeated sprints (HIT_{RS}) reproduces water-polo match demands (Melchiorri et al., 2010; Platanou, 2004; Tan et al., 2009) and is utilized to improve the repeated sprint ability of the players, which is considered a key-component to competitive success in team-sports (Spencer et al., 2005). However, the efficacy of the above-mentioned training methods when applied as part of real setting training with regard to physical fitness and sport-specific variables has never been examined in team sports and in water-polo particularly.

An increased conditioning level of the playersis linked with the match-induced fatigue which impairs critical physical and technical abilities such as repeated sprint performance, 400 m swimming time and shooting accuracy (Botonis et al., 2016b, 2016c).To date, it is unknown whether HIT applied within the pre-season and the subsequent in-season period has a positive effect on alleviating the match-induced fatigue.

The purpose of the study was to examine the changes in performance variables and the match-induced fatigue over a 27-week training period. It was hypothesized that: i) pre-season training including HIT_{4x4} concurrently performed with strength and specific water-polo training would improve important exercise performance variables (V4, V5, V10), ii) in-season training including HIT_{RS} concurrently performed with strength and specific water-polo training would further enhance exercise performance, and, iii) both HIT_{4x4} and HIT_{RS} would equally alleviate decrements of physical/technical abilities.

Methods

Participants

Eight male outfield players (age: 27 ± 6 years, body height: 183 ± 7 cm, body mass: 90 ± 12 kg) of the top-level division of the Greek championship participated in the study and provided written informed consent before its commencement. The study was approved by the Faculty review board of the University of Athens and conformed to the Declaration of Helsinki. The compliance rate of 80% for all training periods was the criteria for completion of the study.

Measures

A 5 x 200 m progressively increasing swimming speed test was performed by all players (Tsekouras et al., 2005). Fingertip blood samples were taken after each 200 m repetition and were immediately analyzed for the determination of lactate concentration (Accusport, Boehringer, Germany). Velocities corresponding to 4.0, 5.0 and 10.0 mmol·l^{-1} (V4, V5, and V10) were calculated from the swimming speed *vs.* lactate concentration curve by interpolation of the second order polynomial function. The lactate tolerance rating was defined as the differential velocity between blood lactate concentrations of 5.0 and 10.0 mmol·l^{-1} (V10-V5) (Pyne et al., 2001).

The repeated sprint swimming test that was applied in the present study involved 8 x 20 m maximal freestyle swimming efforts with 10 s recovery in between (Botonis et al., 2016b; 2016c). The participants' percentage decrement score (S_{dec})for repeated sprints was calculated as previously suggested (Girard et al., 2011). For the shooting accuracy assessment, players performed 5 shots as fast and as accurately as possible toward a wooden target (0.40 x 0.60 m) attached to the goalpost, with a 0.30 m diameter hole in its center to allow the ball to pass through when shooting was accurate. Five points were granted when the ball passed through the target hole, three points if the ball failed to pass through the target hole, but partially covered it, one point if the ball made contact with the edge of the target hole and zero points if the ball did not make contact with the target. Immediately after the shooting accuracy test, the 400 m swim test was performed with the race being started in the water.

On a separate day, the one repetition maximum (1RM) test on the bench press was performed for the evaluation of maximal strength.

Design and Procedures

The timing of training and testing during the experimental period is presented in Figure 1.

Within a 27-week training period, starting with two-week familiarization, the players completed 8 weeks of pre-season training, including HIT_{4x4} and 8 weeks of in-season training including HIT_{RS}. At three different stages within the 27-week plan, before and after the pre-season as well as after the in-season training period, a series of four highly competitive friendly matches were played. These took place within a two-week period (3 testing periods, including 4 matches each, 12 matches in total were analyzed). A five-week period separated the pre-season and the in-season period (2 weeks for the matches and 3 weeks of recovery training). Two days before the first of the four-match series at the beginning of pre-season training (baseline) and after the end of both pre-season and in-season periods, the players' fitness level was evaluated through the incremental swimming test (5 x 200 m). Additionally, repeated sprints and 400-m tests were performed after the recovery training period. At the start (Pre), the middle (Mid) and after (Post) each match a series of performance tests were applied. Repeated sprints, 400-m freestyle swimming and shooting accuracy tests were performed at the Pre- and Post-match. In the Mid-phase, players performed a repeated sprint test only. It was pre-arranged that the participants would play the entire match with no substitution.

