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CAN PHYSICAL TRAINING MINIMIZE THE GENDER DIFFERENCES IN LUNG CAPACITY OF TRAINED TENNIS PLAYERS AGED 14–17 YEARS OLD?

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A – study design, **B** – data collection, **C** – statistical analysis, **D** – interpretation of data, **E** – manuscript preparation, **F** – literature review, **G** – sourcing of funding

ABSTRACT

Background: This study was based on gender differences in male and female trained tennis players.

Aim of the study: The aim of this study was to determine the extent that physical training could minimize the gender differences in lung capacities in trained tennis players aged 14–17 years.

Material and methods: The participants were ten male and seven female lawn tennis players, with a mean ± standard deviation (SD) age of 15.5±1.27 and 14.43±1.13 years, respectively. Physical characteristics and lung volumes were measured on the same day for each participant. Data were presented as mean ± SD, and Student's t-test to compare the measured variables was performed.

Results: Differences between genders were insignificant in terms of age (years), weight (kg), body fat (%), lean body mass (kg) and chest circumference (cm). However, height (cm), and W/H ratio were significantly ($p < 0.05$) higher in male tennis players in comparison to female players. Insignificant differences were found for TV (L), SVC (L), FVC (L), FEV1 (L), FEV1/FVC (%), FEF25-75% (L/s), PEF (L/s) and MVV (L/min). The only significant difference ($p < 0.05$) in lung function measures between male and female trained tennis players was for PIF (L/s).

Conclusions: Male tennis players were taller than female tennis players of same age range, which might be advantageous for males while playing. Insignificant differences between male and female players in the various lung variables measured indicated that the influence of height and gender differences could be minimized by proper training during puberty. A significantly higher PIF in male players indicated stronger and more powerful inspiratory muscle activity compared with female tennis players.

KEYWORDS: tennis player, lung variables, gender differences

Background

The lung volume of an adult male is about 10–12% higher than in an adult female with same age and height [1]. The smaller female lung volume appears to be established within the first few years of life. It is attributable to a lower rate of alveolar multiplication in girls than boys [2], although the reason for this is unknown. It is also reported that there is substantial variation in lung volume among individuals of a particular gender with the same age and stature [3]. These findings suggest that lung growth does not completely follow the longitudinal growth pattern. Even if the stature of males and females is the same, the lower limb length differs between genders. This difference in lower limb length correlates with male and female lung size [4]. It is also reported that the smaller female lung volume could be entirely accounted for by the smaller radial rib cage axial dimension, which is determined by the position of the diaphragm in the thoracic cage [5]. All these findings suggest that thoraco-abdominal configuration is another major factor underlying the difference in lung volumes between males and females. It is also reported that differences in thoraco-abdominal configuration impact on respiratory muscles [6]. Systemic differences in thoracic dimension and configuration between genders, including a disproportionately smaller radial rib cage dimension and shorter diaphragm are documented in females [7]. All these differences between sedentary males and females are due to their innate genetics and hormones, which also contribute to differences between athletic men and women. These include height, weight, muscle mass, body fat and aerobic capacity. The physiological differences between men and women are so great that elite male and female athletes compete with each other rarely.

Lung capacity refers to the volume of air associated with different phases of the respiratory cycle. The average total lung capacity of an adult human male is about 6 litres (L) of air. Lung capacity can be influenced by different types of physical training. Spirometry is the most commonly used pulmonary function test in the objective assessment of respiratory function. Pulmonary function is generally determined by respiratory muscle strength, compliance of the thoracic cavity, airway resistance and the elastic recoil of the lungs [8]. It is well-documented that pulmonary capacity varies with physical characteristics such as age, height, body weight and altitude [9]. Lung function tests provide qualitative and quantitative evaluation of pulmonary function and are of the highest importance in estimating respiratory fitness.

