



Seasonal Changes in Performance Related Characteristics and Biochemical Marker Variability of Adolescent Table Tennis Players

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Abstract

Background: There is a shortage of longitudinal surveys in highly trained adolescent table tennis athletes reporting typical changes in performance related, hematological, and biochemical parameters.

Objectives: The purpose of the study was to: (1) examine yearly variations of performance related parameters, and (2) report the variability of selected hematological and biochemical markers utilized to ascertain health status, and training influences in a group of young Arab table tennis athletes.

Methods: Data were collected from ten male adolescent players with a mean age of 14.2 ± 1.3 years and a mean table tennis training experience of 6 years. Physical and biochemical measures were carried out at three important time points throughout the training season: a baseline measure (PRE - September); a mid-season (transition) measure (MID - February); an end of season measure (END - May).

Results: Performance related parameters tended to significantly improve over time ($P = 0.05$), with lowest values displayed during PRE-measure. Hematocrit ($P = 0.05$), serum testosterone ($P = 0.01$) mean cell volume (MCV) ($P = 0.001$) and reticulocytes (RET) ($P = 0.017$) significantly increased at the END training period compared to PRE. Moreover, 25(OH)D levels ($P = 0.001$) showed a drop during MID to then significantly increase at the END whilst sex hormone binding globulin (SHBG; $P = 0.005$) decreased at the END period compared to MID.

Conclusions: In conclusion, based on our findings, changes in certain physical parameters and, hematological and biochemical markers, take place during the training period. Therefore, coaches, sports scientists and nutritionists should take into consideration these fluctuations and plan and alter their training programs accordingly.

Keywords: Racquet Sport, Hematology, Exercise Physiology, Adolescent Boys, Exercise Testing

1. Background

Table tennis is a complex racket sport that is characterized by an intermittent activity profile. It involves complex skills, physiological and cognitive demands with success highly dependent on the interaction of all these performance factors (1, 2). The requirement of physical abilities is significant. A well-developed aerobic and anaerobic energy system is vital to excel as an elite table tennis player (3-5). Furthermore, a high level of physical fitness aids recovery, reduces injury risk and helps players with decision-making abilities to guarantee a higher level of performance during training and competition (5). To reach top-level performances in table tennis, several years of specific training combined with challenging strength

and conditioning activities are required to ensure physical adaptations take place. These can further enhance the given metabolic pathways for energetic supply to the skeletal muscles (6).

The pubertal growth spurt, as observed during early adolescence, is influenced by the release of important hormones that have shown to influence the development of physical capacity and performance during childhood to adolescence. It has been suggested that monitoring testosterone levels can provide information about maturation and growth. Cortisol and testosterone represent the anabolic-catabolic equilibrium of an athlete and could provide information regarding overtraining or insufficient recovery (7). The changes in levels in serum testosterone (an anabolic indicator that stimulates mus-

cle protein synthesis), and serum cortisol (an indicator of catabolic state which plays a significant role in gluconeogenesis) can provide in-depth information regarding long term training adaptations and stress/overtraining (8).

Additional biochemical markers have been suggested to be linked to growth. In fact, current work on 25 hydroxy-vitamin D (25(OH)D) has highlighted its influence in muscle growth and differentiation and has been closely associated with muscle injuries (9). Considering the prevalence of hypovitaminosis D in Arab adolescents (10, 11) and the nature of table tennis training activities being limited to indoor facilities, it is expected that table tennis athletes might represent an “at risk” population. Therefore, regular assessment of 25(OH)D is required to ensure they can compensate for lack of sun exposure. In addition, regular screening of iron status and complete blood count parameters can provide useful information about the potential for performance. It has been found that athletes with a sub-optimal iron status may experience reduced exercise capacity and compromised sports performance (12).

Despite the growing interest and number of players engaged worldwide in table tennis, there is a paucity of studies providing accurate training information on adolescent players. Many adolescent athletes follow regular and structured training activities often comparable to adult counterparts (3). Such activities can either have positive or negative consequences on growth, metabolites, enzymes and hematological parameters. The training load imposed and its progression as well as competition stresses play a significant role in inducing hormonal and/or inflammatory effects. No information is available regarding the hematological, hormonal and enzymatic activity variability during an annual training cycle in young table tennis athletes. Therefore, through the screening of young athletes at specific time-points of the year, in-depth information can be collected to help safeguard the athlete’s health and, potentially, determine the implications of the applied training loads on growth and maturation in youth table tennis athletes.