Training content

The water-polo players followed two different modes of HIT which were applied in pre-season (HIT_{4x4}) and in-season (HIT_{RS}) training. It is known that high-intensity training with long work intervals such as HIT_{4x4} induces considerable improvements in significant physiological variables (V4, V5, V10) (Botonis et al., 2016a). Moreover, HIT_{RS} is also used empirically in water polo training as it reproduces match demands (Melchiorri et al., 2010; Platanou, 2004; Tan et al., 2009). The pre-season training period consisted of HIT_{4x4} combined with maximal strength and specific water-polo training. HIT_{4x4} required players to perform 4 x 4 min bouts of freestyle swimming at an intensity that corresponded to ~106% of V4, interspersed with 3 min of active recovery at self-selected intensity (twice a week). The total swimming distance covered in each session was approximately 1770 m (swimming bouts: 1170 m, active recovery: 600 m). In addition, all players participated in a dry-land, maximal strength training program twice a week (4 sets of 4 to 5 repetitions at 85 to 90% 1 RM). The exercises (bench press, seated pull-down, triceps press, shoulder press, and leg press) targeted specific muscles that are mainly used in water polo: pectoralis major, latissimus dorsi, triceps, deltoids, and quadriceps. Specific water-polo training consisted of a) sprint training (once a week), b) technical training (5-6 days a week), c) tactical training (5-6 days a week). All players participated in one friendly match per week (Table 1).

Following preseason training, a two week period was spent to complete the friendly matches and additional 3-week recovery training was completed. During this period, the training time given for physical conditioning was reduced and more training time was spent on tactics development. Within the recovery training period, maximal strength training was reduced to once a week and high-intensity training sessions were replaced by low-intensity training. All players participated in one official match per week (Table 1).

In-season training consisted of HIT_{RS} together with maximal strength and specific water-polo training. HIT_{RS} involved 4-5 sets of 8 x 20 m maximal freestyle swimming efforts. Each effort was interspersed by 10 s of passive rest. Four min of active recovery at self-selected intensity was given between sets.Therepeated sprintsessions were performed twice a week. In addition, dry-land strength training characteristics remained similar to pre-seasonal training, but its frequency was reduced (once a week). A greater amount of training time was devoted to team tactics development. All players participated in one official match per week (Table 1).

Statistical analysis

The normality of the data was verified by the Shapiro-Wilk test. One-way ANOVA for repeated measures was applied to detect changes across training periods in physical fitness-related variables. A three-way ANOVA with repeated measures was performed to identify differences between baseline, pre-season and in-season periods in match-induced changes (Pre, Mid, Post) in repeated sprints, the 400 m test, and shooting accuracy. A two-way ANOVA with repeated measures on two factors (training periods x match tests) was employed to identify changes in the 400 m test. A Tukey post-hoc test was used to locate significant differences between means. Post-hoc analysis of power was calculated using G-Power 3.1.9.2 for Windows software (Faul et al., 2007). As a measure of effect size, the Cohen's *d* was calculated. Values of 0.20, 0.50 and above 0.80 were considered as small, medium and large, respectively. Considering the sample size in the present study (n = 8), an effect size of 1.15 was required to achieve a power value greater than 0.8. Data are expressed as mean ± standard deviation (SD) and 90% of confidence limits (CL) were also calculated.Statistical significance was set at $p< 0.05$.