Studies on gender differences in thoracic dimension and configuration indicate that the volume of an adult female lung is typically 10–12% smaller than that of males of the same height and age [10]. Hopkins studied gender and pulmonary gas exchange during exercise and revealed that there were considerable gender-based differences in the response of the pulmonary system to exercise [11]. Specific to pulmonary gas exchange, structural and morphological differences between genders may render females more susceptible to impaired pulmonary gas exchange than males [11]. Studies have proposed respiratory muscle training as an effective means to increase inspiratory muscle strength and improve exercise performance [12]. Women have smaller airways and lung volumes, and lower resting maximal expiratory flow rates relative to men. Female athletes develop expiratory flow limitation more frequently than male athletes, and they have greater increases in end-expiratory and end-inspiratory lung volume at maximal exercise [13].

Only a few studies have investigated lung capacity in trained male and female players during adolescence (14–17 years). This age range is critical for both physiological and physical development. Physical training influences different hormonal systems and triggers the body to develop physically and physiologically. The most important requirement of athletic development is aerobic capacity. Without improvement in cardiorespiratory function, players cannot achieve a proper performance. It is also evident that male players have 8 to 10% higher performance level than female players due to differences in genetics and hormones. If these innate between gender differences can be minimized by appropriate training, the performance level of female athletes will improve to be same or close to male athletes. Most studies have revealed that males have greater physical ability than females due to their physique, and physiological advantages. However, strategies to minimize these gender differences in athletes have not been investigated. If a gender gap can be minimized by proper and timely training then female athletes may be considered on par with male athletes. In general, differences in physique and physiology are not very prominent in males and females during childhood, and likely develop from puberty. Indeed, the 14–17 year age range is when differentiation of male and female physique is initiated. Therefore, this might be the best time to influence hormonal systems using physical training to promote development of different physiological systems as well as physique.

Aim of the study

This study was designed to determine the gender differences in lung capacity of 14–17 year old male and female trained tennis players. The purpose was to identify the extent that physical training can minimize these gender differences.

Material and methods

Study design

This study used male and female trained lawn tennis players aged 14–17 years old. In this age range, males and females have their own active hormonal systems that influence the physiology of the body. The athletic differences in male and female players including height, weight, fat content, muscle mass and aerobic capacity, gradually develop due to their own hormonal influences. The main hypothesis of this study was based on the lung capacity of male and female trained tennis players within the age range of 14–17 years when the influence of their principle hormonal systems develop actively. Moreover, lung capacity depends on respiratory muscle activity and thoraco-abdominal configuration. Thus, it can be assumed that proper training in this age range might minimize the gender gap.

This study evaluated the lung capacity of 10 male and 7 female trained tennis players aged 14–17 years. The two genders were compared in terms of selected physical and lung variables comprising height (cm), weight (kg), fat (%), lean body mass (kg), chest circumference (cm), W/H ratio, TV (L), SVC (L), FVC (L), FEV1 (L), FEV1/FVC (%), FEF25-75% (L/s), PEF (L/s), PIF (L/s) and MVV (L/min).

Setting

Tennis players were from the registered tennis club of West Bengal (India) in March 2017. The criteria for player selection were participation in at least one district level competition and age between 14 and 17 years. The players had trained for around 2–4 hours per day for 5 days per week over at least 2 years. The Individual National Standard of Living Index and Sports Competition Anxiety Tests were performed. All anthropometric measurements and lung function tests were conducted in departmental laboratories of Serampore College. All measurements for each participant were undertaken between 10 am and 4 pm on the same day.

Participants

In this study, the mean ± standard deviation (SD) age of the males and females were 15.5±1.27 and 14.43±1.13 years, respectively. The Institutional Human Ethics Committee approved the study prior to initiation. None of the participants complained of any health problems except for coughs and colds during winter. The tennis club provided written permission to involve their tennis players, with the consent of their guardians. Ambient temperature and humidity were measured by dry bulb, wet bulb and globe thermometer.

Lung function parameters

Pulmonary function tests by spirometer:

Pulmonary Function Tests were performed using automatic spirometer (Spirovit, SP 1 Model) according to American Thoracic Society guidelines. The procedures were simple, non-invasive and harmless to the participants, who were encouraged to perform them at their optimum level. The spirometer was calibrated the day prior to use and a new filter was introduced. The following variables were measured for each player after proper demonstration trials:

I. I.TV (L):
Tidal volume (TV) is the amount of air inhaled or exhaled normally at rest.

II. SVC (L):
Slow vital capacity (SVC) is the maximum volume of air that can be exhaled slowly after slow maximum inhalation.