2. Objectives

Therefore, the purpose of the study was to examine: (1) the yearly fluctuations of performance related parameters and (2) report the variability of several selected biomarkers utilized to ascertain health status, and training influences throughout a yearly training season in a group of young Arab table tennis athletes.

2.1. Hypothesis

We hypothesized that as the training load and intensity of training increases over a season, physical performance

of athletes will also display an increase. In addition, because of pubertal growth and increases in training load and intensity of training, there will be fluctuations in numerous hematological and biochemical markers at different time-points of the training season.

3. Methods

3.1. Selection and Description of Participants

Ten male adolescent table tennis athletes of Arabic origin (age (mean \pm SD) 14.2 ± 1.3 years, body mass 56.0 ± 15.2 kg, stature 164.9 ± 10.5 cm, BMI 20.3 ± 4.0 and PHV 0.27 ± 1.40 at the start of collection) were included in this prospective study. All participants were required to be members and players currently representing the Qatar Table Tennis Association and current students at Aspire Academy for Sporting Excellence. Any individuals who did not meet these criteria were discarded from the study. At the time of first screening all athletes were given clearance from a physician to train and were not taking any medication. Written informed consent was sought and obtained from all participants and their parents. The procedures employed in the study were reviewed and approved by the National Research Ethics Committee of the Aspire Zone Foundation and conformed to the recommendations of the Declaration of Helsinki.

3.2. Technical Information

All physical and biochemical measures were carried out at three selected time points throughout the academic training season (September to May). Athlete screenings were performed at different time-points of the training cycle; a baseline measure (PRE - September); a mid-season (transition) measure (MID - February); an end of season measure (END - May).

3.3. Anthropometric Characteristics

Anthropometric and body composition characteristics were measured on the same day as the hematological measurements. Body mass using an electronic scale (Marsden, MGP250, UK), and height, sitting height and leg length using a stadiometer (Harpenden Stadiometer, Holtain, UK) were obtained on all subjects according to the standardised techniques adopted by the International Society for the Advancement of Kinanthropometry (ISAK). Peak height velocity (PHV) was determined using the equation proposed by Mirwald et al. (13).

3.4. Blood Collection and Analysis

Athletes arrived in a fasted state (overnight) and reported to the laboratory 30 min before providing a blood sample. Venous blood was collected via venipuncture from an antecubital arm vein while at rest in a sitting position (we are aware of the need for venipuncture standardization requirements as it is our standard operating procedure) between 7:30 AM to 9:30 AM by a certified phlebotomist as per the regulatory requirements of Qatar law. The samples were collected in 3.0 mL K2 EDTA vacuum tubes and 4 mL serum separator tubes (SST2 Advance) from Becton-Dickinson (BD, Franklin Lakes, USA).

All hematological markers were evaluated on the same day in a controlled laboratory setting (20°C - 22°C). Serum samples were allowed to coagulate at room temperature for 30 min and were then centrifuged at 1500 g for 15 min to separate the serum. After separation, samples were stored at -80°C until further analysis.

The analysis for complete blood count and reticulocyte (RET) parameters was performed using a Sysmex XT2000i hematology analyzer (Sysmex, Kobe, Japan). The exercise-induced plasma volume (PV) changes were calculated according to Dill, and Costill (14). Serum samples were analysed on a Dimension XPand/RxL (Siemens, Erlangen, Germany) for a variety of biochemical parameters (total iron, ferritin, alanine- and aspartate- aminotransferases, creatine kinase (CK), glucose, creatinine, cholesterol, high- and low- density lipoproteins, sodium, potassium, and chloride).

Furthermore, the concentration of testosterone, cortisol, sex hormone binding globulin (SHBG) were assessed using ELISA kits from R&D (International Inc., New York, USA) while 25(OH)D was analysed with an ELISA kit from EAGLE (EAGLE BIOSCIENCE). The inter-assay coefficient of variation (CV) for testosterone ranged from 5.6% to 6.8%, for cortisol from 9.3% to 21.2%, for SHBG from 3.6% and 6.7% and for 25(OH)D from 7.0 to 8.6%. The variation coefficient (intra-assay variability) was < 5% for all measurements. An erythrocyte sedimentation rate test (ESR) was also performed using automatic erythrocyte sedimentation analyzer (Sediplus S200, SARSEDT).

