



ANTHROPOMETRIC AND PHYSIOLOGICAL CHANGES IN ELITE FEMALE WATER POLO PLAYERS DURING A TRAINING YEAR

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Abstract The aim of the current study was to monitor physiological and anthropometric characteristics of elite female water polo players within the periodized training year. Fourteen subjects participated in the current study. However, only six subjects (Mean \pm SD: Age 22.8 \pm 3.7 years, Height 171.0 \pm 10.8 cm, Body Mass 66.3 \pm 4.7 kg) completed all sessions and thus were used for subsequent analyses. Subjects undertook testing in the general preparation, specific preparation and competition phases, with the final session being during the peaking component of the competition phase. Laboratory-based physiological measurements comprised peak oxygen uptake, anaerobic power, leg power, strength and flexibility, while anthropometric measurements included body fat percentage. Sport-specific tests involved the Multistage Swimming Shuttle Test (MSST) and the 30-second crossbar jumps. A repeated measures ANOVA revealed significant differences between testing sessions for body mass ($F_{3,15} = 4.025$, $P = 0.028$), body fat ($F_{3,15} = 9.194$, $P = 0.001$), MSST ($F_{3,15} = 5.050$, $P = 0.017$) and crossbar jumps ($F_{2,10} = 16.034$, $P = 0.001$). No statistically significant differences were found for any other variables. The results of the study suggest that changes in anthropometric characteristics and performance parameters of elite female water polo players over a periodized training year occur with no changes in laboratory-based physiological measurements.

Key words: monitoring, periodization, sport-specific adaptations, sport-specific testing

INTRODUCTION

Water polo is a high intensity, intermittent sport. It has been reported by Smith [43] that intense bursts of activity last less than 15 seconds each and these are interspersed with periods of less intense activity. Thus, the game poses a number of substantial physiological demands on both the aerobic and anaerobic metabolic pathways [37].

Most of the previous studies on the physiological profiling of water polo have been conducted on male players [17, 29]. Limited studies have investigated the physiological [4] and anthropometrical [10] characteristics of female water polo players, with only one study [31] to date investigating both simultaneously.

Marrin and Bampouras [31] completed an anthropometric and physiological profile of elite female players and reported that their subjects demonstrated higher muscularity compared to elite female water polo players in 1991. It was postulated that water polo necessitates training of the aerobic and muscular systems to ensure that performance matches the changing demands of the game.

Monitoring of a training programme provides useful information to both scientists and coaches in relation to its effectiveness, the athlete's physical condition and preparation for competition [24]. In order for monitoring to be effective (i.e. providing updated and accurate information on physiological profiling), the tests need to be administered at regular, pre-determined intervals based on training cycles.

Additionally, testing should be specific to the sport [36]; ideally conducted in the athlete's training environment in order to obtain ecologically valid and reliable results. A situation where physiological, anthropometric and sport-specific data can be obtained simultaneously provides the most accurate and informative results, due to the ease of comparisons and the complete profiling achieved [40, 46].

Periodized training programs that focus on the development of explosive power in the water, and high-intensity cardiorespiratory conditioning are often utilized to enhance the sports-specific fitness of water-polo players and ensure their performance is maximized during the competitive season. Monitoring can be deemed a vital aspect of periodized planning. Research in other team sports has suggested that changes in performance parameters over the course of a season may not follow the expected trend. For example, Astorino et al., [2] found that preseason training of field hockey players decreased body fat percentage, increased maximum oxygen uptake, but decreased muscular strength. Furthermore, Miller et al., [32] found decreases in maximum oxygen uptake and muscle mass over the course of a competitive women's soccer season. Finally, Gorostiaga et al., [18] found increases in muscular strength, but only in sport-specific activities, in female handball players over the course of a competitive season.

Thus, the aim of the current study was to obtain physiological and anthropometric characteristics of elite female water polo players and to monitor any changes at designated points within the periodized training year.

