

Effect of Training on Body Composition, Physiological and Biochemical Variables of Field Hockey Players

Indranil Manna^{1,*}, Gulshan Lal Khanna², Prakash Chandra Dhara³

¹Department of Physiology, Midnapore College (Autonomous), Midnapore, West Bengal, India

²Department of Health Sciences, ManavRachana International University, Faridabad, India

³Department of Human Physiology, Vidyasagar University, Midnapore, West Bengal, India

Email address:

indranil_manna@yahoo.com (I. Manna)

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Abstract: The aim of study was to investigate the effect of training on selected anthropometric, physiological and biochemical variables of Indian under 23 year field hockey players. A total of 30 male field hockey players (age: 19.00-22.99 years; mean age: 20.9 ± 1.0 yr) volunteered for this study. The training sessions were divided into 2 phases (a) Preparatory Phase (PP, 8 weeks) and (b) Competitive Phase (CP, 4 weeks). The training programme consist of aerobic, anaerobic and skill development, and were completed 4 hrs/day; 5 days/week. Selected variables were measured at zero level (baseline data, BD) and at the end of PP and CP. A significant ($P < 0.05$) reduction in percent body fat, recovery heart rate, hemoglobin, total cholesterol, triglyceride; and significant ($P < 0.05$) increase in anaerobic power, back and grip strength, serum urea, serum uric acid, HDLC level were noted among the players after the training. However, no significant difference was observed in stature, body mass and LBM, maximal heart rate (HR_{max}), VO_{2max} and LDLC level among the players after the training. Since the data on field hockey players are limited in India, the present study may provide useful information to the coaches to develop their training programme.

Keywords: Body Composition, Heart Rate, VO_{2max} , Anaerobic Power, Strength, Lipid Profile

1. Introduction

Field hockey is a sport with a long history that has undergone quite rapid and radical changes. The advent of the synthetic playing surface has changed the technical, tactical and physiological requirements of the game at all levels, but in particular at the elite level. To achieve the best possible performance, the training has to be formulated according to the principles of periodization [1]. The training induced changes observed in various parameters can be attributed to appropriate load dynamics. Physique and body composition have an important role for playing field hockey [2, 3]. In field hockey lots of movements and skills are involved so a high level of physical demand is required for match play [2, 3]. The game of field hockey involves walking, jogging, sprinting in varied directions with and without ball. As the players have to cover a big area in the ground during attack and defence therefore, the game demands for aerobic as well as anaerobic fitness [2, 3]. A high number of accelerations and decelerations, associated with the large number of changes in direction of play create an additional load to the muscles involved as in field hockey, those players better suited to cope with the demands of the game

reach the elite level [2, 3]. The intermittent high intensity pattern of activity during the match requires a high function of both the aerobic and anaerobic energy delivery pathways [2, 3]. Moreover, power and strength has great impact over the game, which is required during sprinting and in execution of various skills with the ball [2, 3].

During aerobic exercise the demand of oxygen increases at the working muscle, so an optimum level of hemoglobin is required to perform at the highest level with high intensity [4, 5]. The serum level of urea and uric acid are used for assessment of training related stress [6]. During the field hockey training these parameters may be evaluated at regular intervals to assess the training load imposed on the athlete. Lipids have important beneficial biological functions that include the use of triglycerides, for energy production or as stored fat in adipose tissue and use of cholesterol as a component, in conjunction with phospholipids of cellular membranes or in the synthesis of steroid hormones [7]. Elevated plasma cholesterol concentrations have been implicated in the development of coronary artery disease (CAD) [7, 8].

This study was focused on the field hockey players as the

game is popular and played through out the world. The anthropometric, physiological and biochemical variables have important role for the evaluation of training of the athletes. Studies on these parameters of field hockey players are lacking in India. In view of the above, a study was undertaken to investigate the effect training on selected anthropometric, physiological and biochemical variables of under 23 years field hockey players.

