

THE EFFECTS OF SIX WEEKS OF TRAINING ON PHYSICAL FITNESS AND PERFORMANCE IN TEENAGE AND MATURE TOP-LEVEL SOCCER PLAYERS

S.M. Ostojic¹, M. Stojanovic¹, I. Jukic², E. Pasalic³, M. Jourkesh⁴

¹Faculty of Sport and Tourism, Metropolitan University of Novi Sad, Serbia;

²Faculty of Kinesiology, University of Zagreb, Croatia; ³Faculty of Sport and Physical Education, University of Sarajevo, Bosnia; ⁴Dep. of Physical Education and Sports Science, Islamic Azad University, Shabestar Branch, Iran

Abstract. The main aim of the present study was to investigate the effects of soccer-specific training on physical fitness components in adolescent elite soccer players and make comparisons with older counterparts. Twenty two male soccer players from the Serbian First Division team were allocated to two assigned trials according to age – young group (YG) and mature group (MG). Players in their teenage years (19 years and younger) were assigned to YG (10 subjects) and others to MG (12 subjects). Between the first and second test session, all subjects followed six weeks of soccer-specific periodized training programme. There were no differences between groups at pre- and post-training trial for body mass, vertical jump height, average anaerobic power and VO_{2max} ($P>0.05$). Body fat was significantly lower in YG before and after training program as compared to MG ($P<0.05$). Body mass and fat dropped significantly in both groups after training program ($P<0.05$). Furthermore, average anaerobic power and VO_{2max} along with vertical jump height, were significantly improved in both groups ($P<0.05$) at post-training performance. Finally, the magnitude of change in VO_{2max} was significantly superior in MG as compared to YG after training program (18.3 vs. 7.8%; $P<0.05$). The findings of the present study indicate that the trainability indices are not highly influenced by age in top-level soccer players.

(Biol.Sport 26:379-387, 2009)

Key words: Trainability - Maturity - Maximal oxygen uptake - Body fat - Anaerobic power

Reprint request to: Assoc. Prof. Sergej M. Ostojic, MD, MSc, PhD, Biomedical Sciences Dept., Exercise Physiology Lab., Faculty of Sport and Tourism, Metropolitan University, Radnicka 30/II, Novi Sad 21000, Serbia

Tel.: (++381)-21-530-633; Fax: (++381)-21-530-232; E-mail: sergej@panet.rs



Introduction

Soccer at the professional level of play is arguably the world's leading team sport, performed by men and women, children and adults with different level of expertise [19]. Aspects such as experience, body composition, endurance, balance between anaerobic and aerobic power, among other factors, are of primary importance in development and evaluation of elite players [17]. More than ever, adolescents with exceptional performance abilities are being encouraged to train and compete intensely and players of teenage years do feature in all top club teams [18]. While adolescent's physiological responses to training are qualitatively similar to those of adults, there are several age and development-related quantitative differences in trainability [4,8,14]. Of special interest to the sport scientist involved in soccer are the effects of training on the young elite players. Relatively little information are available regarding the degree of trainability of muscular function or aerobic power in junior players compared with senior elite soccer players [3,6,9]. Therefore, the main aim of the present study was to investigate the effects of training on physical fitness components in young elite soccer players and make comparisons with older counterparts.

Materials and Methods

Subjects: Twenty two male soccer players from the Serbian First Division Super League team gave their informed consent and volunteered to participate in the study, which had the approval of the Faculty's Ethical Advisory Committee. All participants were fully informed verbally and in writing about the nature and demands of the study. They completed a health history questionnaire and were informed that they could withdraw from the study at any time, even after giving their written consent. All subjects were in good health, participating in consistent soccer training at least for the past 2 years. The first testing was conducted at the beginning of the pre-conditioning period (after two weeks of rest) and the second session at the beginning of the first round of the championship. Between the first and second test session, all subjects followed six weeks of soccer-specific periodized training programme [11], controlled by certified conditioning coach. All subjects were assessed on the same day, and the tests were performed in the same order. Seven days prior to the first and second test session, all subjects consumed similar programmed standardized diet to ensure that their glycogen stores were equally loaded. In the 24 h before the measurements, the subjects refrained from any prolonged exercise. The players were allocated to two assigned trials according



