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# THE EFFECT OF 8 WEEKS OF PLYOMETRIC TRAINING ON HORMONAL CHANGES AND PHYSICAL FITNESS OF YOUNG SOCCER PLAYERS

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## ABSTRACT

The purpose of this study was to investigate the effect of 8 weeks of plyometric training on DHEA and cortisol hormones and physical fitness in young soccer players. Thirty volunteer young footballers were randomly assigned into two groups of plyometric training (n=15) and control (n=15). Plyometric group subjects performed plyometric exercises two sessions per week in addition to soccer practice for eight weeks. Before and after the eight-week study variables were measured. Raw data were analyzed using dependent and independent t-test. Within-group comparison showed significant improvements for plyometric group in the amounts of anaerobic power (p=0.002), explosive power (p=0.015), quadriceps muscle strength (p=0.022), agility (p=0.023), DHEA (p=0.011), cortisol (p=0.019) and DHEA/Cortisol ratio (p=0.010) after eight weeks. In addition, between-groups comparison showed a significant difference in the levels of anaerobic power (p=0.008), explosive power (p=0.033), DHEA (p=0.047), cortisol (p=0.013) and the DHEA/Cortisol ratio (p=0.016). The results showed that plyometric exercises improved young soccer players' physical performance, but its pressure led to the lack of balance between DHEA and cortisol hormones. So it is recommended to the coaches and athletes to use this type of training method to improve their physical fitness levels. However, intensity and duration of these exercises should be controlled so as not to destroy the balance of hormones in young soccer players.

**Keywords: Plyometric Training, Hormonal Changes, Physical Fitness, Young Soccer Players**

## INTRODUCTION

Soccer is the most popular sport in the world played by men, women, children, and adults at different levels of competition. During the football game, elite players run about 10 kilometers at intensity close to the anaerobic threshold and perform many explosive movements such as jumping, shooting, crowds, turns, starts, and positions changes [1,2]. Physical fitness plays a very important and decisive role in the optimal performance of soccer players. Physical fitness needs proper training programs to improve [3].

The physiological purpose of the training is to improve body function and optimize athletic performance. The training method is of great importance in terms of intensity, duration, type of exercise and its combined performance method and other aspects [4]. Plyometric training is one of the most popular methods among athletes of dynamic sports [5,6]. Plyometric training is used as a tool for developing athletes' speed and power. In Eastern Europe, plyometric training was used in 1970 for the first time in order to develop speed and power of soccer players [7]. This type of training can increase muscle strength and explosive ability and can help improve performance and increase vertical jump height in explosive sports such as football [8,9]. It has been shown that plyometric training affects muscle power, strength, power generation in trained muscles and maximal isometric force. These physiological adaptations help to increase vertical jump height [10].

The ultimate goal of training is to improve athletic performance. Athletes perform heavy exercises to improve their athletic performance because of the adaptations in tissue and cellular levels. If volume and intensity of training increase more than the physiological capacity of athletes, then overtraining will happen and athletic performance may be weakened in these conditions [11,12]. For professional athletes this pressure is due to high-intensity exercise programs. When training pressure is at the appropriate level, it will create a positive adaptation in human organism and will lead to developed physical performance. On the other hand, the opposite is also true. And inappropriate levels of training pressure can cause a negative impact and decline in physical performance [13,14].

Hormonal system is one of the physiological systems that are sensitive to exercise pressure. Research has shown that exercise affects the hormones levels and decreases and increases their levels compared to the rest time. In fact, these hormonal fluctuations can be considered as the body's reaction to exercise pressure for establishing homeostasis [15,16]. DHEA is one of the especial adrenal hormones, which has some anabolic effects on several tissues by turning into sex steroids (testosterone and estrogen), and shows androgen responses to exercise better than testosterone. DHEA is one of the three adrenal hormones and the most abundant steroid hormone in the body. Recently DHEA is of great interest because of its multiple effects [17,18].

Cortisol is the most important Glucocorticoid hormones secreted by the adrenal cortex and is released by intermediate layer of pituitary glands. In addition, cortisol accelerates the activity of gluconeogenesis, lipogenesis, Ketogenesis and proteolysis and is effective in immune system suppression. Also, the physiological stress caused by heavy exercise may stimulate the immune system secretion and ultimately lead to its failure [19,20]. Cortisol is an indicator of endocrine response in sports like football where there are body collisions. This hormone is the most important stress hormone and unlike DHEA, leads to increased protein demolition and decreased protein synthesis in muscle cells through its catabolic activity. It is possible that measurement of different hormones and enzymes will be applied in assessment of immediate response and during recovery after training and competition [21,22].