2. Materials and Methods

2.1. Participants

A total of 30 Indian Under 23 years elite male (age: 19.00-22.99 years; mean age: 20.9 ± 1.0 yr) regularly playing competitive field hockey for last 12-17 years, volunteered for this study. The sportsmen represented India in different International competitions including World cup, World Championship, Olympic Games and Asian Games. The selected physiological and biochemical parameters were measured in the laboratory at the beginning of the training (baseline data, BD) and at the end of each training phase (Preparatory Phase, PP; Competitive Phase, CP). Each test was scheduled at the same time of day (± 1 hour) in order to minimize the effect of diurnal variation. All the experiments were performed at $25 \pm 1^\circ\text{C}$, with relative humidity of 60 - 65%. The subjects were informed about the possible complications of the study and gave their consent. The study was conducted at Sports Authority of India and was approved by the Institute Review Board.

Table 1. General training schedule for the field hockey players.

Training	Transition phase	Preparatory phase	Competitive phase
Continuous training	Low	High	Low
Interval training	Low	High	Maintenance
Strength training	Low	High	Low
Power training	Low	High	Maintenance
Speed training	Low	High	Maintenance
Flexibility training	Low	High	High
Skill training	Low	High	Maintenance

2.2. Training

After taking the base line data (BD, zero level) the players went through a training programme. The training sessions were divided into 2 phases: (i) Preparatory Phase (PP, 8 weeks), and (ii) Competitive Phase (CP, 4 weeks). The data were collected at each training phase. The volume and intensities of the training components also varies in each phase of training. In the preparatory phase, the volume and intensity of training increased gradually. On the other hand, in the competitive phase the training volume and intensity was changed according to the competition schedule. At the same time highly specified training related to field hockey and practice match play was followed in the competitive phase. The players generally completed an average of 2 hours of training in morning sessions, which was mostly performed to

improve the physical fitness of the players. On the other hand, in the evening sessions 2 hours of technical and tactical training, which included dribbling, tackle, set up movements, penalty corner, penalty shoot out and match practice. The training sessions were followed 5 days/week, according to the requirement of the game and competitive demand. The training schedule, type of training, volume and intensity is shown in table 1.

2.3. Protocol

2.3.1. Measurement of Body Composition Variables

Body mass (weight) was measured with the accurately calibrated electronic scale (Seca Alpha 770, UK) to the nearest 0.1 kg, and stature (height) with stadiometer (Seca 220, UK) recorded to the nearest 0.5 cm [9]. Body density was estimated from the sum of the skin-fold sites based on the standard procedure [10] and estimated percentage body fat was calculated using standard equation [11]. Lean body mass (LBM) was calculated by subtracting fat mass from total body mass.

2.3.2. Measurement of Physiological Variables

Treadmill (Jaeger, LE 500, Germany) tests were performed to determine the cardiovascular status of the players during maximal exercise. The maximum oxygen consumption ($\text{VO}_{2\text{max}}$) was measured following standard methodology [12]. The subject was asked to run on the treadmill at a speed of 6 km/h for 2 min. thereafter, the workload was increased by 2 km/h for every 2 min. until volitional exhaustion. Expired gases were sampled and measured from a mixing chamber using computerized respiratory gas analyzer (Oxycon Champion, Jaeger, Germany). Heart rate responses during exercise and recovery were also noted. Anaerobic power was measured using cycle ergo-meter (Jaeger, LE 900, Germany) following the Wingate anaerobic test [13]. Strength of the grip and back was measured with the help of dynamometers following standard procedure [9].

2.3.3. Measurement of Biochemical Variables

A 5 ml of venous blood was drawn from an antecubital vein after a 12-hours fast and 24 hours after the last bout of exercise for the subsequent determination of selected biochemical parameters. The biochemical parameters were measured using standard methodology. All the reagents were supplied from Boehringer Mannheim, USA. Haemoglobin was measured using Cyanmethaemoglobin method [14]. Serum urea [15] and uric acid [16] were determined calorimetrically. Serum triglycerides [17], serum total cholesterol (TC) [18] and high-density lipoprotein cholesterol (HDL-C) [18] were determined by enzymatic method. Low-density lipoprotein cholesterol (LDL-C) was indirectly assessed following standard equation [19].