to age – young group (YG) and mature group (MG). Players in their teenage years (19 years and younger) were assigned to YG (10 subjects; 18.5 ± 0.5 years) and others to MG (12 subjects; 25.8 ± 3.2 years). In aim to minimize transitive effects, subjects with age of 20 and 21 were excluded from the study. Groups were matched (YG vs. MG) for subjects' weight (77.5 ± 7.3 vs. 78.6 ± 5.5 kg) maximal oxygen uptake (49.9 ± 3.2 vs. 48.0 ± 2.5 $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), vertical jump height (55.2 ± 3.9 vs. 53.9 ± 4.8 cm) and playing positions (all positional roles were equally represented in both groups) to balance the difference in skill. To ensure greater homogeneity of subjects, only the data for the outfield positions were used (goalkeepers' results were excluded) in this study. There were no statistical differences between the groups ($P > 0.05$) on the items they were matched on.

Experimental procedures: Subjects reported to the examination field at 10 a.m. after rest of between 10 and 12 h. On the test day, subjects consumed a controlled breakfast (providing an average of 700 ± 50 kcal) two hours before the test. After that period, all subjects drank only plain water ad libitum. Upon entering the laboratory, height was measured using a stadiometer (Seca 202, USA) to the nearest 0.1 cm while body mass was obtained to the nearest 0.1 kg using a calibrated balance beam scale (Avery Ltd, Model 3306 ABV). The subjects were measured nude, in the same state of hydration and nourishment after voiding. Total body resistance was measured with a foot-pad bioelectrical impedance analyzer (BF-662W, Tanita Corporation, Japan) at a fixed signal frequency of 50 kHz and $500 \mu\text{A}$. The subject's height, age in years, sex and level of activity were entered into the BIA device. Height was entered to the nearest 1 cm. Level of activity was entered according to manufacturer's definition of athlete (person involved in intense physical activity of approximately 10 hours per week and who has a resting heart rate of approximately 60 beats per min or less). The subjects stood erect with feet shoulder-width apart, arms parallel to the ground and elbows extended. Relative body fat estimated by the manufacturer's equation was digitally displayed and recorded. When these preliminary measurements were finished, subjects completed a warm up (15-min of sprints and individual exercise). Vertical jump height was measured using a contact mat (Just Jump System, US Probotics). All subjects had a preparatory bounce before measurement and the computer connected with platform calculated jump height from time the subject was off the mat. The calculation of jump height assumed that the takeoff and landing positions of the body's center of gravity were the same. Subjects were instructed to keep the trunk as straight as possible and try to land back on the mat on the same spot and with the same body position as when they took off (i.e., trunk and legs straight). Afterwards, each subject completed Running-Based Anaerobic Sprint Test (RAST) [23] with



calculated relative average anaerobic power (AAP) in watts per kilogram. Finally, the endurance multistage shuttle-run test was conducted with maximal oxygen uptake estimated from distance completed [13]. The athletes were familiar with mentioned procedures as part of their regular training process.

The data are expressed as means \pm SD. Statistical analysis was performed using Student's t test with Bonferroni correction for repeated comparisons. To evaluate between-group differences in physical fitness degree of change, analysis of covariance was used. P values of less than 0.05 were considered to be statistically significant. The data were analyzed using the statistical package SPSS, PC program, version 7.5 (SPSS Inc., USA).

Results

Table 1

Results of tests in young (18.5 ± 0.5 years) and mature group (25.8 ± 3.2 years) of professional soccer players

Group	Body mass (kg)	Fat (%)	VJ (cm)	AAP (W/kg)	Estimated VO _{2max} (ml/kg/min)
Young (n=10)					
Pre	77.5 \pm 7.3	8.1 \pm 2.6	55.2 \pm 3.9	9.8 \pm 0.7	49.9 \pm 3.2
Post	76.5 \pm 7.2*	7.2 \pm 1.6*	56.7 \pm 4.2*	10.7 \pm 0.8*	53.8 \pm 3.9*
Mature (n=12)					
Pre	78.6 \pm 5.5	10.0 \pm 2.3†	53.9 \pm 4.8	9.3 \pm 1.0	48.0 \pm 2.5
Post	78.5 \pm 4.5*	8.6 \pm 1.7*†	55.8 \pm 4.9*	10.4 \pm 0.9*	56.8 \pm 4.3*