Results

Fitness and performance changes during the 27-week period

The influence of different training modes on a typical swimming speed *vs.* lactate concentration curve is presented in Figure 2a. Derived variables of V4, V5 and V10 were enhanced pre-seasonally compared to baseline and decreased following in-season training (Figure 2b). No changes were observed in V10-V5 between baseline and pre-season training ($p = 0.93$), whereas improvement was shown after in-season compared to pre-season training (39.0 ± 28.0%, $p = 0.006$, $d = 1.4$). Strength increased pre-seasonallycompared to baseline (baseline: 109 ± 14.3 *vs.* pre-season: 118 ± 15.6 kg; $p = 0.01$, $d = 2.5$) and remained unchanged after in-season compared to pre-seasontraining (116 ± 13.2 kg; $p = 0.40$).

Pre-match mean repeated sprint performance was improved after pre-season training compared to baseline and was decreased after in-season training compared to pre-season returning to baseline levels (Table 2, Figure 2b). In this line, S_{dec} was greater in baseline compared to subsequent training periods, but similar between pre-season and in-season training (baseline: 15.8 ± 3.0%, pre-season: 11.0 ± 3.9%, in-season: 10.6 ± 2.5%, $p = 0.03$ and $p = 0.01$, $d = 2.63$ and 2.16, respectively). Additionally, 400 m performance was improved after pre-season compared to baseline and decreased after in-season training (Table 2, Figure 2b). No changes were observed for shooting accuracy at all time points (baseline *vs.* pre-season *vs.* in-season, $p = 0.49$, Table 2). Moreover, both mean repeated sprint time and 400 m performance were similar between the pre-seasonand the recovery training period ($p = 0.29$ and $p = 0.62$, respectively).

Table 1

A detailed outline of the training modes applied during pre-season training, recovery training, and in-season training. HIT_{RS}: high-intensity interval training with repeated sprints, HIT_{4x4}: high intensity training with 4 x 4 min and 3 min active recovery, STR: strength training, tech+tact: technical and tactical training, LIT: low-intensity aerobic training.

Training period-duration	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Pre-season – 8 weeks	HIT_{4X4} (30 min), tech+tact (45 min)	STR (50-60 min) tech+tact (45 min)	HIT_{4X4} (30 min), tech+tact (45 min)	STR (50-60 min), tech+tact (45 min)	sprint training (30 min) tech+tact (45 min)	Friendly match	Rest
Recovery training – 3 weeks	LIT (20 min) tech+tact (30 min)	tech+tact (45 min)	STR (50 min) tech+tact (45 min)	LIT (20 min) tech+tact (45 min)	sprint training (20 min) tech+tact (45 min)	Match-play/ rest	Match-play/ rest
In-season - 8 weeks	LIT (20 min) tech+tact (30 min)	HIT_{RS}: (20 min), tech+tact (60 min)	STR (50 min) tech+tact (60 min)	HIT_{RS} (20 min) tech+tact (45 min)	sprint training (20 min) tech+tact (45 min)	Match-play/ rest	Match-play/rest

Table 2

*Performance variables (Mean ± SD) before (Pre), at the middle (Mid) and after (Post) water polo matches performed at the end of the transition period (Baseline), at the end of pre-season and after in-season training. The relative performance changes, confidence limits (%, ±CL90%) for Pre-Mid, Mid-Post and Pre-Post match tests as well as effect sizes (d) for each comparison are also included. RS: repeated sprints, SA: shooting accuracy,*Significant difference from baseline, p < 0.01, ‡ Significant difference from pre-season,p < 0.01, # Significant difference from Pre, p < 0.01.*