When athletes bear great training pressure some changes happen in their anabolic-catabolic hormones. The balance between catabolic hormones (cortisol) and anabolic ones (DHEA) has an important application in the course of implementation and recovery. DHEA and cortisol changes are dependent on intensity, duration and environmental practice conditions. DHEA/Cortisol ratio is used as an indicator of training pressure for athletes [23]. Any changes in this ratio can be associated with the risk of changes in immune function. During the matches soccer players are permanently in conditions that they have to play against opponents with higher fitness and more toned body [24]. Therefore, it is necessary for athletes to use appropriate training methods in order to prepare themselves for competitions. Hence, this study investigates the effect of eight weeks of plyometric training on hormonal changes and physical fitness of young soccer players.

## METHODOLOGY

This was a quasi-experimental study. After informing and expressing the nature, purpose and risks of the research, 30 young soccer players voluntarily participated in the study. Then the subjects voluntarily consented to participate in the study and signed a medical health questionnaire. Inclusion criteria were age, sports field, not participating in plyometric exercises 6 months prior to the implementation, training experience (5-3 years), general health, lack of a specific diet and drug consumption. A reputable doctor also evaluated subjects' health status. The subjects were randomly assigned into two plyometric (n=15) and control (n=15) groups. The external characteristics of the subjects are presented in Table 1.

**Table 1: Participant Characteristics**

| Parameter | plyometric training | Control group |
|---|---|---|
| Age (year) | 23.27±3.15 | 22.47±3.42 |
| Height (cm) | 178.46±8.77 | 176.53±9.91 |
| Body weight (kg) | 71.73±6.60 | 70.13±10.26 |
| Body Mass Index (kg/m2) | 22.56±1.59 | 22.58±3.16 |

A week before beginning the study, the subjects participated in an orientation session and got familiar with the way to perform exercises properly through a graphical representation and repeated some of them. Measurement of physical fitness of both groups was performed by the Cooper test (aerobic capacity), RAST (anaerobic power), Sargent jump (explosive power), the modified Hoger test (flexibility), dynamometer (strength of quadriceps femoris muscle), illinois agility test (agility) and 30 m (speed).

Plyometric group performed plyometric exercise (Table 2) for eight weeks, two sessions per week and 30 minutes each session with three sessions of regular football exercises per week. The control group only performed three sessions of regular football exercises per week. After eight weeks subjects' physical fitness were evaluated again. Subjects' weight was measured by Beurer digital scale made in Germany. Their height was also measured by tape meter model Mabas made in Japan. Cortisol was measured by Monobind Company Kits made in America with the model number of (eia-36 kb 2) and DHEA by Monobind Company Kits made in America with the model number of (eia-51k2a2).

**Table 2: Plyometric training program**

| Week / Training | 1-2 | 3-4 | 5-6 | 7-8 |
|---|---|---|---|---|
| Running gait with both feet | 1 rep | 2 rep | 3 rep | 4 rep |
| Foot switch leap upward | 15 rep | 20 rep | 30 rep | 40 rep |
| Jump on 8 cones Side | 2 set | 3 set | 4 set | 5 set |
| Jump from the cone 8 directions | 2 set×30sec | 2 set×40sec | 2 set×50sec | 2 set×60sec |
| Medicine Ball Move the ball up and down and vice versa | 30 sec | 40 sec | 60 sec | 75 sec |
| Medicine Ball wing throwing the ball forward with both hands from behind. | 30 thr | 40 thr | 50 thr | 60 thr |
| Medicine Ball throws the ball down the wing upward with both hands | 30 thr | 40 thr | 50 thr | 60 thr |

Rep: repetition, sec: second, Thr: throw

## Statistical Methods

Statistical analysis was performed using SPSS version 18. Data normality was investigated using Kolmogorov-Smirnov test. Paired t-test was used for within-group comparison and independent t-test was used for between-groups comparison. The significance level of the test was considered p≤0.05.

**RESULTS**

Within-group comparison of research variables is presented in table 3. Within-group comparison of research variables is presented in table 3. In plyometric training group significant improvements were observed in levels of anaerobic power (p=0.002), explosive power (p=0.015), quadriceps femoris muscle strength (p=0.022), agility (p=0.023), DHEA (p=0.011), cortisol (p=0.019) and DHEA/Cortisol ratio (p=0.010) after eight weeks. But there were no significant changes in the levels of aerobic power (p=0.146), flexibility (p=0.209) and speed (p=0.620) in post-test compared to pre-test. The research variables in the control group also showed no significant changes in posttest compared to the pretest (p>0.05).