MATERIALS AND METHODS

SUBJECTS

The subjects employed in the present study were fourteen female water polo players from the Scottish National team (Mean \pm SD: Age 22.0 \pm 4.4 years, Height 168.7 \pm 7.9 cm, Body Mass 65.9 \pm 6.1 kg) preparing for the 2006 Commonwealth Water Polo Championship. All the players had been part of the team for a minimum of 3 years. The team was ranked 6th in the Commonwealth Championship. The study was approved by the Departmental Ethics Committee and the players provided written, informed consent to participate.

All subjects were familiar with all the testing that took place, which included both field and laboratory assessments. The inclusion criteria for the current study dictated that all subjects must have completed the full testing battery on all testing sessions. From the above sample, only six subjects met these criteria, and thus, only these subjects (Mean \pm SD: Age 22.8 \pm 3.7 years, Height 171.0 \pm 10.8 cm, Body Mass 66.3 \pm 4.7 kg) were used for subsequent analysis.

TESTING PROCEDURE

Testing took place at four points during the periodized training year; at the beginnings of general preparation (T1), specific preparation (T2), and competition (T3) phases of training and peaking (T4). A full testing battery was conducted at T1 and T4, while two minor testing sessions were conducted at T2 and T3. A schematic figure of the periodized year can be found in Figure 1.

May	June	July	Aug	Sep	Oct	Nov	Dec	Jan
<i>General Preparation</i>			<i>Specific Preparation</i>			<i>Competition</i>		<i>Peak</i>
T1			T2			T3		T4

Figure 1. A schematic representation of the periodized training year of the Scottish National Women's water polo team. The different training phases, as well as the testing points (T1-T4) are presented.

The study commenced after the end of the previous competitive season and at the beginning of the general preparation phase of training. The training year was divided into three mesocycles (general preparation, May to July; specific preparation, August to October; competition, November to mid-January) and peaking (mid-January to end of January). Training for general preparation followed a low intensity, high volume 'build up' (60-70% maximum heart rate and 8-12 hours training over a weekend). The training progressed to 'high intensity, low volume' (~85% maximum heart rate and ~6 hours over a weekend) at peaking. The training focus also changed from developing the relevant components of fitness to maintenance and game preparation. The training weekends were designed to increase the player's training loads in the general preparation phase while increasing the intensity and

sport-specific training during the latter specific preparation and competition stages. A similar approach was followed for the games and tournaments, where more difficult tournaments were entered later in the year. Two reduced-training periods were used, one at the end of the general preparatory phase and the other at the end of the specific preparation phase. Finally, it is important to note that the periodized training year presented above relates to the physical training completed for the national squad only. The players also trained with their own club squads and thus it is not possible to quantify exact training loads. The tests conducted for T1 and T4 were anthropometric measurements, aerobic power, anaerobic power, strength and flexibility. This order was followed to minimize the effects of previous tests on subsequent test performance, as suggested by the American College of Sports Medicine [1]. The same order was followed for T2 and T3, although the incremental treadmill test, the Wingate anaerobic test and flexibility were omitted. Furthermore, the strength and jump-based tests were not included in T3. The equipment was calibrated according to manufacturers' standardized procedures.

The battery of tests utilized was based on selected anthropometrical and physiological characteristics, comprising both laboratory and sport-specific protocols. All subjects were familiarized with the procedures prior to testing. Sport-specific testing had been used frequently as part of the training programme, while for the laboratory-based tests the subjects undertook specific familiarization trials prior to the testing sessions. The subjects had been instructed to refrain from strenuous exercise for forty-eight hours prior to testing and to avoid food and caffeine intake for two hours preceding the assessments. All subjects completed testing at the same time of day to avoid any circadian rhythm effects [3].

ANTHROPOMETRIC MEASUREMENTS

Standard International Society for the Advancement of Kinanthropometry (ISAK) procedures were followed. Height was measured to the nearest 0.1 cm using a stadiometer (Harpden, UK). Body mass was measured using a calibrated balance beam scale (Seca, UK) and recorded to the nearest 0.1 kg. Body fat percentage was predicted from skinfold measurements at the biceps, triceps, subscapular and suprailiac sites [14]. Although this equation presents certain limitations, such as comprising only of upper body measurements and derived from a non-athletic sample, it has been previously used in athletic populations [19, 47, 48]. The experimenters' technical error of measurement (TEM) for skinfolds was less than the 5 % that is deemed the acceptable value [35].

