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Ventilation characteristics of young soccer players

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Original scientific paper

Abstract

The basic goal of this research was to determine differences in ventilation characteristics of soccer players in different age groups. The research was conducted on a sample of 66 soccer players competing in the Croatian First Soccer League. The subjects were divided into three age groups: U-15, U-17 and U-19. Along with height, weight, and body mass index, the following ventilation variables were measured: maximum minute ventilation, minute ventilation at anaerobic threshold, respiratory frequency, respiratory frequency at anaerobic threshold, forced vital capacity, forced expiration volume in the first second, the Tiffeneau index, peak expiration flow and forced expiration flows at 50%FVC and 25%FVC. Factorial ANOVA with Fischer LSD post-hoc test was used to determine the differences between groups of soccer players. The load required by a large respiratory minute volume stimulates growth and development of the thorax in young soccer players, thus making the thorax wider, longer and with more capacity. This is how the "athlete's lungs" are developed, having a larger volume of air, but also blood, and an enlarged surface of pulmonary alveoli. Soccer training strengthens and leads to the hypertrophy of the muscles of respiration, as well as to more economical breathing with lower frequency. Physical strain results in the increased capability of the respiratory airways to conduct air, i.e. the increase of the ventilation function of lungs. Obtained results suggest that the size and function of lungs increase with the increase in the size of the body.

Key words: **maximal ventilation, spiroergometric parameters, soccer**

Sažetak

Osnovni cilj ovog istraživanja bio je utvrditi razlike ventilacijskih osobitosti između nogometaša različitih dobnih skupina. Istraživanje je provedeno na uzorku od 66 nogometaša koji se natječu u Prvoj hrvatskoj nogometnoj ligi. Ispitanici su podijeljeni u tri dobne kategorije: pioniri, kadeti i juniori. Osim visine, težine, indeksa tjelesne mase, izmjerene su sljedeće ventilacijske varijable: maksimalna minutna ventilacija, minutna ventilacija na anaerobnom pragu, respiratorna frekvencija, respiratorna frekvencija na anaerobnom pragu, forsirani vitalni kapacitet, forsirani ekspiracijski volumen u prvoj sekundi, Tiffeneau index, vršni ekspiracijski protok kao i forsirani ekspiracijski protoci pri 50%FVC i 25%FVC. Za utvrđivanje razlika između skupina nogometaša korištena je Factorial ANOVA s Fischer LSD pos-hoc testom. Opterećenje koje zahtijeva veliki minutni volumen disanja potiču rast i razvoj prsnog koša kod mladih nogometaša, te na taj način grudni koš postaje širi, dulji i ima veću zapreminu. Tako se razvijaju „sportska pluća" s većim obujmom zraka, ali i krvi, te povećanom površinom plućnih alveoloa. Nogometni trening jača i dovodi do hipertrofije dišne muskulature, kao i do ekonomičnijeg disanja s manjim frekvencijom. Fizički napor ima za posljedicu povećanje provodljivosti dišnih puteva, odnosno povećanje ventilacijske funkcije pluća. Dobiveni rezultati sugeriraju kako se povećanjem veličine tijela povećava veličina i funkcija pluća.

Ključne riječi: **Bodovni pravilnik FIG, preskok, sportska gimnastika, biomehanika**