2.4. Statistical Analysis

All the values of anthropometric, physiological and biochemical variables were expressed as mean and standard deviation (SD). Analysis of Variance (ANOVA) with repeated measures followed by multiple comparison tests was

performed, to find out the significant difference in selected anthropometric, physiological and biochemical variables among the training phases. In each case the significant level was chosen at 0.05 levels. Accordingly, a statistical software package (SPSS) was used.

3. Results

Table 2. Effect of Training on Anthropometric Characteristics of Field Hockey Players.

Parameters	Base Line Data (BD)	Preparatory Phase (PP)	Competitive Phase (CP)
Stature(cm)	171.6 ± 3.4	171.6 ^{NS} ± 3.6	171.6 ^{NS} ± 3.7
Body Mass (kg)	63.9 ± 3.2	63.4 ^{NS} ± 3.1	62.1 ^{NS} ± 3.0
Body Fat (%)	13.7 ± 1.3	12.5* ± 1.2	12.2* [#] ± 1.3
Lean Body Mass (kg)	50.2 ± 4.0	51.5 ^{NS} ± 4.3	51.8 ^{NS} ± 4.4

Each values represents mean ± SD. Computed using alpha = 0.05; * when compared to BD, # when compared to PP, NS= not significant

Effect of Training on Anthropometric Characteristics of Under 23 years Field Hockey Players

A significant ($P < 0.05$) reduction in percent body fat was noted in preparatory and competitive phase of training when compared to base line data of the field hockey players. In addition, when comparing preparatory phase with that of the competitive phase, a further significant ($P < 0.05$) decrease in percent body fat was noted among the players. However, no significant difference was observed in stature, body mass and LBM of the field hockey players after the training programme (Table 2).

Table 3. Effect of Training on Physiological Characteristics of Field Hockey Players.

Parameters	Base Line Data (BD)	Preparatory Phase (PP)	Competitive Phase (CP)
VO _{2max} (ml kg ⁻¹ min ⁻¹)	56.3 ± 3.3	57.2 ^{NS} ± 4.5	57.3 ^{NS} ± 3.8
HR _{max} (beats min ⁻¹)	184.8 ± 3.9	185.0 ^{NS} ± 4.1	185.1 ^{NS} ± 4.4
RHR1 (beats min ⁻¹)	147.0 ± 2.3	145.8 ^{NS} ± 2.4	145.0* ± 4.3
Anaerobic Power (W kg ⁻¹)	13.5 ± 0.7	14.3* ± 1.1	14.5* ± 1.3
Back Strength (kg)	123.4 ± 3.3	125.5* ± 4.0	125.6* ± 3.5
Grip Strength Right Hand (kg)	35.1 ± 1.7	36.0 ± 1.4	36.2* ± 1.3
Grip Strength Left Hand (kg)	32.2 ± 1.6	33.3* ± 1.3	33.6* ± 1.4

Each values represents mean ± SD. Computed using alpha = 0.05; * when compared to BD, NS= not significant; VO_{2max} = maximal aerobic capacity, HR_{max} = maximal heart rate, RHR1= recovery heart rate 1st min.

Effect of Training on Physiological Characteristics of Under 23 years Field Hockey Players

Heart rate recorded during recovery after maximal exercise decreased significantly ($P < 0.05$) in competitive phase of training when compared to base line data of the players. However, no significant change was noted in recovery heart rate when comparing base line data with that of the preparatory phase. Further, no significant change was observed in maximal heart rate (HR_{max}) and VO_{2max} of the field hockey players following the training programme (Table 3). However, when comparing base line data with that of the

preparatory phase, a significant ($P < 0.05$) increase in anaerobic power, back strength and grip strength of left hand were noted among the players. In addition, when comparing base line data with that of the competitive phase significant ($P < 0.05$) increase in anaerobic power, back strength and grip strength of both hands were noted among the players. However, when comparing preparatory phase with that of the competitive phase no significant change was noted among these parameters (Table 3).