III. FVC (L):
Forced vital capacity (FVC) is the volume of air that can forcibly be blown out after full inspiration.

IV. FEV1 (L):
Forced expiratory volume in one second (FEV1) is the volume of air that can forcibly be blown out in one second, after full inspiration.

V. FEV1/FVC (L):
FEV1/FVC (FEV1%) is the ratio of FEV_1 to FVC.

VI. FEF25-75% (L/sec):
Flow speed of the expired air by 25–75% of the vital capacity.

VII. PEF (L/sec):
Peak expiratory flow (PEF) is the maximal flow (or speed) achieved during the maximally forced expiration initiated at full inspiration.

VIII. PIF (L/sec):
Peak inspiratory flow rate (PIFR) is the fastest flow rate during the inspiratory cycle.

IX. MVV (L/min):
Maximum voluntary ventilation (MVV) is the maximum amount of air that can be inhaled and exhaled, as deeply as possible, within one minute.

Statistical analyses

The mean, standard deviation and level of significance of all measured variables were determined. The distribution of raw data was normal. The main objective of this study was to determine if the male and female differences were significant, which was assessed using Student's t-test.

Results

The mean, standard deviation and level of significance of selected anthropometric variables such as age (years), height (cm), weight (kg), fat (%), lean body mass (kg), chest circumference (cm) and W/H ratio of the participants are shown in tab. 1. There were no significant differences between males and females in age, weight, fat, lean body mass or chest circumference. However, height and W/H ratio were significantly ($p < 0.05$) higher in males (tab. 1).

The mean values, standard deviation and level of significance the lung function tests, TV (L), SVC (L), FVC (L), FEV1 (L), FEV1/FVC (%), FEF25-75% (L/s), PEF(L/s), PIF(L/s) and MVV (L/min) of male and female trained tennis players are shown in tab. 2. There were

Table 1. Selected anthropometric variables

Variables	Mean ± standard deviation		p value	Level of significance
	Male tennis players [n=10]	Female tennis players [n=7]		
1. Age (years)	15.5±1.27	14.43±1.13	0.09	not significant
2. Height (cm)	165.19±7.54	159.04±2.09	0.03	p<0.05
3. Weight (kg)	55.4±10.91	56.57±10.08	0.82	not significant
4. Fat (%)	11.85±6.99	15.79±6.03	0.23	not significant
5. Lean body mass (kg)	48.32±7.46	47.16±5.56	0.72	not significant
6. Chest circumference (cm)	83.43±10.69	80.81±8.50	0.58	not significant
7. W/H ratio	0.8±0.06	0.74±0.04	0.02	p<0.05

no significant differences in TV, SVC, FVC, FEV1, FEV1/FVC, FEF25-75%, PEF and MVV. However, PIF was significantly different ($p<0.05$) between male and female trained tennis players (tab. 2).

Discussion

A young body is flexible and susceptible to various stimuli. These stimuli may sometimes exceed the limit of the body's biological tolerance. Thus, it may be too much for the child's level of somatic development and motor ability, resulting in effects on growth and maturation. Somatic features are an important factor for conditioning and achievement in sports [15]. It is also an important aspect taken into consideration during the selection process for specific sports events.

In this cross-sectional study, insignificant differences were observed in weight, fat percentage, lean body mass and chest circumference between male and female lawn tennis players of similar age (tab. 1). The amount of body fat and a central pattern of fat distribution might relate to lung function via several mechanisms. These include mechanical effects on the diaphragm (impeding descent into the abdominal cavity) and on the chest wall (changes in compliance, and in the work of breathing and elastic recoil) [16]. Reduction in physical activity affects body composition parameters such as fat percentage and muscle mass. In this study, no significant difference in fat percentage was observed between male and female tennis players. This contrasts other studies that showed a higher percentage of body fat in females than males [17], although the age ranges of the study participants were different. These conflicting results might be for reasons such as age, ethnicity, body build, and the training pattern and load of the players.