Introduction

Diagnostic procedures in sport consist of determining the health status of an athlete, the level of fitness, abilities and characteristics important for success in sport. With the help of functional abilities diagnostics, through integrative cardiopulmonary load testing in controlled conditions and gas exchange measurement, i.e. spiroergometric parameters, the capacities of the cardiovascular and respiratory systems can be precisely evaluated. Ventilation is the exchange of gases between the external area and alveolar areas in lungs and vice versa. It is tested by methods of spirometry and body pletismography. These methods measure pulmonary volumes and capacities and the amount of air flow (the resistance to air flow) in the respiratory airways. Breathing is a process that consists of ventilation, diffusion of oxygen and carbon dioxide through the alveolar membrane and the corresponding blood flow through the pulmonary capillaries. Breathing, i.e. the exchange of oxygen and carbon monoxide between a cell and the atmosphere changes with physical activity. The integral part of function diagnostics is also the testing of the pulmonary ventilation function. The testing of pulmonary ventilation in practice comprises the measurement of lung volume and capacity, as well as the amount of the air flow. Pulmonary volumes are basic capacities of the lungs, i.e. capacities of air that the lungs contain in different breathing positions. Two or more pulmonary volumes make up the capacity of lungs. Spirometry is a method that measures the capacity of air which the lungs breathe, and it is used in measuring static and dynamic pulmonary volumes and capacities. Obtained results are compared with reference (normal, theoretical) values according to sex, age, height and body weight. There is an entire series of other physiological parameters used in the training process and during diagnostic procedures, such as: maximum minute ventilation (VE_{max}), minute ventilation at the anaerobic threshold (VE_{VP}), respiratory frequency (RR_{max}), respiratory frequency at the anaerobic threshold (RR_{VP}), as well as many others. The amount of air we can ventilate in one minute is the respiratory minute volume (RMV). During physical activities both the depth and frequency of breathing increase, so the respiratory minute volume, i.e. minute ventilation increases proportionally to the intensity and duration of work. Ventilation at maximum loads reaches values of the so-called maximum respiratory minute volume. When measuring ventilation, we actually measure respiratory minute volume. Breathing frequency is the number of respiratory cycles in one minute. The respiratory frequency while resting amounts to between 12 and 20, while it increases to 50-60 cycles per minute at maximum load, and even more. The interpretation of functional abilities of soccer players is more difficult than in individual sports, where results are more easily and more correctly predicted based on functional abilities. In spite of this, determining functional abilities of soccer players results in numerous useful information, both for the team and the individual.

Method

Sample of the examines

The research was conducted on a sample of 66 soccer players competing in the Croatian First Soccer League. The subjects were divided into three age groups: U-15 (N=22), U-17 (N=22) and U-19 (N=22). The majority of subjects play for national U-15, U-17 and U-19 teams, so we can say that the sample is representative.

Sample of the variables

Except for height (cm), weight (kg), and body mass index, maximum minute ventilation (VE$_{max}$), minute ventilation at anaerobic threshold (VE$_{VP}$), respiratory frequency (RR$_{max}$), and respiratory frequency at the anaerobic threshold (RR$_{VP}$) were also measured. VE$_{max}$, VE$_{VP}$, RR$_{max}$, as well as RR$_{VP}$, were obtained through spiroergometric testing of progressive load on the spiroergometric system Quark PFT 4ergo (COSMED, Italy) which enables a continuous on-line, breath-by-breath monitoring of all ventilation and metabolic parameters. Procedures for measuring spiroergometric parameters and parameters at the ventilation anaerobic threshold were defined according to Wasserman et al., 1999, Green and Dawson, 1996; Brisswalter et al., 1996. Spirometric procedure on the spirometric system MicroQuark PC-based spirometer (COSMED, Italy) was used to measure static and dynamic volumes, as well as the flow-volume curve. The forced vital capacity (FVC) was measured from the group of static capacities, and the forced expiration volume in one second (FEV1) and the Tiffeneau index (TIFF) were measured among the dynamic capacities. The flow-volume curve measured the peak expiration flow (PEF), as well as the forced expiration flows at 50%FVC (FEF50) and 25%FVC (FEF25). Measurement procedures were conducted according to well-known standards (Knudson et al., 1976, and Miller et al., 2005).

Data processing methods

Factorial ANOVA with the Fischer LSD post-hoc test was used to determine differences between groups of soccer players.