AEROBIC POWER

An incremental treadmill (Powerjog, UK) test to exhaustion was used to assess aerobic power. A gradient of 1% was used for the duration of the test [25]. After an initial 5-minute warm up at a velocity of $9 \text{ km}\cdot\text{h}^{-1}$, the velocity was increased by $1 \text{ km}\cdot\text{h}^{-1}$ every two minutes until volitional exhaustion. Expired air was collected throughout the test and analyzed using a Cardio2 automated gas analyzer (Medgraphics, UK), to determine peak oxygen uptake. Heart rate was recorded by using a telemetric heart rate monitor (Polar, Finland). At the end of the test, a capillary blood sample was taken from the earlobe and analyzed for lactate concentration (Analox Instruments Ltd., UK). The criteria for attaining a peak value was that the subjects reached volitional exhaustion, rating of perceived exertion [8] was 19, heart rate reached within 10 beats of the age predicted maximum and Respiratory exchange ratio (RER) was > 1.1 , to ensure reliable and valid measures.

Sports specific tests involved the Multistage Swimming Shuttle Test (MSST). The MSST is a valid and reliable test (ICC = 0.99), assessing aerobic fitness of water polo players. Its procedures have been described elsewhere [39]. Briefly, the subjects swam a 10-metre distance at a progressively increasing speed until volitional exhaustion. Each stage lasted approximately one minute and the shuttles were signalled by an audio cue. At the end of the test, peak blood lactate concentration was measured as described above.

ANAEROBIC POWER

Anaerobic power was measured via the Wingate Anaerobic Test (WAnT). The subjects performed a 5-minute warm up at a workload of 100 W (with a 5 second sprint at 3 minutes), and, subsequently, rested for 5 minutes [49]. Following rest, the subjects cycled maximally for 30 seconds on an ergometer (Monarch, UK) against a resistance of 7.5% body mass [7] and peak power, mean power and fatigue index were calculated (Cranlea, UK). Test-retest reliability values (r) for the WAnT are high and have varied from 0.89 to 0.99 [22].

Leg power was estimated using a countermovement vertical jump where height was measured (Takei Scientific Inst. Co. Ltd, Japan). In order to avoid any extraneous movement, the subjects performed

the jumps with their hands placed on their hips throughout the movement, a procedure which has previously been found highly reliable (ICC = 0.98; [30]). Sports-specific tests involved the 30-second cross-bar jump test. Notwithstanding the limitations of this test [6], it is currently the only test which is readily available to coaches and requires no equipment. It was deemed that in order to provide a useful profile, this test should be included. The results interpretation is conducted with the limitations in mind. For the actual test, the subjects had to repeatedly touch the vertical bar of the water polo goal by jumping out of the water using breaststroke kicks, aiming to achieve as many jumps as possible in 30 seconds.

STRENGTH

Maximum leg, back and handgrip strength (left and right arm) were assessed with the use of a dynamometer (Takei Scientific Inst. Co. Ltd, Japan). All procedures have been shown to be reliable with high test-retest correlations for the leg and back strength measurements of $r = 0.80$ and $r = 0.91$, respectively [11], and $r = 0.99$ for the handgrip strength procedures [12]. A half-squat position was adopted for leg strength and a stiff leg dead lift position for back strength. Following that, the subjects had to perform a maximal contraction. For the handgrip strength, the subject performed a maximal contraction, requiring them to lower their arm (extended) while gripping on the dynamometer (Takei Scientific Inst. Co. Ltd, Japan). The best result out of three efforts was recorded for all tests.