Lean body mass has a definite relationship with the lung function [18] of an individual. Earlier observations indicated that reduced FEV1 may be due to reduced skeletal muscle and, consequently, respiratory muscle [19]. This study did not identify any difference in lean body mass in adolescent male and female tennis players, although the male had significantly higher stature than the female (tab. 1). This finding might be due to a lower of percentage of body fat in the trained female players. Apparently, chest circumference is a determinant of lung function in healthy individuals. We did not identify a significant difference in chest circumference between male and female adolescent tennis players. This might be due the lack of age variation between genders, or to a more appropriate training load for the females. Further studies are needed to explain this. The ratio of waist and hip circumference has been used for calculating the WHR index, which indicates an individual's central obesity. In this study, males had a significantly higher central fat distribution than the females. As there are no reference values for trained individuals of the age range focused upon in this work, the reasons for this observation cannot be ascertained.

The lung function measures i.e. TV, SVC, FVC, FEV1, FEV1/FVC, FEF25-75%, PEF, PIF and MVV were assessed male and female trained tennis players, aged 14–17 years old (tab. 2) to ascertain whether any significant differences were present. In this study, mean values of FVC and FEV1 in male trained tennis players were 3.03 and 2.41 L, respectively. In females, the values were 2.95 and 2.10 L, respectively. FEV1/FVC was 80.29% and 76.66% in male and female tennis players, respectively. MVV in males and females was 83.33 and 79.81 L/min, respectively. All of these between gender differences were insignificant and indicated that the lung capacities were almost identical in the 14–17 year age range. This might be due to insignificant differences in body composition between the two groups, and an effective training load for the female tennis players. However, males were of a significantly taller stature than the females. So, it can be claimed from this study that differences in lung capacity in adolescent tennis players not only depends upon stature but may also depend on other factors that influence lung function. Insignificant differences in body fat percentage and lean body mass between gender groups, and effective training schedule for the females likely had an important role in minimizing the gender differences in lung capacity.

Table 2. Selected pulmonary function tests

Variables	Mean ± standard deviation		p value	Level of significance
	Male tennis players [n=10]	Female tennis players [n=7]		
1. TV (l)	0.87±0.32	0.74±0.14	0.29	not significant
2. SVC (l)	2.95±0.64	2.76±0.22	0.39	not significant
3. FVC (l)	3.03±0.92	2.95±0.40	0.81	not significant
4. FEV1 (l)	2.41±0.72	2.10±0.2	0.33	not significant
5. FEV1/SVC (%)	80.29±14.69	76.66±19.14	0.68	not significant
6. FEF25-75% (l/s)	2.37±0.85	2.04±0.67	0.39	not significant
7. PEF (l/s)	3.72±1.23	2.80±1.12	0.13	not significant
8. PIF (l/s)	3.58±1.19	1.94±0.28	0.001	$p<0.05$
9. MVV (l/min)	83.33±27.77	79.81±9.39	0.72	not significant

This study identified that PIF was significantly higher in male than female trained tennis players (tab. 2). PIF is a reliable measure of airway resistance and inspiratory muscle strength in humans. It has already been reported that aerobic and interval training improves inspiratory muscle strength [20]. It has also been shown that increased inspiratory muscle strength does not contribute to maximal oxygen consumption in human [21]. In this study, the significantly higher PIF in male tennis players was an additional advantage over females, in terms of higher inspiratory muscle strength.

Significant differences have been found in height, W/H ratio and PIF between male and female lawn tennis players, with all values significantly higher ($P < 0.05$) in the males. The greater height found in males of a similar age is advantageous for this gender. It might result from their own growth pattern under the influence of different hormones, which were not considered in this study. The males also had more centrally located fat, which might be due to less effective physical training in male adolescents. Greater central fat distribution may hinder lung capacity by influencing the abdominal cavity. Higher peak inspiratory flow in the male trained tennis player indicated that inspiratory muscles are more powerful in males of this particular age range.

Conclusions

The insignificant differences in body composition between the two gender groups and the effective training load for female tennis players though stature of male players are significantly higher than female tennis players. Therefore, it can be concluded from this study that gender differences in lung capacity can be minimized with a proper training load in females, at least in the 14–17 year age range. This study also suggests that stature is not the only decisive factor for lung capacity in adolescent male and female trained tennis players. Body composition, central fat distribution, active inspiratory muscles and proper physical training have definite role in improving lung capacity of young male and female trained tennis players.

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