Training period		Pre	Mid	Post	Pre-Mid (%; ±CL90%) and *d*	Mid-Post (%; ±CL90%) and *d*	Pre-Post (%; ±CL90%) and *d*
Baseline	Mean RS (s)	14.44 ± 0.6	15.17 ± 10#	15.36 ± 1.1#	-5.0; 1.4 *d*: 0.5	-1.2; 1.0 *d*:0.7	-6.3; 2.1 *d*:1.7
	400 m (s)	301.9 ± 8.8		322.6 ± 21.1#			-6.8; 3.0 *d*:1.5
	Mean SA (points)	2.8 ± 0.4		2.4 ± 0.8			-15.2; 12.9 *d*: 0.7
Pre-season	Mean RS (s)	13.81 ± 0.5*	14.44± 0.7*#	14.67 ± 0.8*#	-4.6; 1.4 *d*: 1.8	-1.6; 1.3 *d*: 0.7	-6.2; 1.5 *d*: 2.3
	400 m (s)	290.4 ± 8.4*		311.8 ± 12.7*#			-7.4; 1.4 *d*: 3.0
	Mean SA (points)	3.1 ± 0.6		2.5 ± 0.6			-17.5; 13.6 *d*: 0.8
In-season	Mean RS (s)	14.21 ± 0.5‡	14.62 ± 0.7*#	14.76 ± 0.6*#	-2.9; 1.8 *d*: 0.9	-3.9; 1.2 *d*: 0.4	-1.0; 1.3 *d*: 1.8
	400 m (s)	298.1 ± 3.2		320.4 ± 10.8#			-7.5; 2.0 d: 2.2
	Mean SA (points)	2.7 ± 0.7		2.8 ± 0.7			6.9; 20.9 *d*: 0.0

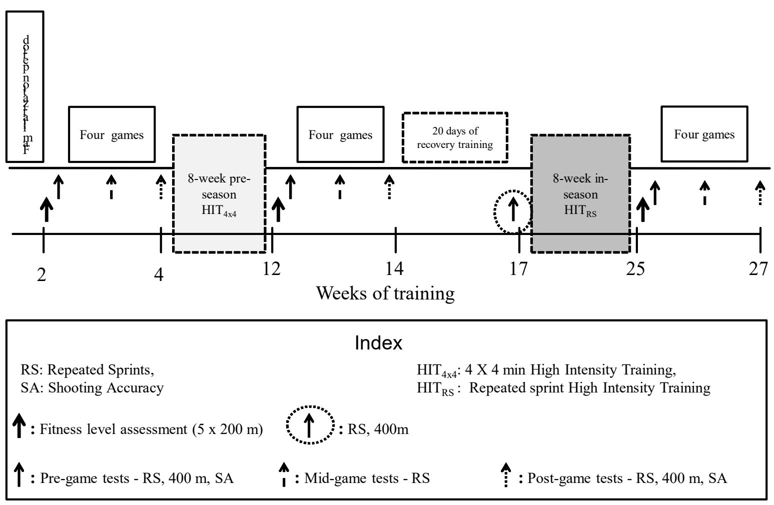

Figure 1

The study protocol overview. Each arrow represents the time point of testing for all tests (see Index).