Table 4 presents the between-groups comparison of research variables. There was a significant difference in the values of anaerobic power (p=0.008), explosive power (p=0.033), DHEA (p=0.047), cortisol (p=0.013) and DHEA/Cortisol ratio (p=0.016. However, there was no significant difference in levels of aerobic power (p=0.201), quadriceps muscle strength (p=0.180), flexibility (p=0.220), agility (p=0.118) and speed (p=0.245) between the two groups.

**Table 3: Comparison of within-group variables in both groups (Means±Sd)**

| Parameter | phase | plyometric training | P-value | Control group | P-value |
|---|---|---|---|---|---|
| Age (year) | - | 23.27±3.15 | - | 22.47±3.42 | - |
| Height (cm) | - | 178.46±8.77 | - | 176.53±9.91 | - |
| Body weight (kg) | - | 71.73±6.60 | - | 70.13±10.26 | - |
| Body Mass Index (kg/m2) | - | 22.56±1.59 | - | 22.58±3.16 | - |
| Aerobic | pre | 45.84±8.52 | 0.146 | 44.97±9.48 | 0.571 |
| | post | 49.28±6.22 | | 45.36±9.44 | |
| Anaerobic | pre | 540.47±49.15 | 0.002 | 543.68±32.28 | 0.359 |
| | post | 567.23±47.55 | | 547.37±34.99 | |
| Explosive power | pre | 37.20±10.01 | 0.015 | 37.73±11.93 | 0.164 |
| | post | 40.60±10.79 | | 38.27±11.69 | |
| Strength | pre | 35.72±8.10 | 0.022 | 35.94±9.22 | 0.054 |
| | post | 37.91±7.34 | | 36.83±8.71 | |
| flexibility | pre | 44.67±7.83 | 0.209 | 44.93±6.54 | 0.651 |
| | post | 45.80±7.14 | | 44.53±6.88 | |
| Agility | pre | 9.37±1.50 | 0.023 | 9.51±1.61 | 0.859 |
| | post | 8.94±1.54 | | 9.48±1.64 | |
| Speed | pre | 5.18±0.80 | 0.620 | 5.09±0.72 | 0.183 |
| | post | 5.11±0.71 | | 5.21±0.76 | |
| DHEA | pre | 1.51±0.61 | 0.011 | 1.57±0.54 | 0.096 |
| | post | 1.40±0.50 | | 1.54±0.55 | |
| Cortisol | pre | 11.32±1.48 | 0.019 | 11.49±1.21 | 0.744 |
| | post | 12.09±1.69 | | 11.48±1.23 | |

| | | | | | |
|---|---|---|---|---|---|
| **DHEA/Cortisol ratio** | **pre** | **0.138±0.068** | **0.010** | **0.137±0.049** | **0.170** |
| | **post** | **0.132±0.063** | | **0.135±0.050** | |

**Table 4: Comparison of between-group variables in both groups (Means±Sd)**

| Parameter | plyometric training | Control group | P-value |
|---|---|---|---|
| **Aerobic** | **-3.43±8.63** | **-0.38±2.58** | **0.201** |
| **Anaerobic** | **-26.76±27.47** | **-3.68±15.04** | **0.008** |
| **Explosive power** | **-3.40±4.73** | **-0.53±1.40** | **0.033** |
| **Strength** | **-2.19±3.28** | **-0.88±1.63** | **0.180** |
| **flexibility** | **-1.13±3.33** | **0.40±3.35** | **0.220** |
| **Agility** | **0.43±0.65** | **0.03±0.69** | **0.118** |
| **speed** | **0.06±0.51** | **-0.12±0.33** | **0.245** |
| **DHEA** | **0.11±0.14** | **0.02±0.05** | **0.047** |
| **Cortisol** | **-0.77±1.13** | **0.01±0.13** | **0.013** |
| **DHEA/Cortisol ratio** | **0.020±0.026** | **0.002±0.006** | **0.016** |

## DISCUSSION

The present study was designed to investigate the the effect of plyometric training on hormonal changes and physical fitness was young soccer players. Within-group comparison of physical fitness in the plyometric group showed significant improvements in levels of anaerobic power, explosive power, quadriceps femoris muscle strength and agility. In addition, between-groups comparison showed a statistically significant difference in the levels of anaerobic power and explosive power. Khodajo et al (2014) studied the effect of 8 weeks of plyometric training on anaerobic power, explosive power and quadriceps femoris muscle strength in young soccer players and observed signifficant improvements [10]. In plyometric exercises muscles stretch quickly due to an immediate shortening (stretch-shorten contraction) by elastic energy stored during stretching phase [25,26]. These exercises improve agility, vertical jump and muscle strength. Discrepancies in studies can be attributed to different factors such as gender, status, training, testing and training intensity ratio during exercises [27,28].