3.5. Physical Performance Testing

All athletes performed four physical tests during three separate time points to determine their table tennis performance related characteristics. The physical tests chosen cover the main performance characteristics and competencies required to excel at table tennis during adolescence and are routinely used as part of normal assessments for children involved in sport (24; Ortega et al. 2010; Kondric et al. 2013). Physical performance testing sessions

were completed within two days. All sessions were performed in the following order: a counter-movement jump (CMJ), a sprint test (5, 10, 20 and 30 m), a modified Aspire Table Tennis Agility Test (mATTAT) and a multi-stage fitness test (MSFT). Prior to testing, athletes underwent a guided routine warm-up by a strength and conditioning coach that lasted 10 min consisting of a 5 min general warm-up and 5 min of running, jumping and stretching. The same protocol and intensity was repeated in all testing sessions. The physical performance testing procedures are described below in more detail.

3.5.1. Day 1

3.5.1.1. Counter Movement Jump

The CMJ (a vertical jump test) as previously used in youth athletes was performed to assess the explosive power of the leg musculature. The athletes were asked to perform the test with hands on hips and repeat this test a minimum of 3 times. A rest period of 30 s was provided in between each jump using the protocol already described by Komi and Bosco (15) on a KMS Jump mat (Fitness Technology, Adelaide, Australia). This test has previously been reported to be both valid and reliable (16). Jumping height was computed on a custom software (Ballistic Measurement System, Fitness Technology, Adelaide, Australia) measured as an estimate of the height change in the athlete's center of mass, taking into consideration the total duration the athlete spends in the air with no ground contact. The highest CMJ recorded was used for further analysis.

3.5.1.2. Sprint Test

Acceleration, maximum running speed and speed endurance were determined during the sprint test. The athlete was required to run a single maximal sprint over a 30 m distance. Sprint times were recorded using infrared timing gates (Fusion Sport Smartspeed, Queensland, Australia). The timing gates were positioned at 0 m, 5 m, 10 m, 20 m and 30 m, with all the split times recorded. Previous research has established reliability with a CV of ~ 2% for youth athletes performing all-out sprints over similar distances (17). The starting position was standardized for each sprint. All athletes repeated the test 3 times with a 3 min recovery period to ensure results were reliable. The times of the best 30 m sprint was then used for further analysis.

3.5.1.3. Modified Aspire Table Tennis Agility Test

The mATTAT (18) was used to measure table tennis specific agility and has previously been used in youth table tennis athletes. The protocol consisted of measuring the time taken to complete a set sequence of 5 table tennis specific motor tasks. The athlete starts with a table tennis

racket in hand and is required to hit 3 stationary instrumented table tennis balls (2 of these are hit twice) in the correct sequence whilst ensuring good table tennis technique is used. The athlete performs 3 trials, 18 s apart with a 3 s countdown where the player must adopt a 'service return ready position'. The tester reviewed the output file to check whether the trial was valid. Any trial where the response time was below 0.55 s or where the table tennis ball was not hit was discarded and not deemed to be valid. Only the valid trials were analysed and the best (lowest) total time for the agility test and its associated stages was used for further analysis.

3.5.2. Day 2

3.5.2.1. Multi-Stage Fitness Test

The MSFT test is aimed at assessing maximal cardiorespiratory function and is a popular test for children involved in sport or physical activity. Athletes were asked to perform continuous running between two lines 20 m apart in relation to a recorded auditory signal. The athletes were required to run as long (as many levels) as they could, and the test was stopped if the athlete failed to reach the line (within 2 m) for two consecutive times after receiving a warning. The athlete's score was the level and the number of shuttles (20 m) reached before he was unable to keep up with the auditory signal. This level score was then converted to a predicted $\text{VO}_{2\text{max}}$ score ($\text{pVO}_{2\text{max}}$) using a regression equation developed by Ramsbottom et al. (19).

3.6. Typical training weekly structure

The maximal weekly training program of the athletes consisted of 8 training sessions per week which were characterized according to three basic types: 5-6 table tennis specific sessions, 1-2 strength & conditioning sessions and 1 recovery session. This is in accordance with the operating procedure in our sports academy and in other academies around the world. All sessions had a maximum duration of 90 min; accounting for a maximum total of 12 h per week. These are typical training times when comparing similar age groups in other sports. Training exposure data from absent and/or ill athletes were not accounted for. The exposure periods to training were during school periods, which took place from September until May. The average total training time per athlete over the examined training period was 237 h 42 min.