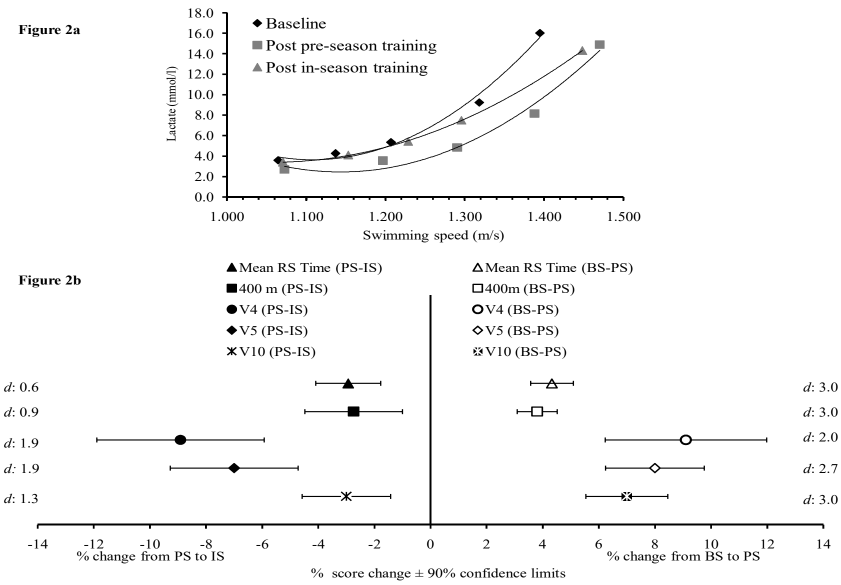

Figure 2

Changes in the swimming speed vs. lactate concentration profile of the group of players tested at baseline, after pre-season and after in-season training periods (Figure 2a). All points are mean values; standard deviations have been omitted for clarity. Figure 2b presents percentage score changes and 90% confidence limits from baseline (BS) to pre-season (PS) and from PS to in-season (IS) training for selected fitness indices (V4, V5, V10: speed corresponding to 4.0, 5.0, 10.0 mmol·l^{-1} lactate concentration, respectively) and pre-match tests (repeated sprints; RS, and 400 m performance time). Effect sizes (d) for each change are also included.

Within match performance changes during the 27-week period

Regardless of the training period, repeated sprints and 400-m performance were decreased as the match progressed (Table 2), while no changes were observed between Mid- and Post-match tests for mean repeated sprint time (p = 0.28). Mean shooting accuracy tended to decrease towards the end of the match (p = 0.08).

In both the Mid- and Post-match measurements, mean repeated sprint performance was greater after pre-season training compared to baseline (Mid: 4.7 ± 2.3%, Post: 4.4 ± 1.9%, p< 0.001, p< 0.001, d = 1.84 and d = 2.0, respectively, Table 2). Likewise, the mean repeated sprint performance was greater in the Mid- and Post-match test after in-season training compared to baseline (p< 0.001, p = 0.001, d = 0.9, d = 1.0, respectively, Table 2). No differences were shown between pre-season and in-season periods (p = 0.40 and p = 0.95). However, S_{dec} was similar in Mid and Post between baseline (Mid: 11.6 ± 4.0, Post: 9.7 ± 3.7%), pre-season training (Mid: 9.2 ± 3.5%, Post: 12.3 ± 4.9%) and in-season training (Mid: 10.2 ± 3.2%, Post: 10.4 ± 7.0%, $p > 0.05$). Regarding the 400-m post match test, a better performance was observed after pre-seasonthan both baseline (3.2 ± 2.7%, $p = 0.001$, $d = 1.1$) and in-season training (2.8 ± 2.6%, $p = 0.001$, $d = 1.1$). Both training periods had no influence on shooting accuracy reduction from the start to the end of the match ($p > 0.05$).

Discussion

This study is the first to provide new insight into the effects of different HIT modes applied within a real-setting training season on physical fitness and sport-specific performance measures. The main findings are that: a) players following pre-season HIT4x4 combined with maximal strength and specific water-polo training, showed significant improvements in aerobic fitness and enhanced exercise performance, b) in-season HITRS induced improvements in anaerobic indices, but decreased aerobic power and capacity which returned to baseline levels, and c) both HIT4x4 and HITRS attenuated match-induced fatigue indices.

According to the first hypothesis, the enhanced performance in Pre-game tests after pre-season training may be attributed to the improvements in participants' aerobic and anaerobic capacity. In fact, the improvement of V4 by 9% after HIT4x4 is in accordance with previous findings in water-polo (Botonis et al., 2016a) and suggests that the fatigue index in repeated sprints may be reduced after endurance improvements (Bishop et al., 2011). Interval swimming at intensities and duration similar to those applied in the present study elicits the heart rate and VO2 responses approaching >90% (Bentley et al., 2005) and this stimulus induces significant cardiovascular as well as peripheral adaptations (i.e. increased O2 transport and utilization, an increased lactate metabolism in type II muscle fibers; Buchheit and Laursen, 2013; Kohn et al., 2011). Apart from improvement of aerobic and metabolic variables, the speed corresponding to anaerobic training pace was also enhanced as a result of pre-season HIT4x4, that was indicated by the improvement of V10 by 7%. It is likely that the high neuromuscular loads applied pre-seasonally may also lead to anaerobic performance enhancement (Buchheit and Laursen, 2013a).