Effect of Training on Biochemical Characteristics of Under 23 years Field Hockey Players

A significant reduction ($P < 0.05$) in hemoglobin level was noted in competitive phase when compared to base line data of the field hockey players. However, no significant change was noted in hemoglobin level in preparatory phase when compared to base line data of the field hockey players (Table 4). On the other hand, significant ($P < 0.05$) increase in serum urea was noted in preparatory phase and competitive phase when compared to base line data of the field hockey players. In addition, when comparing preparatory phase with that of the competitive phase significant ($P < 0.05$) increase in serum urea level was noted among the players (Table 4). Further, when comparing competitive phase with that of the base line data a significant ($P < 0.05$) increase in serum uric acid level was noted among the players. However, no significant change in serum uric acid level was noted in preparatory phase when compared to base line data of the field hockey players (Table 4).

Table 4. Effect of Training on Hb, Urea and Uric Acid Levels of Field Hockey Players.

Parameters	Base Line Data (BD)	Preparatory Phase (PP)	Competitive Phase (CP)
Hemoglobin (g dl ⁻¹)	14.3 ± 0.3	14.2 ^{NS} ± 0.4	14.0* ± 0.5
Urea (mg dl ⁻¹)	30.2 ± 2.4	31.1* ± 2.3	33.3* [#] ± 2.3
Uric acid (mg dl ⁻¹)	4.4 ± 0.2	4.5 ^{NS} ± 0.4	4.8* ± 0.4

Each values represents mean ± SD. Computed using alpha = 0.05; * when compared to BD, # when compared to PP, NS= not significant.

A significant reduction ($P < 0.05$) in total cholesterol level was noted in competitive phase when compared to base line data of the field hockey players. However, no significant change was noted in total cholesterol level in preparatory phase when compared to base line data of the players (Table 5). In addition, when comparing base line data with that of the preparatory and competitive phase significant ($P < 0.05$) reduction in triglyceride level was noted among the field hockey players. However, no significant change was noted in triglyceride level when comparing preparatory phase with that of the competitive phase of the players (Table 5). On the other hand, significant increase ($P < 0.05$) in HDLC level was noted in competitive phase when compared to base line data of the players. But, no significant change was noted in HDLC level in preparatory phase when compared to base line data of the players (Table 5). In addition, when comparing base line data with that of the preparatory and competitive phase no significant change in LDLC level was noted among the players (Table 5).

Table 5. Effect of Training on Lipids and Lipoproteins Profiles of Field Hockey Players.

Parameters	Base Line Data (BD)	Preparatory Phase (PP)	Competitive Phase (CP)
TC (mg dl ⁻¹)	163.1 ± 5.5	161.4 ^{NS} ± 5.4	160.3* ± 5.1
TG (mg dl ⁻¹)	97.4 ± 4.6	94.0* ± 4.0	93.1* ± 4.5
HDLc (mg dl ⁻¹)	40.7 ± 3.0	42.4 ^{NS} ± 3.3	42.8* ± 3.6
LDLC (mg dl ⁻¹)	102.2 ± 3.8	100.5 ^{NS} ± 5.1	99.7 ^{NS} ± 4.2

Each values represents mean ± SD. Computed using alpha = 0.05; * when compared to BD, NS= not significant; TC= total cholesterol, TG= triglyceride, HDLC= high density lipoprotein cholesterol, LDLC= low density lipoprotein cholesterol.