3.7. Statistics

The normality of distribution of all hematological and biochemical parameters was examined in each group using the Shapiro-Wilk's test, confirming the homogeneity.

The data were analyzed by means of the statistical package for social sciences (SPSS) for windows (SPSS, Chicago, IL, USA) for all parameters. To correct violations of sphericity, the degrees of freedom were corrected in a normal way, using Huynh-Feldt ($\epsilon > 0.75$) or Greenhouse-Geisser ($\epsilon < 0.75$) values for ϵ , as appropriate (20). Graphical comparisons between means and bonferroni pairwise comparisons were made where main effects were present. The results are presented as the mean \pm standard deviation (SD) throughout the text, unless otherwise stated.

Effect sizes were determined by calculating Cohen's *d*. The magnitude of the effect size was classified as; trivial < 0.2 , small 0.21-0.60, moderate 0.61-1.20, large 1.21-1.99, and very large > 2.0 (21). The alpha level of significance was set at 5% ($P < 0.05$).

4. Results

Table 1 shows the group means (\pm SD) for the anthropometric and performance related characteristics throughout a training year. Performance parameters tended to significantly improve over the training season. Athletes significantly improved sprint test times over 5, 10 and 20 m at MID period (2.5 to 5.3%) and END period (3.5 to 8.1%) when compared to their PRE-scores ($P < 0.05$). No significant changes were found over 30 m ($P > 0.05$).

Similarly, the pVO_2 values also showed significant improvements during the MID (3.4%) and END (9.7%) periods of the training season when compared to PRE-measures ($P > 0.05$). The time of completion for the mATTAT (11.2%) and the height of the CMJ (16.1%) only showed significant improvements during the END period of the season when compared to PRE-measures ($P < 0.05$).

Other measures of anthropometry or performance related characteristics showed no significant difference between any of the phases of training ($P > 0.05$). There was no significant change in height, weight, BMI and PHV during the observed period ($P > 0.05$).

Table 2 presents the effect of long-term training and competition on different hematological and iron status related markers in adolescent table tennis athletes. Hematocrit (Hc) values showed a main effect for condition with lower values 3.6% lower during PRE and 3.2% lower during MID season, when compared to the END of season values ($P < 0.05$). RET values were also lower by 10.9% during PRE and 22.9% during MID season when compared to end of season values ($P < 0.017$). Values for mean cell volume (MCV) displayed a similar trend with values 2.7% lower during PRE and 2% lower during MID season when compared to END of season values ($P < 0.001$).

Conversely, values for mean corpuscular hemoglobin concentration (MCHC) during END of season decreased

Table 1. Anthropometric and Physiological Characteristics for the Entire Group of Adolescent Athletes (Mean \pm SD) at Baseline, MID Season and END Season Time-Points^a

Parameters	Baseline (T ₁)	MID Season (T ₂)	END Season (T ₃)
Years	14.2 \pm 1.3	14.6 \pm 1.3	14.8 \pm 1.4
Height, cm	164.9 \pm 10.5	166.5 \pm 10.3	167.3 \pm 10.4
Weight, Kg	56.0 \pm 15.2	57.6 \pm 15.3	58.5 \pm 14.8
BMI, kg/m ²	20.3 \pm 4.0	20.5 \pm 4.0	20.7 \pm 3.9
PHV, y	0.27 \pm 1.40	0.61 \pm 1.40	0.78 \pm 1.36
CMJ, cm	29.07 \pm 5.63	30.76 \pm 4.74	33.74 \pm 8.16 ^b
5m sprint, s	1.22 \pm 0.07	1.15 \pm 0.06 ^b	1.12 \pm 0.07 ^{bc}
10m sprint, s	2.09 \pm 0.14	2.03 \pm 0.12 ^b	2.0 \pm 0.13 ^{bc}
20m sprint, s	3.71 \pm 0.24	3.61 \pm 0.22 ^b	3.58 \pm 0.20 ^{bc}
30m sprint, s	5.27 \pm 0.37	5.17 \pm 0.31	5.14 \pm 0.31
p VO ₂ , ml/kg/min	45.65 \pm 6.45	47.21 \pm 5.59	50.07 \pm 7.68 ^{bc}
mATTAT, s	3.27 \pm 0.35	3.07 \pm 0.35	2.91 \pm 0.32 ^b

Abbreviations: BMI, body mass index; CMJ, countermovement jump; mATTAT, modified Aspire table tennis agility test; PHV, peak height velocity (when negative is before PHV, when positive, after PHV); p VO₂, predicted VO₂; T, time point.