FLEXIBILITY

The sit and reach test was utilized to assess flexibility of the lower back and hamstrings. The sit and reach test has been previously shown to be highly reliable for females ($r = 0.96$; [21]). Standard procedures for this test were followed. Briefly, the subjects were instructed to maintain their legs extended and to reach forward as far as possible in a controlled manner. The best result out of three efforts was recorded. Shoulder flexibility was measured using video analysis (Quintic, UK). The top of humerus and olecranon were marked. The subjects' hyperextended their arm along the sagittal plane, maintaining an upright posture, with no rotation of the upper body permitted. Shoulder hyperextension angle was measured relative to the vertical line (vertical line = 0°).

STATISTICAL ANALYSES

Descriptive statistics were calculated for all variables. A repeated measures analysis of variance (ANOVA) was utilized to determine significant differences for each variable between the testing sessions. Tukey's *post-hoc* test was used to locate differences between testing sessions. Significance level was set at $P \leq 0.05$. All statistical analyses were conducted using SPSSv14.0.

RESULTS

Descriptives (mean \pm SD) of the results can be found in Table 1.

Repeated measures of analysis of variance (ANOVA) indicated significant differences between testing sessions for body mass ($F_{3,15} = 4.025$, $P = 0.028$), body fat ($F_{3,15} = 9.194$, $P = 0.001$), MSST ($F_{3,15} = 5.050$, $P = 0.017$) and crossbar jumps ($F_{2,10} = 16.034$, $P = 0.001$). No statistically significant differences were found for any other variables.

Post-hoc analysis revealed that the significant differences for body mass existed between T2-T4, for body fat percentage between T1-T4, T2-T4, T1-T3, for cross bar jumps between T1-T2 and for MSST shuttle scores between T1-T2 and T2-T4.

The percentage reduction for body mass between T2-T4 was 3.5%. The reductions in body fat percentage between T1-T4, T2-T4, and T1-T3 were 3.6%, 2.2%, and 3.0%, respectively. The crossbar jumps improved towards the end of the year by 9.5% between T1-T2 and by 15.7% between T1-T3. MSST shuttle results indicated a decrease by 21.6% between T1-T2 and an increase towards the end of the season by 48.3% between T2-T4.

DISCUSSION

This is the first study to monitor physiological and anthropometrical characteristics over an entire periodized season in elite female water polo players. Periodization aims to maximize performance by organizing the training duration into distinct periods [27] and reducing the potential for injury [44]. The training duration is usually divided into larger training phases (macrocycles) further divided into smaller ones (microcycles) [27, 44]. Each cycle has its own aims, emphasizing different objectives, with the athlete ideally peaking at the major goal of the training programme [27].

Table 1. Anthropometric and physiological assessment results for all four testing sessions (T1, T2, T3 and T4).

Testing session	T1	T2	T3	T4
Height (cm)	171.0 ± 10.8	171.0 ± 10.8	171.0 ± 10.8	171.0 ± 10.8
Body mass (kg)	66.3 ± 4.7	67.5 ± 3.6	66.4 ± 3.9	65.1 ± 4.2
Body Fat (%)	23.1 ± 4.0	21.7 ± 3.3	20.1 ± 3.9	19.5 ± 3.8
Peak oxygen uptake (L·min ⁻¹)	3.6 ± 0.2			3.3 ± 0.3
Peak oxygen uptake (ml·kg ⁻¹ ·min ⁻¹)	53.1 ± 2.8			51.4 ± 5.9
Peak blood lactate (mmol·L ⁻¹) (treadmill)	6.7 ± 1.5			6.2 ± 1.4
Peak heart rate (bpm)	195 ± 2			193 ± 3
MSST (shuttles)	37 ± 11	29 ± 7	36 ± 11	43 ± 17
Peak blood lactate (mmol·L ⁻¹) (MSST)	6.9 ± 2.2	6.2 ± 3.0	8.8 ± 3.3	7.8 ± 1.8
Peak heart rate (bpm) (MSST)	192 ± 2	192 ± 2	195 ± 4	195 ± 2
Peak power (W)	636.6 ± 69.7			608.7 ± 39.9
Mean power (W)	444.4 ± 46.1			458.2 ± 30.3
Fatigue index (%)	47.6 ± 3.9			42.8 ± 10.9
Vertical jump (cm)	33.7 ± 4.2	35.0 ± 2.5		33.5 ± 4.5
Cross-bar jumps (jumps)	21 ± 3.0	23 ± 2.6		24.3 ± 2.4
Leg strength (kg)	128.7 ± 30.9	134.2 ± 19.3		132.4 ± 20.8
Back strength (kg)	84.8 ± 8.0	94.3 ± 6.9		91.7 ± 22.8
Handgrip strength (kg)				
- left arm	31.1 ± 4.1	32.8 ± 5.1		29.8 ± 4.6
- right arm	34.5 ± 2.2	36.5 ± 5.6		35.0 ± 4.7
Flexibility				
- Sit and reach (cm)	35.0 ± 8.0			35.8 ± 7
- Shoulder hyperextension (°)	21.6 ± 8.1			21.9 ± 6.8