4. Discussion

Performance of the hockey players is affected by body composition and physique. A lean body is desirable for sports like field hockey [2, 3]. A low-body fat may improve athletic performance by improving the strength-to-weight ratio [20]. Excess body fat adds to the load without contributing to the body's force-producing capacity [20]. A significant ($P < 0.05$) reduction in percent body fat was noted in preparatory and competitive phase when compared to base line data of the field hockey players. The possible reason for reduction in body fat might be due to endurance training which increases greater utilization of fat [20]. Similar findings were also noted by some researchers, who studied on field hockey players and reported that percent body fat was significantly lower in-season and postseason vs. preseason [21]. Therefore, it can be stated that field hockey players can accumulate body fat in the pre-season and lose body fat during preparatory phase and competitive phase of training. This might be due to intensive training during preparatory phase and high level of performance during the competitive phase. In this study no significant difference was observed in stature, body mass, LBM of the field hockey players after the training programme. It might be due to the shorter duration of the training. It has been reported that short term exercise training has no significant effect on body mass of the sports persons [20].

Aerobic capacity certainly plays an important role in modern field hockey and has a major influence on technical performance and tactical choices. The present study showed no significant change in maximal aerobic capacity (VO_{2max}) in the elite field hockey players in preparatory phase and competitive phase when compared to base line data. It might be due to the short duration of the training in elite group of players [20]. Ideally, endurance training for hockey players should be carried out using the ball, because the player motivation is also normally considered to be higher when the ball is used. The players might then additionally develop technical and tactical skills similar to situations experienced during the game. Heart rate increases with an increase in work intensity and shows linear relationship with work rate [12]. The highest rate at which the heart can beat is the maximal heart rate (HRmax). Quick recovery from strenuous exercise is important in hockey which involves intermittent efforts interspersed with short rests [20]. The heart rate recovery curve is an excellent tool for tracking a person's progress

during a training program [20]. Heart rate recorded during recovery after maximal exercise decreased significantly ($P < 0.05$) in competitive phase when compared to base line data among the field hockey players. It has been observed that training reduces the rise in heart rate during exercise and hastens the fall in heart rate during recovery [20]. Exercise cardio acceleration results from release of parasympathetic inhibition at low exercise intensities and from both parasympathetic inhibition and sympathetic activation at moderate intensities [20]. Nevertheless, parasympathetic activation is considered to be the main mechanism underlying exponential cardio deceleration after exercise [20]. The players might have been adapted to the load and no further increase in load dynamics might have been stressed on. During the match play the activities are not continuous; instead it is intermittent that means it involves short sprinting and casual recovery. Sometimes running with the ball and sometimes without the ball. Thus less increase in heart rate during exercise and rapid fall in heart rate during casual recovery may help the player to perform better [20]. On the other hand, no significant change was noted in HRmax and resting heart rate of the players after the training. This might be due to shorter duration of the training. It has been seen that short term exercise has no significant effect on HRmax [20]. The results of the present study suggest that the strain on the circulatory system during playing hockey is relatively high. Exercising at this intensity should provide a good training stimulus, provided such participation is frequent enough.

The game of hockey demands high anaerobic power as accelerate and decelerate quickly is the part of the game [22]. It is acceleration that is critical to hockey performance rather than maximal speed [22]. A high anaerobic power is essential for such activities. In the present study, significant ($P < 0.05$) increase in anaerobic power was noted among the field hockey players in preparatory phase and competitive phase of training when compared to base line data. This might be due to training in the elite players. Playing field hockey involves intermittent activities i.e., short sprinting and casual recovery. Thus a high anaerobic power helps to develop sprint quality of the player. It would appear, therefore, that a high anaerobic power is desirable for success in top-class hockey [22]. On the other hand, strength is the central component of a field hockey training program [22]. Upper body strength allows players to shoot more powerfully and pass over a greater range of distances. In field hockey grip strength may have importance in handling the stick during execution of different skills in practice and competition. Many activities in field hockey are forceful and explosive (e. g. tackling, jumping, hitting the ball, turning and changing pace). The power output during such activities is related to the strength of the muscles involved in the movements. Thus, it might be beneficial for a hockey player to have a high muscular strength, which also diminishes the risk of injury [23]. The results of the present study showed a significant ($P < 0.05$) increase in back and grip strength in preparatory phase and competitive phase of training when compared to base line data of the field hockey players. Similar observation has been reported by many

researchers [22, 23]. They studied on field hockey players and reported that the strength increased after training. The game requirements are for frequent, high intensity bursts of activity involving acceleration, deceleration and turning movements [22, 23]. Although the majority of the game is spent in low-level activity such as walking and light jogging, repeated back-to-back sprints make speed and tolerance to lactic acid an important characteristic in players [22, 23]. Therefore, sprint training regimens is beneficial to field hockey players [22, 23].