Results and Discussion

Table 1 shows that there is a rising trend of morphological variables towards the older age group of soccer players. The U-17 soccer players are slightly taller than the U-15 group, but these differences are not statistically relevant. The U-19 soccer players are significantly taller than both the U-15 and the U-17 players. Considering the weight and body mass index it is evident that there are statistically significant differences between all the studied groups of soccer players. The U-15 soccer players from this research are anthropometrically most similar to Belgian soccer players from the same age group (175 cm, 65 kg, Segers et al. 2002). The heights of Brazilian U-17 soccer players (Dourado et al. 2007, Da Silva et al., 2008) range from 173 to 177 cm, and the weights between 60 and 71 kg. Furthermore, the U-17 soccer players from Japan are within the stated ranges (173 cm, 65 kg, Tahara et al., 2006), while the U-17 players from Switzerland (177 cm, 69 kg, Rico-Sanz, 1998) are anthropometrically the most similar group to the studied sample of the U-17 soccer players. A partial overview of past research of anthropometric characteristics in Brazilian U-19 soccer players recorded results for height in ranges of 174-181 cm, and for weights between 66-77.5 kg (Da Silva et al. 2008). Similar values for heights and weights in the stated ranges were recorded in players of the same category from Tunisia (Chamari et al., 2004), Greece (Metaxas et al., 2005), Switzerland (Rampinini et al. 2007), Singapore (Aziz et al. 2005), Great Britain (McMillan et al. 2005) and Norway (Helgerud et al., 2001). According to their morphological characteristics (Table 1), the studied sample of the U-19 soccer players is very similar to Italian football players (181 cm, 73 kg, Di Salvo and Pigozzi, 1998), and the Spaniards (180 cm, 75 kg, Mujika et al., 2000). The body mass index values for the U-15, U-17 and U-19 categories of soccer players are very similar to Brazilian soccer players (Dourado et al. 2007). The average height value of a U-15 player (176.40 cm) is considerably higher than the reference values, and is found above the 75th percentile in comparison with the results from previous studies. The average height of a U-17 (178.04 cm) and U-19 (181.88 cm) player goes along the line of the 75th percentile. The value of the average U-15 player's weight (63.52 kg) is considerably higher as compared with the reference values, and is located above the 75th percentile in comparison with the results from previous studies. The average weight of the U-17 (69.00 kg) and U-19 (75.05 kg) player is on the line of the 75th percentile. When observing soccer players from this research, it can be concluded that the U-15 players "deviate" from the stated scope. The probable reasons for that should be looked for in the fact that a lot of the studied U-15 soccer players are ones who experienced accelerated growth, i.e. they matured earlier. The changes in size and composition of the body occur and increase with puberty and maturation (Malina et al. 2004). The differences between boys of different maturity (equal chronological, but different biological age) are most obvious between the age of 13 and 16 (Malina et al. 2004). The growth and maturation of young soccer players may affect the selection processes, which is probably the case with the U-15 soccer players from this research. The soccer players were selected based on their size and maturity. At the time of selection they were probably the best players because of their size, strength and power, which is connected to the early maturation in U-15 soccer players.

Table 1. Comparative analysis of the morphological variables applied to the soccer players of various age groups

	U-15 (N = 22)	U-17 (N = 22)	U-19 (N = 22)
Variables	**AM (SD)**	**AM (SD)**	**AM (SD)**
H (cm)	176,40 (5,60)	**178,04 (4,98)†**	**181,88 (4,72)^2**
W (kg)	**63,52 (7,41)***	**69,00 (6,53)††**	**75,05 (6,07)^3**
BMI (kg/m^2)	**20,35 (1,63)****	**21,72 (1,24)†**	**22,67 (1,49)^3**

Key: analysis of variance - Factorial ANOVA with Fisher LSD post-hoc test; (AM – arithmetic mean; SD - standard deviation);
*p<0.05; **p<0.01; ***p<0.001 – significance of differences between the U-15 and U-17 group of soccer players
†p<0.05; ††p<0.01; †††p<0.001 – significance of differences between the U-17 and U-19 group of soccer players
^{1}p<0.05; ^{2}p<0.01; ^{3}p<0.001 – significance of differences between the U-15 and U-19 group of soccer players