In contrast to our second hypothesis, in-season HITRS combined with strength and specific water-polo training did not further enhance exercise capacity of our participants. On the contrary, performance was reduced in Pre-match tests after in-season compared to the corresponding values measured after pre-season training. There are no reports concerning the effects of HITRS on water-polo, however, a considerable decrease in V4 was shown after the in-season compared to the end of pre-season training in the present study. Conversely, large increments in the lactate tolerance (V10-V5, 39%) were observed. This indicates increased anaerobic potential. It was expected that repeated sprints with incomplete recovery intervals would highly activate both the anaerobic and aerobic metabolism (Peyrebrune et al., 2014), leading to aerobic and anaerobic potential enhancement. However, this was not the case in the present study, where it seems that only anaerobic potential was enhanced. Although the present experimental setting does not allow direct comparisons between HIT modes, the negative changes in the selected fitness variables observed after HITRS (Figure 2a) indicate its detrimental effects on aerobic capacity when this type of training is applied in-seasonally. It should be noted that a 3-week period of recovery training was included between pre-season and in-season periods and this was applied after two weeks including highly competitive friendly matches. Thus, any changes observed after in-season training should be considered with the possible physiological alterations induced within two weeks of matches and the recovery training period. This period of reduced volume and intensity may have induced adaptations similar to a taper period within the first two weeks but deterioration later. Therefore, players benefited from the recovery training period, but presented deterioration in their fitness level as this period extended. Indeed, elongation of this period (i.e. > 2 weeks as in the present study) may decrease selected fitness variables (Van Handel et al., 1988). Additionally, it is likely that after completing two training sessions of repeated 20 m bouts per week for the eight-week period, players received increased neuromuscular loads (carry–over effect). Thus, they may require a period of tapering to show significant improvements in endurance capacity. It is recognized that adequate recovery sessions are required to allow team-sport players to maintain high-intensity training during the in-season (Buchheit and Laursen, 2013a).

It was also assumed in our third hypothesis that both training programs (HIT4X4 and HITRS) would attenuate match-induced fatigue indices. In fact, it was expected that the aforementioned training modes would alleviate the decrements of performance towards the end of the game through different physiological pathways; specifically, HIT4x4 through improvements in aerobic capacity, whereas HITRS through the high activation of the aerobic and anaerobic metabolism and increased buffering capacity (Ronnestad et al., 2014), both leading to attenuation of match-induced fatigue. In accordance with our hypothesis, considerable improvements were observed in mean repeated sprints and 400 m time after pre-season HIT4x4 training at Mid- and Post-match measurements. Moreover, the repeated sprint ability was maintained in the Mid- and Post-match tests after the in-season period despite a lower pre-match performance.

It is well-documented that long interval training such as HIT4x4 positively affects repeated sprint performance through enhanced aerobic contribution, increased lactate removal and phosphocreatine restoration (Tomlin and Wenger, 2001). Accordingly, it decreases reliance on carbohydrates and more lipids are used at the same relative exercise load leading to greater muscle glycogen sparing (Perry et al., 2008). As a consequence, the greater exercise capacity in repeated sprints and 400 m tests at all time points of the match may also be linked to improvements in swimming economy.