The primary findings of the current study demonstrated that significant reductions in body fat percentage occurred, together with sports-specific adaptation in anaerobic power (as indicated by the 30 second cross bar jump test) and aerobic fitness (as indicated by MSST). No changes, however, occurred during the season in any measure of strength, power, laboratory based anaerobic fitness, peak oxygen uptake or flexibility.

It should be noted that the results must be interpreted with caution. Firstly, periodization poses extra challenges with national teams as the players' periodized training plan is heavily regulated by their own club team's planning. Therefore, although the players were all in the same training phase, the aims of the microcycles for each individual player may have differed. The number of games (friendly, in training camps and official) played by the team increased from 6 games in the general preparation phase to 12-15 games in the competition phase. Additionally, due to the inclusion criteria, the final sample used for analysis was small.

ANTHROPOMETRIC CHARACTERISTICS

The water polo season generally resulted in significant reductions in body mass as well as body fat percentage. Body fat is largely seen as a disadvantage in many sports. In water polo, it has been suggested that body fat may not be as hindering as in other sports, because it helps buoyancy [13]. However, this benefit is outweighed by the greater moment of inertia required to undertake explosive and acceleratory actions in water polo [46]. Due to the lack of consistency in body composition measurement techniques in previous studies, no guidelines for body fat percentage exist for elite female water polo players. However, the value of 23.1% at the general preparation phase of training (T1) is marginally below the recommended value of < 25 % for an athletic female population [28]. Given that the team

was working towards its major goal at the end for the periodized year, explosive and quick movements in the water were of utmost importance, and therefore, the decrease in body fat was a desired feature.

AEROBIC POWER

No significant difference in aerobic power was found when measured with an incremental exhaustive treadmill test. It has been reported that peak oxygen uptake is not a sensitive enough indicator of fitness when changes in aerobic performance are small [45] and as the current study employed elite athletes, further improvements in this parameter would not be expected.

This notion is supported by the fact that the peak oxygen uptake obtained in this study ($52.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ averaged across the season) was slightly lower compared to elite female soccer players ($54.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, [20]; $57.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, [23]). When one considers that this small difference can be attributed to the closer nature of soccer to the testing mode (treadmill running), it follows that changes in peak oxygen uptake in the current study would have been too small to be detected. Interestingly, the MSST improved significantly towards the end of the periodized year, indicating that despite no significant change in peak oxygen uptake, the training and game demands positively affected the players' endurance in the water. Rechichi et al. [39] demonstrated that this test is a valid and reliable measure of aerobic fitness in competitive water polo.

Therefore, it is argued that it is its specificity that explains the differences in the results across the season. In addition, the competition phase included a substantially higher number of games, which could have improved the players' match fitness [34].

ANAEROBIC POWER

No differences were found in WAnT parameters. WAnT was deemed an appropriate laboratory test as it offered non-weight bearing, cyclical lower limb activity without the utilization of the stretch-shortening cycle, which resembles the eggbeater move of the players in the water. Nevertheless, the two activities also have some differences. Most notably, the eggbeater jumps benefited from some arm contribution, while it was disadvantaged from a lack of fixed resistance and power transfer between biarticular muscles [38]. Indeed, the performance of the in-water jump has previously been shown to be more reliant on skilful execution than powerful movements [41].