Hemoglobin concentration in blood which is mainly used for the transport of oxygen from blood vessels to exercising muscles, and transport of carbon dioxide from working muscles to blood vessels. Hemoglobin also represents the iron status of the body [24, 25]. In the present study a significant reduction ($P<0.05$) in hemoglobin was noted in competitive phase of training when compared to base line data of the field hockey players. During the pre-training period the training load was lesser than preparatory phase and competitive phase; therefore, reduced hemoglobin level was observed in the latter phases. Moreover, as the training load increased in the competitive phase, the declined in hemoglobin level was more prominent when compared with the pre-training period. Similar observations have been noted by many researchers in their recent studies [24, 25]. Studies on professional athletes showed that hemoglobin values were higher at the beginning of the competition season, and then declined in well-trained athletes [24, 25]. It can be suggested that the decline in hemoglobin level may be due to haemolysis [25, 26]. Intravascular haemolysis is one of the most emphasized mechanisms for destruction of erythrocytes during and after physical activity [27, 28]. In addition, exercise training induced reduction in hemoglobin concentration also may be due to hemodilution which is a common physiological effect of endurance training also exist among the well trained athletes due to increased in plasma volume [24]. A recent study reported declined haematocrit during the race and continued falling on the next day with a corresponding rises in plasma volume following an ultra endurance cycling. They reported that the impact on the plasma volume is pronounced leading to marked haemodilution post-exercise [24-26]. Another study reported a decrease in hemoglobin concentration during the post race recovery period following an ultra marathon race and that the greatest reduction in hemoglobin concentration was observed 48 hours after the race [24-26]. They suggested that this reduction in hemoglobin concentration is due to hemodilution [24-26].

The serum urea and uric acid level has been considered as an indicator of overtraining. In this study, significant increase ($P<0.05$) in serum urea level was noted in the field hockey players in preparatory phase and competitive phase of training when compared to base line data. In addition, significant increase ($P<0.05$) in serum uric acid level was also noted in the field hockey players in competitive phase of training when compared to base line data. Increased level of serum urea and uric acid were observed after training, but the urea and uric acid level were found to be within the normal range. The

highest level of urea and uric acid were noted in the competitive phase when the training load was highest. It is believed that a pronounced increase in the urea and uric acid concentration indicates strong influence of a training session, whereas normalization of the urea and uric acid level in blood is an index of time to perform subsequent strenuous training sessions [24]. The possible reason for the increased urea level is the breakdown of proteins. Similar observations have been reported by many researchers [24]. It has been reported that prolonged exercises have been shown to cause increased urea concentration in the blood, liver, skeletal muscles, urine, and sweat [24, 29]. This considered as an augmented urea production. The increased uric acid level is also attributed the degradation of adenonucleotides [24]. Uric acid has been found in sweat and urine collected during exercise [24]. In fact, despite being an end product of the purine nucleotide system, uric acid scavenges OH_2 radicals as well, and there is evidence that it may be an important biological scavenger against free radicals in human plasma and in skeletal muscle during and after acute hard exercise [30]. This may be one of the reasons for increase in urea and uric acid level after exercise training [30].