Note Values are mean \pm SD; VO_{2max} = maximal oxygen uptake; AAP = average anaerobic power; VJ = vertical jump. *Indicates significant differences pre- versus post at P<0.05; †significant difference young versus mature at P<0.05

All results are shown in Table 1 and Table 2. There were no differences between groups at pre- and post-training trial for body mass, vertical jump, AAP and VO_{2max} (P>0.05). Body fat was significantly lower in YG before and after training program as compared to MG (P<0.05). Body mass and fat dropped



significantly in both groups after training program ($P < 0.05$). Furthermore, AAP and VO_{2max} along with vertical jump height, were significantly improved in both groups ($P < 0.05$) at post-training performance. No significant differences were found for degree of changes in body mass, body fat, vertical jump, and AAP after training between MG and YG ($P > 0.05$). Finally, the magnitude of change in VO_{2max} was significantly superior in MG as compared to YG after training program (18.3 vs. 7.8%; $P < 0.05$). No subjects dropped from the study.

Table 2

Degree of change (%) of physical and physiological characteristics of young and mature soccer players after 6 weeks of programmed training

	Type of change	Young	Mature
Weight	↓	1.3	0.1
Body fat	↓	11.1	14.0
Vertical jump	↑	2.7	3.5
AAP	↑	9.2	11.8
Aerobic power	↑	7.8	18.3*

Note Values are shown in percentage of change. ↓ = decrease; ↑ = increase.

*Indicates significant difference young versus mature at $P < 0.05$

Discussion

Although more and more young athletes successfully train and compete at top-level in soccer, there are concerns about the physiological limitations of adolescents trainability. Compared with training studies in adults, relatively little is known about the trainability of adolescents, probably due to major methodological constraints in designing studies [4]. Yet, it is generally accepted that adolescents respond to basic conditioning or specific training regimens with less improved exercise performance as compared to older athletes [3]. However, the findings of the present study indicate that the trainability indices are not highly influenced by age in top-level soccer players. We found similar physiological responses to soccer-specific training program in both teenagers and mature players.

Physique of soccer players is likely to change during the pre-season conditioning as a result of intensive training schedule and heavier metabolic loading imposed [18]. The greatest change in body composition of the adolescents occurs in lean body mass and fat mass [7,14]. In the present study we found



significant body mass and fat loss after 6-weeks of training program in both groups of subjects, with similar magnitude of change. Decrease of body fat and weight as a consequence of increased energy expenditure through training has been demonstrated in several studies with both young and mature athletes [16,20]. It appears that in active adolescent males fat deposition declines as a complex and interactive result of biological inheritance, growth and sex hormones, nutritional status and energy expenditure [14]. Moreover, we found that body fat was significantly lower in teenage subjects both pre- and post-training as compared to their older counterparts. Guo *et al.* [10] clearly demonstrated that late adolescent boys tended to show a lower body fat percentage as compared to adults. Reported difference could be related with decrease of leptin [5] or predominance of androgenic hormones in young athletes which could contribute to lipolysis and inhibited the fat-storing capacity of lipoprotein lipase [7].

Recent training studies showed relatively clear picture of how biological maturation influences adaptations to physical stress [1,8]. Yet, the trainability of young athletes in activities that rely largely on anaerobic metabolism is difficult to define. Several investigators claimed that indices of relative anaerobic performance during high intensity exercise are lower in adolescents than in adults [6,9]. Various physiological mechanisms have been postulated to explain lower anaerobic fitness and trainability in younger populations. Lower sympathoadrenal and enzymatic activity, maturational differences in muscle fiber distribution, immature testosterone responses, among other factors, could be responsible for suboptimal anaerobic performance and inadequate trainability in youngsters [14]. On the other side, Fournier *et al.* [8] postulated that anaerobic trainability of young athletes could be similar to adults since the activity of the rate-limiting glycolytic enzyme increased by 21% due to 3 months of sprint training in adolescent boys. According to the results of the present study, we didn't found any significant differences in anaerobic indices between young and mature players before and after training program. Moreover, it seems that anaerobic power and capacity are almost equally trainable in both adolescent and mature soccer players. The magnitude of improvement in anaerobic fitness through superior vertical jump and improved relative average anaerobic power in RAST after the training are similar in both groups. The equality of anaerobic potential and trainability between groups could be due to adaptive response to years of anaerobic training practices in young athletes. It seems that particular group of adolescent players in our study developed enhanced anaerobic responses as their older counterparts. The similar gains in anaerobic potential induced by training could be due to increased enzymatic