No differences were found for leg power. The vertical jump is a field-based test commonly used to assess anaerobic leg power. The lack of any increase in jump height in this test would normally imply absence of power improvement. However, due to the difference in the environment in which the jump is executed in, and subsequently, the different mechanics required, improvements in leg power in the water may not be transferable to the land-based test. This notion is supported by the current study, which suggests that the vertical jump test is not appropriate to detect leg power changes in water polo athletes.

There was a significant improvement in the number of crossbar jumps from the beginning of the year towards its end. As this is the first study to use sport-specific tests to monitor water polo players, there is no published data to allow direct comparisons. It is worth noting that, similarly to aerobic power findings, the sport-specific tests appear to indicate changes in the measured performance, despite no such indication from the laboratory or even field-based tests. The crossbar jumps improved as the training focus switched from low to higher intensities and more scrimmaging. In contradiction with the aerobic power tests, however, the reliability of the crossbar jump test has been questioned [5]; hence attention needs to be exercised to avoid erroneous conclusions.

STRENGTH

No difference was found in any of the tests of strength, i.e. leg, back and handgrip strength. In order to maximize their water polo jump height, the players execute a sudden and powerful extension of the back while vigorously treading water [42]. The mechanical requirements of this movement would suggest that leg and back strength were important. However, although strength is certainly a desirable feature, power is a more appropriate variable in elite sporting performance [27]. The issue of leg anaerobic power was discussed in the previous section. Future studies should utilize methods, ideally sport-specific, to evaluate back strength and power in water polo players.

Handgrip strength was not significantly different between testing sessions. Additionally, it was higher at all testing points than the norms presented by Brown and Miller [9] after being converted accordingly. The lack of any changes in handgrip strength is attributed to water polo ball-handling technique. Players are discouraged from 'grabbing' the ball to prevent the ball from slipping due to

excessive pressure. In addition, female players involve the wrist less when handling the ball [15]. Therefore, hand grip strength maintenance rather than increase is an objective for the water polo player, as demonstrated in the current study.

FLEXIBILITY

Shoulder hyperextension has only a small contribution to the ball speed [16] and excessive levels can cause shoulder injuries [26]. In addition, a wider range of movement for female players would be disadvantageous as a more vertical ball movement is required to accommodate for the hand-span to ball-diameter ratio [16]. Therefore, an optimal level of flexibility should be maintained. In the current study, the players' flexibility was comparable with the results of Morales and Arellano [33], indicating good levels of shoulder flexibility. More importantly, it was maintained throughout the year, thus alleviating some of the aforementioned problems with increased flexibility.

The sit and reach results from the current study are lower than the 47.2 ± 3.1 cm provided by Brown and Miller [9] for this age group, suggesting stiffer lower back and hamstring muscles. It would seem advantageous for a water polo player to have high flexibility at the back and hamstrings, as the optimal preparatory position for a water polo jump is leaning the upper body forwards while maintaining the legs under the body [41] thus being in a position of increased hip flexion. However, a position in which the back and hamstrings are too flexible would be a hindrance rather than an advantage, as it would a) not assist in the upward force generation required for the jump [41], and b) reduce the jump power, and subsequently the height achieved. Similarly to shoulder hyperextension, an optimal level of flexibility would be preferable.

CONCLUSIONS AND PRACTICAL APPLICATION

The current study is the first to examine the anthropometric and physiological characteristics of elite female water polo players over the course of a periodized training year using both laboratory and field-based tests. The results demonstrated that significant reductions in body fat percentage occurred as the training year progressed. Increased performance was found as indicated by the sport-specific tests of anaerobic power (the 30 second cross bar jump test) and aerobic fitness (the MSST). However, no changes occurred during the season in any measure of strength, power, laboratory based anaerobic fitness, peak oxygen uptake or flexibility.

Future studies should attempt to examine training loads simultaneously with monitoring, utilizing a larger sample size. It is suggested that sport-specific tests may be better indicators of performance-related measures. A modern battery of water polo specific tests should be developed to enable accurate evaluation of the players' abilities, in addition to overall performance evaluation.

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