^aP < 0.05.

^bSignificantly different from phase T₁.

^cSignificantly different from phase T₂.

by 2.7% when compared to PRE-season and 2% when compared to MID-season values $P < 0.001$). Further, the plasma volume for the whole group of athletes decreased by 3.6% in MID-period and by -5.9% and END-period.

MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; MCV, mean corpuscular volume; MPV, mean platelet volume; RBC, red blood cell; Hb, hemoglobin; Ret%, reticulocyte percentage; Ret-He, reticulocyte hemoglobin equivalent; T, time point; WBC, white blood cells.

Table 3 presents the values of the various biochemical markers affected by long-term training and competition in adolescent table tennis athletes. A main effect of condition was found for SHBG, which significantly decreased by 41.3% when compared to END-season values ($P < 0.005$). Serum testosterone showed a significant increase in the END-season period of 25.9% compared to PRE-season and 25.3% to MID-season values ($P < 0.01$). 25(OH)D levels were also significantly higher during the END-season period when compared to PRE-season and MID-season values.

No significant variations were observed in any of the examined enzymes during these training periods. The effect size of the yearly changes of various biochemical parameters ranged from trivial to small with mean corpuscular hemoglobin content (MCHC), CK, glucose, testosterone and 25(OH)D indicating a moderate to very large effect size

(i.e. Cohen's $d > 0.60$).

5. Discussion

Physical testing of athletes throughout the year helps build up an accurate physiological profile and helps coaches develop a tailored fitness program. In addition, it provides reference ranges to athletes and coaches to improve the quality of training prescription which helps facilitate the long-term athletic development. No information in the literature is available when it comes to providing accurate training information on adolescent table tennis players which follow regular and structured training activities. Therefore, the first purpose of the study was to examine the yearly fluctuations of performance related parameters in adolescent table tennis athletes over a training season.

In general, it is well accepted that children's strength, anaerobic and aerobic power is trainable. Overall improvements may be smaller than those seen in adults. Young, physically active children, who are exposed to training activities can demonstrate significant gains of 13% - 30% in muscle strength with resistance training as well as improvements of 5% in aerobic fitness (for a review see (22)). Most studies are limited to specific training periods and it is unclear what the typical improvements are in young athletes involved in full-time table tennis programs. Previous work has highlighted the importance of tracking growth and development in young athletes in combination with physical performance (23, 24). The competitive demands of training and competition impose strains on certain physiological systems of young players. In turn, this produces adverse outcomes like injuries and/or burnout if not correctly managed (25). Therefore, routine screening activities and the daily monitoring of training can provide vital information, which is why previous studies highlight the need of assessing physical parameters.

Our results showed significant improvements during the END-period in measures of linear running speed over 5, 10 and 20 m, CMJ, mATTAT and predicted VO_{2max} across a training season when compared to PRE-measures. Only findings of linear running speed over 5, 10 and 20 m, and p VO_{2max} were significantly better MID-period compared to PRE-measures. Seasonal changes assessing longitudinal data for growth rates of various physical performance measures throughout adolescence in elite sport is limited (26). Previous research has generally been conducted in general populations (27, 28). In the present study, it was found that performance variables closely related to table tennis significantly changed at specific time-points of a training year. It is believed this could be due to athletes undergoing continuous training periods and/or growth (29, 30).