This research recorded an increase in the minute ventilation (Table 2) towards the older age group. U-15 and U-17 players achieve similar values, while the ventilation values achieved by U-19 soccer players are however slightly higher. Differences between different age groups of soccer players exist, but they are not statistically relevant. A similar rising trend is found in the values of ventilation at the anaerobic threshold. The U-19 players have statistically higher values than both the U-15 and U-17 players. The U-15 soccer players achieve higher values of minute ventilation than U-15 soccer players from Belgium (Segers et al. 2002). The U-17 players have similar minute ventilation values as the soccer players from previous studies (Tahara et al. 2006), while the U-19 players achieve higher values of minute ventilation with regard to the soccer players from Greece (Metaxas et al. 2005) and Singapore (Aziz et al. 2005). Maximum ventilation can be increased by training, e.g. the average ventilation of a group of Danish players increased from approximately 142 to 148 L/min after four weeks of intensive training (Bangsbo, 1994). Pulmonary ventilation on the increase during the load is in direct proportion with metabolic needs of the body. Maximum minute ventilation depends on the size of the body. Ventilation values of around 100 L/min are common for “smaller” individuals, whereas the values of 200 L/min can be found in “larger” individuals. Pulmonary function changes significantly with age. Minute ventilation increases with age up to physical maturity, after which it decreases with the age increase. These changes are connected with the growth of the entire pulmonary system. As the body size increases with growth and development, the size and function of lungs increase accordingly, which explains the obtained differences in minute ventilation of the studied soccer players. During the exercise, i.e. load, the ventilation increases due to the increased demand of muscles for oxygen, reaching up to 100 L/min for untrained individuals, and over 200 L/min for extremely fit athletes.

The recorded values of the maximum respiratory frequency / breathing frequency are similar in the U-15 and U-17 players, while the U-19 players have statistically significantly lower values in comparison with the U-17 group. The values of respiratory frequency in the U-19 soccer players (53.7) are somewhat lower than those of the Greek soccer players of the same age group (55.3-59.8; Metaxas et al. 2005). The values of the respiratory frequency at the anaerobic threshold are similar in all three groups of soccer players and there are no statistically significant differences among them. The breathing frequency continuously decreases during growth and development, which is evenly continued during puberty as well. The decrease of the breathing frequency with age is the sign of a more economical breathing in the older age group of soccer players.

The overview of spirometric variables (Table 2) shows an evident rise in relative values of all applied variables towards the older age group. It is noticeable that the U-15 and U-17 players statistically significantly differ in the FEV1, PEF and MEF50 variables. In the FVC, TIFF and MEF25 variables there are no statistically significant differences between the U-15 and U-17 soccer players. It is interesting to note that there are no statistically significant differences in the studied spirometric variables between the U-17 and U-19 soccer players. The U-15 and U-19 players statistically significantly differ in 4 out of 6 spirometric variables. The differences are not statistically significant in the TIFF and MEF25 variables. Furthermore, it can be said that soccer players achieve above-average values in almost all parameters with regard to the predictive values. The obtained results are very similar to the results of athletes of the same age (soccer players and handball players) from the research by Goić-Barišić et al. 2006. The U-17 soccer players have above-average results of spirometric parameters in relation to the standardized values of the U-17 male population. The FEV1 (forced expiration volume in one second – 113.61%) values are higher than those of elite Scottish swimmers (83.9%; McKey et al. 1983). Furthermore, it is noticeable that the U-19 soccer players also have above-average results in comparison with standards for the U-19 age group. The achieved FEV1 values amount to 116%. Elite Scottish U-19 swimmers have FEV1 value of 93.4% (McKey et al. 1983). The studied soccer players have higher values of all spirometric parameters in relation to competitive sailors (Uljević et al. 2008), while the results are very similar to the achieved values of the U-19 soccer players from the same

Table 2. *Comparative analysis of the ventilation variables applied to the soccer players of various age groups*

	U-15 (N = 22)	**U-17 (N = 22)**	**U-19 (N = 22)**
Variables	**AM (SD)**	**AM (SD)**	**AM (SD)**
RR_{max} (1/min)	57,06 (6,76)	**59,18 (6,45)†**	53,68 (8,08)
VE_{max} (L/min)	142,28 (21,99)	141,83 (16,72)	149,29 (21,70)
RR_{VP} (1/min)	43,74 (7,55)	42,43 (7,74)	45,25 (8,44)
VE_{VP} (L/min)	88,07 (19,31)	**83,95 (12,01)†††**	**102,66 (16,53)^{2}**
FVC (%)	99,73 (7,74)	103,67 (7,47)	**104,74 (6,96)^{1}**
FEV1 (%)	**106,56 (4,84)****	113,61 (7,87)	**116,00 (9,09)^{3}**
TIFF (%)	108,67 (10,98)	112,28 (8,30)	111,55 (6,39)
PEF (%)	**101,98 (23,46)****	122,65 (12,59)	**132,79 (20,35)^{3}**
FEF50 (%)	**108,46 (18,95)***	123,35 (21,58)	**132,45 (26,11)^{2}**
FEF25 (%)	120,64 (31,61)	119,96 (26,58)	140,23 (42,77)