activity, increase of muscle cross-sectional area and total muscle mass and/or anabolic responses in adolescent players, which needs further investigation.

Training-induced changes in aerobic fitness have been extensively studied in young athletes but the subjects of the responses to aerobic training of late adolescents are particularly controversial. It seems that aerobic training (interval or continuous) leads to a mean improvement of 5-10% of VO_{2max} in active children and adolescents as compared to improvement magnitude of 20% or more in adult athletes [1]. In the present study we found significant increase of aerobic capacity in both young and adult soccer players as a consequence of training, with no difference between groups at pre- and post-training performance. However, the magnitude of change is superior in mature players (18.3 vs. 7.8%) as compared to their younger counterparts. Several authors confirmed diminished level of physiological aerobic trainability in young athletes [2,22]. With a period of endurance training, increases in VO_{2max} in young athletes are generally no more than one third of those expected in adults [12]. According to this, the superior gain in aerobic capacity in older subjects could be due to increased plasma volume, proportionally higher muscle mass, higher blood oxygen carrying capacity and larger maximal cardiac output, which requires further investigation. Since the training load was similar, older subjects greatly improved aerobic fitness probably due to fully developed endocrine, cardio-respiratory and musculoskeletal system. Moreover, longer professional training experience (soccer-specific training) could induce different adaptability of mature athletes to aerobic training stimulus [15,21]. Yet, the relative improvement of nearly 20% of VO_{2max} in mature group could be related with lower initial level of conditioning before training program. Significant reduction in aerobic fitness have been reported to occur within 2 to 4 weeks of training cessation, despite the prior prolonged periods of aerobic training [15]. It appears that two weeks of rest before the first test performance could result in substantial loss of aerobic power in mature subjects. In other words, young players were probably partially trained or more active during the rest period while mature subjects were detrained. More research with appropriate study design is needed to confirm this claim.

Conclusions

The trainability of elite adolescent athletes presents a unique challenge to the sport scientists. According to our results, it seems that adolescents could improve their aerobic and anaerobic performance through similar mechanisms as adult athletes. However, it's difficult to determine physiological changes induced by



training from those accompanied with maturation, particularly in group of late adolescents. Simply dividing players by age is a major limitation of the study, as chronological age does not provide a reliable indication of biological age and maturity level. Unfortunately, we were unable to select a comparable control group that does not train and with controlled habitual activity along with similar developmental stage with trainees, in aim to isolate the training effect. It is apparent from the limited data available that the understanding of trainability during adolescence requires future research so the conclusions based on the present study should be taken as tentative. In conclusion, since there was no strong effect of age for the trainability, the findings of the present study are more likely to be the result of the training background of the players than their age. According to the results of the present study it seems that late adolescent and mature professional soccer players are almost equally trainable.