Table 2. Hematological and Iron Related Parameters for Entire Group of Adolescent Athletes (Mean \pm SD) at Baseline, MID Season and END Season Time-Points^a

Parameters	Baseline (T ₁)	MID Season (T ₂)	END Season (T ₃)	Cohen' d	Interpretation
RBC, 10 ⁶ /μL	5.0 \pm 0.3	5.1 \pm 0.2	5.1 \pm 0.3	0.33	Small
Hb, g/dL	14.2 \pm 1.3	14.2 \pm 1.2	14.3 \pm 1.0	0.08	Trivial
HCT, %	40.7 \pm 3.3	40.5 \pm 2.8	42.0 \pm 3.2 ^{b,c}	0.39	Moderate
MCV, fl	80.6 \pm 3.5	80.1 \pm 3.5	82.2 \pm 3.7 ^{b,c}	0.44	Moderate
MCH, pg	28.1 \pm 1.6	28.0 \pm 1.6	27.9 \pm 1.8	0.11	Trivial
MCHC, g/DL	34.8 \pm 1.1	35.0 \pm 1.1	33.9 \pm 1.0 ^{b,c}	0.85	Very large
RET, %	0.84 \pm 0.28	0.93 \pm 0.28	1.03 \pm 0.36 ^b	0.53	Large
Ret-He, pg	33.1 \pm 1.8	32.5 \pm 2.5	33.2 \pm 1.8	0.05	Trivial
IRF, %	5.1 \pm 2.5	5.6 \pm 2.6	5.8 \pm 2.5	0.28	Small
Iron, umol/L	17.0 \pm 5.2	14.0 \pm 4.7	15.7 \pm 5.5	0.24	Small
Fe, ug/L	45.5 \pm 47.3	42.9 \pm 35.4	45.3 \pm 34.3	0.01	Trivial
WBC, 10 ³ /μL	5.8 \pm 1.2	5.8 \pm 1.4	5.8 \pm 1.8	0.01	Trivial
Neutrophils, %	43.7 \pm 9.2	47.5 \pm 9.1	47.0 \pm 11.4	0.31	Small
Lymphocytes, %	42.7 \pm 8.2	39.8 \pm 6.1	40.6 \pm 11.1	0.21	Small
Monocytes, %	8.8 \pm 2.4	8.4 \pm 2.0	8.1 \pm 1.3	0.36	Moderate
Eosinophils, %	4.2 \pm 2.4	3.8 \pm 2.4	3.9 \pm 2.9	0.11	Trivial
Basophils, %	0.48 \pm 0.20	0.44 \pm 0.28	0.41 \pm 0.13	0.43	Moderate
Platelets, 10 ³ /μL	233.9 \pm 52.4	256.2 \pm 57.7	260.5 \pm 62.9	0.47	Moderate
MPV, fl	10.6 \pm 0.8	10.4 \pm 0.9	10.3 \pm 0.6	0.42	Moderate
ESR, mm/h	2.8 \pm 1.8	3.3 \pm 1.4	3.7 \pm 2.7	0.39	Moderate
%ΔPV	-	-3.6% (PRE-MID)	-5.9% (PRE-END)	-	

Abbreviations: %ΔPV, plasma volume changes; ESR, erythrocyte sedimentation rate; Fe, ferritin; Hct, hematocrit;

^aP < 0.05.

^b Significantly different from phase T1.

^c Significantly different from phase T2.

Agility is a key component of fitness for table tennis players as players are required to move quickly in a variety of directions using numerous footwork techniques and speeds (18). We found that our players only significantly improved agility at the END-period of the season. Previous research in youth football players also found significant improvements in agility towards the END of the season or competition period (29). It could be suggested that a prolonged exposure to specific training activities is necessary before observing meaningful improvements in this quality as assessed by typical agility tests. The same pattern was observed in other measures of physical fitness as the bulk of training activities in this cohort was table tennis specific which further provides support as to why improvements in the mATTAT were only present at the END of season testing. Furthermore, agility is closely related to running speed (31) and has previously been observed to significantly improve in young athletes (25, 29) over varying distances ranging from 5 to 50m. Surprisingly, and in agree-

ment with Dragijsky et al. (29), we also found that 30m running speed did not show any changes over the course of the season. This is because table tennis training does not stimulate, or target skills related to 30m linear running speed. The focus of training is targeted towards improving speed, agility and quickness (SAQ) while emphasizing specific table tennis game aspects, such as movement games and quick changes of direction and speed in a small space. A 30m sprint test may be useful for establishing speed abilities in a generic population but can be considered redundant in a young table tennis cohort.