A new finding of the present study is the maintenance of repeated sprint ability in the Mid and Post-match tests after the in-season HITRS period despite a lower pre-match performance. As it has also been reported, anaerobic potential is a crucial constraint for the repeated sprint ability of water-polo players (Meckel et al., 2013). In fact, the increased lactate tolerance observed after in-season HITRS indicates increased anaerobic potential and may be linked with the maintenance of exercise performance in the Mid and Post-match tests. Besides, previous studies in water-polo demonstrated that intensified training improved exercise capacity (Botonis et al., 2016a; D'Ercole et al., 2012). Despite the maintenance of repeated sprint ability within the match, 400 m performance at the Post-match test was deteriorated. The meaningful descent of players' aerobic capacity (V4) after in-season training is probably the main explanation. Since 400 m performance is related to the players' ability to resist the game-induced fatigue (Botonis et al., 2016c), it emerges that in-season HITRS should be applied with caution (i.e. lower frequency and/or volume). It seems that HITRS may be effective for repeated sprint maintenance, but detrimental to aerobic capacity. The lower exercise capacity observed in most of the tests after the in-season period may have been influenced by the accumulation of fatigue in the last part of in-season training. In this case, the quantification of the internal training load (Lupo et al., 2014a) throughout training sessions would be useful providing more information on the effects of different training modes on fitness and match-related performance variables.

In line with previous water-polo studies (Botonis et al., 2016a; Saez de Villarreal et al., 2014), the strength level of players was improved (~6%) in the bench press pre-seasonally. Additionally, both training periods had no impact on shooting accuracy at pre- and post-match tests. Although it has been reported that the fitness level may affect technical skills (Botonis et al., 2016c), the present data indicate that physical fitness enhancement alone was not enough to improve shooting accuracy at pre- and post-match tests.

The current experimental setting simulated a realistic training plan of a 27-week period. Decreased performance after the in-season period may be attributed to the long duration or low intensity content of the previous recovery training which separated pre-season and in-season training, or to an inappropriate stimulus within in-season training per se.

We acknowledge that the current study presents some limitations. The experimental setting, with a limited number of players (n = 8) does not allow for direct comparisons between HIT4x4 and HITRS training programs since they were applied in this specific order in consecutive training periods. Moreover, we did not measure the internal training load of our participants. Most possibly, the measurement of the internal training load would have allowed us to draw a safer conclusion regarding the effects of different modes of HIT on players' physiological responses and performance.

Several practical implications can be derived from this study which may be helpful for coaches in the construction of training programs. First, our data indicate that HIT4x4 is effective at improving exercise performance and attenuating the water-polo match-induced fatigue. As a consequence, it should be used in training practice. Moreover, HITRS may also be used as it is efficient at maintaining the repeated sprint ability within a high-competitive match. Nonetheless, coaches should be aware that high volume (4-5 sets of 8 x 20 m) and high frequency (twice per week) in-season repeated sprint training is not appropriate to maintain aerobic capacity and should be supplemented with aerobic stimuli to maintain athletes' physical fitness. Additionally, recovery periods of more than 3 weeks between seasons may deteriorate the players' physical abilities and the training plan should focus on their maintenance. Overall, high-intensity interval training with 4 x 4 min may be preferable compared to repeated sprint training in enhancing water-polo specific fitness and performance variables within a long duration training period. Last, but not least, the strength gains obtained following pre-season concurrent training are maintained during the in-season period when a high-resistance training stimulus is applied once a week.

We conclude that pre-season HIT4x4 together with maximal strength and specific water-polo training enhances both aerobic and anaerobic fitness variables improving performance and attenuating match-induced fatigue. However, in-season training comprised of HITRS, maximal strength and specific water-polo training decreased aerobic capacity and pre-match related performance while maintaining within match repeated sprint performance.

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Corresponding author:
Petros G. Botonis
Department of Aquatic Sports, School of Physical Education and Sports Science, University of Athens, Athens, Greece. -41, Ethnikis Antistasis Ave, 17237, Dafni, Greece.
Phone: +302107276065; +306974709907, E-mail: pboton@phed.uoa.gr