However, there are so many unanswered questions about the mechanism of the effects of plyometric training, especially from the nervous perspective. Measurable Neurology parameters such as nerve conduction speed, Electromyography and called motor unit may change in response to physical activity [29]. They are considered as possible mechanisms in performance improvement due to plyometric training including better use of muscles elastic energy, Golgi tendon organs decreased sensitivity, changes in temporary muscle activation displacement motor for greater efficiency and rapid retrieval of the motor unit and motor neuron excitability [30,31]. What is certain is that neural control of movement includes central and peripheral parts, which have key roles in power generation of the stretch-shortening cycle. The specific importance of neural control in muscle activation is in the leg before hitting the ground and reflexes in final extrovert and near extrovert stages [32].

These exercises are associated with increased muscle strength and muscle fibers length and stimulate the nervous-muscular system by stretching-contraction cycle, in order to enable it to respond to short and rapid muscle length changes more quickly and strongly [33]. These exercises also increase knee strength and six weeks of training reduces serious knee injuries. Higher strength of leg muscles helps prevent common injuries. In addition, it has been reported that long-term plyometric training may increase bone strength. All the above factors are the characteristics of plyometric training because of its high explosive nature and stretch reflex [34]. Although plyometric training leads to increased vertical jump height, muscle soreness and injuries are reported especially when athletes are exposed to unfamiliar training stimuli. During unfamiliar plyometric training especially in extrovert types, rate of force generation in muscular-skeletal system increases and it can lead to delayed muscle soreness [35].

As it was observed, there was a significant difference between the two groups anaerobic power and explosive power. Probably plyometric exercises increased strength, muscle strength and muscle fiber size and stimulated the neuromuscular system through the pull-contraction cycle in order to respond to the short and fast changes in muscle length.

Within-group comparison showed significant improvements in the amount of DHEA, cortisol and DHEA/Cortisol ratio for the plyometric group after eight weeks. In addition, between-groups comparison showed a significant difference between the levels of DHEA, cortisol and DHEA/Cortisol ratio. Khodami et al (2014) studied the effect of plyometric training on levels of DHEA, cortisol and DHEA/Cortisol ratio in young badminton players and observed a significant decrease in cortisol levels and a significant increase in levels of DHEA and DHEA/Cortisol ratio levels [7].

Physical activity leads to significant changes in plasma levels of hormones and metabolites. These changes will depend on the intensity and duration of physical activities. In recent years, physiologists suggest that exercise intensity and muscle adaptations can be evaluated by measuring the levels of lactic acid changes [36]. During physical activity, lactic acid changes may be associated with hormonal changes, so that research has shown that increased levels of serum lactic acid during intense physical activity may stimulate the cortisol hormone levels by stimulating the hypothalamic-adrenal axis chemical receptor [37].

DHEA/Cortisol ratio is used as an indicator of exercise pressure in athletes. This ratio is influenced by the intensity and duration of exercise and any changes in this ratio can be associated with the risk of changes in immune function. When athletes endure high pressure, hormonal changes will occur and among them the changes in anabolic-catabolic hormones are outstanding [38].

Cortisol is an appropriate indicator to evaluate stress levels and the hypothalamic-pituitary-adrenocortical axis performance. Cortisol levels will change in response to exercise and competition. Evaluating the levels of cortisol, alone and in combination with DHEA is another valuable indicator associated with physiological stress [39]. In fact, DHEA/Cortisol ratio is used to evaluate metabolism in relation with anabolic-catabolic balance. The balance between catabolic and anabolic hormones in athletes is often recognized by this ratio. It has been shown that DHEA/Cortisol ratio will reduce after endurance exercises and high volume endurance training [40].

As it was observed, there were significant differences between the levels of DHEA, cortisol and DHEA/Cortisol ratio in groups. The results showed that the simultaneous participation in soccer specialized and plyometric exercises will disrupt DHEA and cortisol hormones balance, and reduce the levels of DHEA and increase cortisol levels. Given that, DHEA/Cortisol ratio is used as an indicator of exercise pressure in athletes, it is observed that exercise pressure has disrupted the hormonal balance in these subjects.

**CONCLUSIONS**

The results showed that plyometric exercises improved young footballers physical performance, while the pressure of these exercises disrupted the balance of DHEA and cortisol hormones. So it is recommended that coaches and athletes use this training method to improve their fitness levels. However, this intensity and duration of exercises should be controlled so as not to disrupt the hormonal balance in young soccer players.

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