A well-developed aerobic energy system in table tennis is vital to help players cope with the demands of training and competition (3, 5). Seasonal changes in predicted p VO₂ has previously been assessed in young elite football athletes (29). It was found that seasonal changes in p VO_{2max} are present following a specific training period, such as pre-season. However, when training does not focus specifically on improving or maintaining aerobic en-

Table 3. Various Biochemical Markers for Entire Group of Adolescent Table Tennis Athletes (Mean \pm SD) at Baseline, MID Season and END Season Time-Points^a

Parameters	Baseline T ₁	MID Season (T ₂)	END Season (T ₃)	Cohen' d
CK, U/L	224.3 \pm 108.7	274.9 \pm 193.3	166.7 \pm 67.7	0.63
Creat., umol/L	64.9 \pm 12.0	65.3 \pm 18.8	70.0 \pm 18.9	0.32
ALT, U/L	28.9 \pm 11.5	27.0 \pm 8.4	26.0 \pm 8.2	0.29
AST, U/L	24.6 \pm 15.7	24.2 \pm 6.7	22.4 \pm 7.0	0.18
Glu., nmol/L	5.0 \pm 0.6	5.6 \pm 0.9	5.7 \pm 0.9 ^b	0.91
Chol., nmol/L	3.8 \pm 0.6	3.8 \pm 0.5	3.7 \pm 0.5	0.18
HDL, nmol/L	1.36 \pm 0.2	1.40 \pm 0.3	1.37 \pm 0.3	0.03
LDL, nmol/L	2.24 \pm 0.5	2.33 \pm 0.5	2.16 \pm 0.4	0.17
C, nmol/L	227.5 \pm 74.9	289.8 \pm 89.6	261.8 \pm 104.5	0.37
T, nmol/L	21.2 \pm 10.0	21.3 \pm 8.2	28.5 \pm 5.4 ^{bc}	0.90
T/C ratio	0.87 \pm 0.33	0.65 \pm 0.31	0.85 \pm 0.46	0.04
25(OH)D, ng/mL	32.2 \pm 1.5	28.6 \pm 11.5 ^b	41.9 \pm 16.5 ^{bc}	0.82
SHBG, nmol/L	90.1 \pm 84.1	112.4 \pm 80.4	66.0 \pm 48.0 ^c	0.34
Na, nmol/L	138.7 \pm 1.6	137.6 \pm 1.3	138.3 \pm 1.9	0.27
K, nmol/L	4.4 \pm 0.3	4.3 \pm 0.3	4.4 \pm 0.2	0.01
Cl., nmol/L	101.4 \pm 1.4	101.3 \pm 1.4	101.1 \pm 2.2	0.01

Abbreviations: 25(OH)D, 25 hydroxyvitaminD; ALT, alanine aminotransferase; AST, aspartame aminotransferase; C, cortisol; Chol., cholesterol; CK, creatine kinase; Cl., chloride; Creat., creatinine; Glu., glucose; HDL, high-density lipoproteins; K, potassium; LDL, low-density lipoproteins; Na, sodium; SHBG, sex hormone binding globulin; T, testosterone; T, time point.

^ap < 0.05.

^b Significantly different from phase T₁.

^c Significantly different from phase T₂.

duration, varying responses can be observed (32). Therefore, the observed improvements in endurance capacity observed at the END-period in our cohort of table tennis players is likely to be the effect of accumulated training load and strength and conditioning activities conducted throughout the training season. Improving explosive strength was a target during weekly strength and conditioning sessions (1 - 2 depending on training focus). Hence, the results of this study showed significant improvements in CMJ at the END-period of the season. Our results yielded similar findings to a study performed by Bergeron et al. (25), which found CMJ to be improved significantly over a 3y period in young football players. However, even though our results are like previous findings in elite adolescent athletes, these were conducted on football players and not table tennis players who are likely to perform more running and jumping activities. Therefore, it makes comparison between groups very difficult. Our study is the first to provide information on changes in physical variables in young table tennis players.

The secondary aim of the study was to report the variability of selected biomarkers utilized to ascertain health and training status and training effects. A few hematological parameters: Hct, MCV and RET changed significantly

over the course of this specific training period of 9 months. Because growth and maturation cannot be separated from training activities, it is difficult to quantify whether findings are due to training load and intensity or due to growth and maturation. Previous studies have found that red blood cells are relatively stable in adolescent athletes while levels of hemoglobin (Hb) and Hct are found to be lower (33, 34). However, our results only found Hct levels to be increased during END-season (3.2%) while concentration levels of Hb and red blood cells did not change. The observed variances between cohorts could be explained by the differing observation periods (longer) and the nature of the investigated sports in other studies. Most studies in the literature were conducted on youth athletes in other sports (33, 34).