Lipids and lipoprotein profile indicate the cardiovascular and the metabolic status of the athlete [7, 8]. Activity levels have impact on the lipids and lipoprotein levels of the athletes. As the training load increased from pre-training period to preparatory phase and competitive phase, the level of total cholesterol and triglyceride were decreased significantly ($P<0.05$) whereas the level of HDL-C increased ($P<0.05$) gradually. Therefore, it can be stated that the training load has a negative relation with total cholesterol and triglyceride; and a positive relation with HDL-C level of the athletes. The possible reason for the reduction in total cholesterol and triglyceride; and elevation in HDL-C is that exercise especially, which increases metabolism and utilization of blood lipids and lipoprotein for energy production [20, 30]. However, no significant change was noted in LDL-C level of the players after the training. This might be due to the short duration of the training or improper optimization of the training load. Our findings are in conformity with the observations of other researchers in their recent studies. Cross-sectional studies also reported an increase in HDL-C level and decrease in triglyceride level after exercise [7, 30]. A recent study showed significant increase in HDL-C level and decrease in LDL-C level, with no change in triglyceride after 9 weeks of training [7, 8, 30]. Another study reported that 4 weeks of aerobic exercise training significantly decreased the levels of total cholesterol, LDL-C, and increased HDL-C [8, 30]. Similar observations have been reported in the present study.

5. Conclusion

It may be concluded that these changes are due to training as well as due to participating in an increasing number of competitions. The introduction of synthetic playing surface has changed the game towards more of anaerobic side therefore, the game demands for high anaerobic power and strength. However, development of high aerobic capacity is essential for field

hockey as the players has to cover a big area in the ground during the game. Regular monitoring of hemoglobin; serum urea and uric acid; lipids and lipoproteins profiles of the field hockey players is essential to optimize their health status which has direct relation with their performance. The unique profile should be taken into consideration while administering training to the players. As the studies on field hockey players are limited in India, the data of the present study can be a handy tool and can act as a frame of reference for monitoring of training of field hockey players of different age groups. This would enable the coaches to assess the current status of an athlete and the degree of training adaptability and provide an opportunity to modify the training schedule accordingly to achieve the desired performance.