Key: analysis of variance - Factorial ANOVA with Fisher LSD post-hoc test; (AM – arithmetic mean; SD - standard deviation);
*$p<0.05$; **$p<0.01$; ***$p<0.001$ – significance of differences between the U-15 and U-17 group of soccer players
†$p<0.05$; ††$p<0.01$; †††$p<0.001$ – significance of differences between the U-17 and U-19 group of soccer players
$^{1}p<0.05$; $^{2}p<0.01$; $^{3}p<0.001$ – significance of differences between the U-15 and U-19 group of soccer players

research. When comparing the individual spirometric parameters of U-19 soccer players with Gaelic football players of similar anthropometric characteristics, it can be stated that the studied soccer players have higher values of the FEV1 (116%) and PEF (133%) variables than Gaelic football players (FEV1-112%, PEF-114%; Watson 1995). Gaelic football players have higher values of the FVC variable (115%; Watson 1995) than the studied U-19 soccer players (105%). Competitive cyclists and triathletes (Kippelen et al. 2005) achieve somewhat higher FVC values (117%) than the U-19 soccer players from this research (105%). However, the values of the FEV1 (116%) and the Tiffeneau index (112%) are higher in the studied soccer players than in competitive cyclists and triathletes (FEV1-112%, TIFF-81%; Kippelen et al. 2005). Table 2 shows that the studied U-15, U-17 and U-19 soccer players have considerably higher values of the FEV1 variable (107%, 114%, 116%) than elite adult (19+) soccer players from Hong Kong (Chin et al. 1992). The lung volume in young soccer players depends on body size and it changes approximately as the height changes up to around 25 years of age. In late childhood and adolescence, the abovementioned changes happen mostly through the widening of the existing alveoli and respiratory airways. However, the effect of training on the respiratory system is extremely significant. Exercises which require a large respiratory minute volume stimulate the growth and development of the thorax in young soccer players, thus making the thorax wider, longer and with a larger capacity. The so-called “athlete’s lungs” develop in the larger thorax, with a larger volume of air, but also blood, and an enlarged surface area of pulmonary alveoli. In addition, the training strengthens and leads to the hypertrophy of the muscles of respiration, as well as to more economical breathing with a lower frequency. In healthy people physical strain results in the increased capability of the respiratory airways to conduct air, i.e. the increase in the ventilation function of lungs. This effect of the physical strain is based on the increased number of functionally active small respiratory airways and dilation of bronchi and bronchioles, and is probably the result of a decreased tone of the parasympathetic nervous system. The size and function of lungs increases with the increase in body size, which explains the differences found in studied soccer players.

Conclusion

The results of this research confirm the thesis that changes in body size and structure, as well as functional capacities occur and increase with puberty and maturation. The growth and development of children last continuously until the adult age. Entering puberty is marked with a significant acceleration of body dimensions growth. Children continue to grow after puberty, but at a considerably slower pace. The beginning of the adolescent accelerated growth and the year of highest height increase are indicators of the child’s maturity. The increase in body dimensions is followed by the growth and development of cardiovascular and respiratory systems. If soccer training is performed throughout a longer time period, functioning of the system for transport and usage of oxygen improves. Naturally, the abovementioned changes are connected with the growth of the entire pulmonary system as well. As the body size increases with growth and development, so does the size and function of lungs, and this explains the differences found in the studied soccer players. Soccer training has a major effect on the development of functional abilities, and the results get progressively better towards older age so it can be expected that the U-15 and U-17 players will reach similar values in the U-19 age group.

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