Further, the mean value for total iron was close to the lower end of the clinical reference range (14.0 \pm 4.7 umol/L), which suggests that 42% of athletes had a low concentration of iron (pediatric reference intervals). In addition, the mean value for ferritin (42.9 \pm 35.4 ug/L) suggests that 75% of athletes were on the borderline of the proposed clinical reference ranges for the adolescent population. Concerning MCV, a parameter related to microcytic anemia, has been reported to be deficient in the Middle

East (35) and therefore essential to be assessed in young athletes from this region. Our cohort presented relatively low values when compared to similar age groups previously studied in the literature (33). Previous data on MCV in adolescent soccer athletes has shown a significant reduction after five months of a structured training period with no marked decrease in the red blood cell count (33). However, our results are like what has previously been observed in a bigger group of young Arab athletes (36). MCV values of 80.6 ± 3.5 (fl) at baseline screening increased progressively to 82.3 ± 1.7 (fl) at the END period of the training season.

The process of erythropoiesis can be monitored through the measurement of RET-He, RET% and IRF in growing athletes. RET are the earliest form of erythrocytes released into the blood and have been identified to be an important indicator of effective erythropoiesis (37). In this study, the mean values for adolescent table tennis players ranged from 0.84 ± 0.28 % at PRE-screening and increased to 1.03 ± 0.36 % in May (END of season), displaying a high rate of erythropoiesis which is in line with other studies.

It has been established that elevated cortisol levels at rest can reflect long-term training stress (38, 39) while the ratio between both cortisol and testosterone has been proposed to indicate the balance between anabolic and catabolic activity. Many researchers suggest that a decrease of 30 % or more implies overtraining and/or an unfavored level of anabolic to catabolic hormonal balance (8, 40). Although cortisol concentrations did not significantly fluctuate throughout the season, its mean value exceeded the upper threshold in mid-season measure. However, testosterone levels were significantly higher during the END period of the training season. It is believed to be because of in-season supplementation of 25(OH)D (41). Further, testosterone levels increased in parallel to a decrease in SHBG. Testosterone is largely bound to SHBG and albumin. Therefore, as SHBG falls the level of bioavailable testosterone increases over the same period. Although the testosterone/cortisol ratio decreased by 25% during MID period, this variation was not significant. Moreover, results showed that 25(OH)D significantly decreased during MID period, resulting in athletes receiving 25(OH)D supplementation through recommendation from the medical team. As a result, 25(OH)D displayed a significant increase at the END-period. Based on the literature, changes in 25(OH)D can also have played a role in the observed changes in testosterone.

The training process and growth rates in adolescent athletes in table tennis causes several changes in various physical, hematological and biochemical markers related to health and performance. The relevance of such observations on a specific population in order to enhance train-

ing prescription and health interventions is of great importance. Finally, as the aim of this study was to report some initial observations on a table tennis cohort, we hope that the data provided in this pilot work can be the beginning of a series of studies aimed at improving our understanding of training and adaptations in young table tennis players in order to provide effective and appropriate training guidelines to safeguard athletes' health. This study can provide more information on how regular monitoring and evaluation of biochemical and hematological markers can help (a) prevent the adverse effects of intense exercise, (b) assist in the design of training programs that will safeguard athletes' health, and (c) improve table tennis performance.

This study is not without limitations. The lack of control group means we are unable to compare our results simultaneously with recreational athletes. Furthermore, we intentionally kept our sample size small as our aim was to examine high level athletes, which are members of the national table tennis team and students of Aspire Academy.

5.1. Conclusions

In conclusion, based on our findings, changes occur in certain physical parameters, biochemical and hematological markers, throughout the training period. Therefore, coaches, sports scientists and nutritionists should take into consideration these fluctuations to plan and alter their training programs and provide specific nutritional strategies if required.

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Footnotes

Authors' Contribution: Study concept and design: Samuel Andrew Pullinger, Evdokia Varamenti and Marco Cardinale; analysis and interpretation of data: Samuel Andrew Pullinger and Evdokia Varamenti; drafting of the manuscript: Samuel Andrew Pullinger and Evdokia Varamenti; critical revision of the manuscript for important intellectual content: Samuel Andrew Pullinger, Evdokia Varamenti, Marco Cardinale, Zoran Nikolovski and Mohamed

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