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References

- [1] Bompa T.O., Periodization Training for Sports, Human Kinetics, Champaign, IL 1999.
- [2] Montgomery D.L., Physiological profile of professional hockey players - a longitudinal comparison. *Appl Physiol Nutr Metabol*, 2006, 31, 181-185.
- [3] Quinney H.A., Dewart R., Game A., Snyder Miller G., Warburton D., Bell G., A 26 year physiological description of a National Hockey League team. *Appl Physiol Nutr Metabol*, 2008, 33, 753-760.
- [4] Nielsen M.S., Weber R.E., Antagonistic interaction between oxygenation-linked lactate and CO₂ binding to human hemoglobin. *Comp Biochem Physiol MolInte Physiol*, 2007, 146, 429-434.
- [5] Suhr F., Porten S., Hertrich T., Brixius K., Schmidt A., Platen P. et al., Intensive exercise induces changes of endothelial nitric oxide synthase pattern in human erythrocytes. *Nitric Oxide*, 2009, 20, 95-103.
- [6] Urhausen A., Kindermann W., Diagnosis of over training: what tools do we have? *Sports Med*, 2002, 32, 95-102.
- [7] Kelley G. A., Kelley K.S., Impact of progressive resistance training on lipids and lipoproteins in adults: a meta-analysis of randomized controlled trials. *Pre Med*, 2009, 48, 9-19.
- [8] Apostolidis N., Bogdanis G. C., Kostopoulos N., Souglis A., Papadopoulos C., Changes in the lipid profile of elite basketball and soccer players after a match. *Res Sports Med*, 2014, 22, 100-110.
- [9] Jonson B. L., Nelson J.K., Practical measurements for evaluation in physical education, Macmillan Publishing Co, London 1996.
- [10] Durnin J.V.G.A., Womersley J., Body fat assessed from total body density and its estimation from skin fold thickness: measurements on 481 men and women from 16 to 72 years. *Br J Nutr*, 1974, 32, 77-97.
- [11] Siri W.E., The gross composition of the body. In: Tobias C.A., Lawrence J.H. (ed.), *Advances in Biological and Medical Physics*, Academic Press, New York 1956, 239-280.
- [12] Astrand P.O., Rodhal K., Textbook of work physiology, McGraw-Hill, New York 1986.
- [13] Inbar O., Bar-Or O., Skinner J.S., The Wingate anaerobic test, Human Kinetics, Champaign IL 1996.
- [14] Mukharjee K.L., Medical laboratory technology. A procedure manual for routine diagnostic tests, Vol I – III. Tata McGraw-Hill Publishing Company Limited, New Delhi 1997.
- [15] Wybenga R., Di Giorgio J., Pileggi V.J., Manual and automated methods for urea nitrogen measurement in whole serum. *ClinChem*, 1971, 17, 891-895.
- [16] Martinek R.G., Review of methods for determining inorganic phosphorus in biological fluids. *J Am Med Technol*, 1970, 32, 237.
- [17] Schettler G., Nussei E., Maßnahmen zur Prävention der Arteriosklerose. *Arb Med Soz Med Prav Med*, 1975, 10, 25.
- [18] Wybenga R., Pileggi V.J., Dirstine P.H., Di Giorgio J., Direct manual determination of serum total cholesterol with a single stable reagent. *ClinChem*, 1970, 16, 980-984.
- [19] Friedewald W.T., Levy R.I., Fredrickson D.S., Estimation of the concentration of low density lipoprotein cholesterol in plasma without use of the preparative ultracentrifuge. *ClinChem*, 1972, 18, 499-501.
- [20] Katch V.L., Mc Ardle W.D., Katch F.I., Essentials of Exercise Physiology, 4th ed. Lippincott Williams and Wilkins, Philadelphia PA 2011.
- [21] Astorino T.A., Tam P.A., Rietschel J.C., Johnson S.M., Freedman T.P., Changes in physical fitness parameters during a competitive field hockey season. *J Stren Cond Res*, 2004, 18, 850-854.
- [22] Grant J.A., Bedi A., Kurz J., Bancroft R., Gagnier J.J., Miller B.S., Ability of preseason body composition and physical fitness to predict the risk of injury in male collegiate hockey players. *Sports Health*, 2015, 7, 45-51.
- [23] Ebben W.P., Carroll R.M., Simenz C.J., Strength and conditioning practices of National Hockey League strength and conditioning coaches. *J Stren Cond Res*, 2004, 18, 889-897.
- [24] Kargotich S., Keast D., Goodman C., Bhagat C.I., Joske D.J., Dawson B. et al., Monitoring 6 weeks of progressive endurance training with plasma glutamine. *Int J Sports Med*, 2007, 28, 211-216.
- [25] Suhr F., Porten S., Hertrich T., Brixius K., Schmidt A., Platen P. et al., Intensive exercise induces changes of endothelial nitric oxide synthase pattern in human erythrocytes. *Nitric Oxide*, 2009, 20, 95-103.
- [26] Fujitsuka S., Koike Y., Isozaki A., Nomura Y., Effect of 12 weeks of strenuous physical training on hematological changes. *Mil Med*, 2005, 170, 590-594.
- [27] Francisco J.O., Manuel R., Manuel R.P., Regular physical activity increases glutathione peroxidase activity in adolescents with Down syndrome. *Clin J Sports Med*, 2006, 16, 355-356.

- [28] Pialoux V., Mounier R., Ponsot E., Effects of exercise and training in hypoxia on antioxidant/pro-oxidant balance. *Eu J Clin Nutr*, 2006, 60, 1345-1354.
- [29] Tsahar E., Arad Z., Izhaki I., Guglielmo C.G., The relationship between uric acid and its oxidative product allantoin: a potential indicator for the evaluation of oxidative stress in birds. *J Comp Physiol*, 2006, 176, 653-661.
- [30] Mazloom Z., Salehi M., Eftekhari M.H., Blood lipid and lipoprotein profile of female athletes with respect to their jobs and nutrients intake. *Pak J Biol Sci*, 2008, 11, 142-144.