References

1. Baquet G., E.Van Praagh, S.Berthoin (2003) Endurance training and aerobic fitness in young people. *Sports Med.* 33:1127-1143
2. Baxter-Jones A.D.G., H.Goldstein, P.J.Helms (1993) The development of aerobic power in young athletes. *J.Appl.Physiol.* 75:1160-1167
3. Baxter-Jones A.D.G., P.Helms, N.Maffulli, J.C.Baines-Preece, M.Preece (1995) Growth and development of male gymnasts, swimmers, soccer and tennis players: a longitudinal study. *Ann.Hum.Biol.* 22:381-394
4. Blinkie C.J.R., O.Bar-Or (1996) Trainability of muscle strength, power and endurance during childhood. In: O.Bar-Or (ed.) *The Child and Adolescent Athlete.* Blackwell Science, Oxford, pp. 113-129
5. Blum W., P.Englaro, S.Hanitsch, A.Juul, N.T.Hertel, J.Muller, N.E.Skakkebaek, M.L.Heiman, M.Birkett, A.M.Attanasio, W.Kiess, W.Rascher (1997) Plasma leptin levels in healthy children and adolescents: dependence on body mass index, body fat mass, gender, pubertal stage and testosterone. *J.Clin.Endocr.Metab.* 82:2904-2910
6. Chrostou M., I.Smilios, K.Sotiropoulos, K.Volaklis, T.Pilianidis, S.P.Tokmakidis (2006) Effects of resistance training on the physical capacities of adolescent soccer players. *J.Strength Cond.Res.* 20:783-791
7. Cowell C.T., J.Brady, S.Lloyd-Jones, C.Smith, B.Moore, R.Howman-Giles (1997) Fat distribution in children and adolescents: the influence of sex and hormones. *Horm.Res.* 48:93-100
8. Fournier M., J.Ricci, A.W.Taylor, R.J.Ferguson, R.R.Montpetit, B.R.Chaitman (1987) Skeletal muscle adaptation in adolescent boys: sprint and endurance training and detraining. *Med.Sci.Sports Exerc.* 14:453-456



9. Gissis I., C.Papadopoulos, V.I.Kalapotarakos, A.Sotiropoulos, G.Komsis, E.Manolopoulos (2006) Strength and speed characteristics of elite, subelite, and recreational young soccer players. *Res.Sports Med.* 14:205-214
10. Guo S.S., W.C.Chumlea, A.F.Rosche, R.M.Siervogel (1997) Age and maturity-related changes in body composition during adolescence into adulthood: The feels longitudinal study. *Int.J.Obesity* 21:1167-1175
11. Hoff J., J.Helgerud (2004) Endurance and strength training for soccer players: Physiological considerations. *Sports Med.* 34:165-180
12. Kobayashi K., K.Kitamura, M.Miura, H.Sodeyama, Y.Murase, M.Miyashita, H.Matsui (1978) Aerobic power as related to body growth and training in Japanese boys: a longitudinal study. *J.Appl.Physiol.* 44:666-672
13. Leger L.A., J.Lambert (1982) A maximal multistage 20-m shuttle run test to predict $\dot{V}O_2$ max. *Eur.J.Appl.Physiol.* 49:1-12
14. Naughton G., N.J.Farpour-Lambert, J.Carlson, M.Bradney, E.Van Praagh (2000) Physiological issues surrounding the performance of adolescent athletes. *Sports Med.* 30:309-325
15. Neuffer P.D. (1989) Effect of detraining and reduced training on the physiological adaptations to aerobic exercise training. *Sports Med.* 8:302-320
16. Ostojic S.M. (2003) Seasonal alterations in body composition and sprint performance of elite soccer players. *J.Exerc.Physiol.* 6:11-14
17. Ostojic S.M. (2004) Elite and nonelite soccer players: preseasonal physical and physiological characteristics. *Res.Sports Med.* 12:143-150
18. Reilly T., D.Doran (2003) Fitness assessment. In: T.Reilly and A.M.Williams (eds.) Science and Soccer. 2nd Ed. Routledge, London, pp. 21-46
19. Shephard R.J. (1999) Biology and medicine of soccer: An update. *J.Sports Sci.* 17:757-786
20. Silvestre R., W.J.Kreamer, C.Wet, D.A.Judelson, B.A.Spiering, J.L.Vingren, D.L.Hatfield, J.M.Anderson, C.M.Maresh (2006) Body composition and physical performance during a National Collegiate Athletic Association Division I men's soccer season. *J.Strength Cond.Res.* 20:962-970
21. Toraman N.T. (2005) Short term and long term detraining: is there any difference between young-old and old people? *Br.J.Sports Med.* 39:561-564
22. Turkley K.R. (1997) Cardiovascular responses to exercise in children. *Sports Med.* 24:241-257
23. Zacharogiannis E., G.Paradisis, S.Tziortzis (2004) An evaluation of tests of anaerobic power and capacity. *Med.Sci.Sports Exerc.* 36:S116

Accepted for publication 30.05.2008

