

VITAL CAPACITY OF THE LUNGS OF TRAMPOLINE GYMNASTS AGED 10-13

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Abstract

Vital capacity (VC) tests are an important tool in assessing the functioning of the respiratory system. Low levels of vital capacity can indicate health problems such as asthma, chronic obstructive pulmonary disease, and other respiratory conditions. The volume of VC depends on many factors, especially the strength of the respiratory muscles, body and chest structure, lung and chest compliance, airway patency, gender, environmental factors, and physical activity. The aim of this study is to determine the level of vital capacity (VC) in girls and boys aged 10-13 who practice trampoline jumping, and to compare the results with reference values for a given gender and age category. The research was conducted among 100 trampoline jumpers (including 57 girls and 43 boys) aged 10-13. As part of the research, spirometric measurement was performed using the portable EasyOne model 2001 spirometer. The obtained results were then compared to reference values calculated on the basis of a study by the European Respiratory Society. The average level of vital capacity in the girls aged 10 was 2.2 liters, in 11-year-olds - 2.45 l, in 12-year-olds 2.54 l, and in 13-year-olds it was 3.02 l. The average level of vital capacity of the examined boys aged 10 was 2.36 l, in 11-year-olds 2.56 l, in 12-year-olds 2.89 l, and in 13-year-olds 3.33 l. These research results indicate that trampoline jumpers show a VC value within the reference values (between the LLN and ULN values). The girls stand out with higher percentage of predicted values for VC at the age of 11 (95.26%) and 13 (100.34%), in comparison with boys at the age of 10 (96.38%) and 12 (96.23%).

Keywords: trampoline gymnastics, spirometry, vital capacity.

INTRODUCTION

Spirometry is a method of functional examination of the respiratory system. The test enables measurement and recording of volumes and static capacities such as: tidal volume (TV), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), inspiratory volume (IC) and vital capacity (VC), i.e., the largest change in lung capacity as measured between maximum inhalation

and maximum exhalation ($VC = TV + IRV + ERV$) (Neder et al., 1999; Miller et al., 2005). Vital capacity constitutes the sum of the respiratory volume, including inspiratory and expiratory reserve volume. It ranges from 2.5 to 6.7 liters in men and from 1.2 to 4.6 liters in women (Gutkowski & Konturek 2018). The volume of VC depends on many factors, especially the strength of

the respiratory muscles, body and chest structure, lung and chest compliance, airway patency, gender, environmental factors, and physical activity. (Neder et al., 1999; Gutkowski & Konturek 2018).

Vital capacity tests are an important tool in assessing the functioning of the respiratory system. Low levels of vital lung capacity may indicate health problems such as asthma, chronic obstructive pulmonary disease, and other respiratory conditions (Pellegrino et al., 2005; Quanjer et al., 2012; Gutkowski & Konturek, 2018). Research suggests that vital capacity is also an important tool in assessing the health and physical performance of children and adolescents. Monitoring vital capacity can assist in early detection of respiratory health issues (Beydon et al., 2007; Graham et al., 2019).

In the context of sports, vital capacity is an important indicator of physical performance. In endurance disciplines, the development of aerobic capacity is particularly important, and depends primarily on the efficiency of the circulatory and respiratory systems. The constant development of aerobic capacity is measured using VO₂ max and results from the simultaneous improvement of the functioning of these systems in the development period (Wojciechowska-Maszkowska et al., 2005). In addition to determining the oxygen max (VO₂ max) to assess the efficiency of the respiratory system, a parameter such as vital capacity of the lungs (VC) can be used. While VC is a static value, it can provide an assessment of the functional capabilities of the respiratory system to some extent (Wojciechowska-Maszkowska et al., 2005).

In trampoline jumping, top competitors perform very complex stunts, including double and triple somersaults with additional

turns in the transverse plane ("twists") - all performed in mid-air, at heights approximately 5-6 meters after bouncing from an elastic surface measuring 426x213 cm (Kosendiak et al., 2013). Success in this sport hinges on high physical fitness, optimal body structure, and specific physiological features (Mohammed & Joshi, 2015; Seredyński & Polak, 2015). Assessing the functions of athletes' respiratory and circulatory systems enables the identification of physiological readiness to execute complex maneuvers, thereby maximizing the utilization of athletes' technical skills. (Mohammed & Joshi, 2015). Monitoring parameters such as pulse, blood pressure, respiratory rate, and vital capacity during trampoline jumping training aids in optimizing the training process and selecting appropriate training loads, ultimately contributing to the athletes' skill development. (Mohammed & Joshi 2015).

In order to accurately evaluate the results of vital capacity testing in young athletes, it is important to consider reference values and standards for a given age group and gender. Such standards define the expected value of vital capacity at a given age and gender, which allows for comparison of the test results with the appropriate expected value (Quanjer, et al., 2012). In this way, potential problems with the functioning of the respiratory system can be detected and the progress of sports training can be monitored on an ongoing basis.

The aim of this study is to determine the level of vital capacity in girls and boys aged 10-13 who practice trampoline jumping and to compare the results with reference values for a given gender and age category. The findings from this research can serve professionals specializing in youth trampoline training by aiding in athlete

health diagnosis and designing sports training tailored to the specific needs of the age group and gender

METHODS

The research was conducted in June 2018 during the Polish Junior Championships in Acrobatic Gymnastics, Trampoline Gymnastics and Tumbling. It involved a total of 100 trampoline jumpers (57 girls and 43 boys) aged 10-13 who. These athletes, classified by the Polish Gymnastics Association as sports class III and II, represented 12 clubs from across Poland.

On average, the examined girls participated in 4.9 training sessions per week, each lasting approximately 2.1 hours. Conversely, boys averaged 5.5 training sessions per week, with each session lasting about 1.9 hours.

To assess the vital capacity (VC) of the athletes, spirometry tests were conducted using the portable EasyOne Model 2001 spirometer. Testing took place on the day of the competition, in the morning before training, while the athletes were at rest and in an upright position. Each athlete underwent the test twice, and the better result was used for analysis according to the adopted procedure.

Written consent for participation in the research was obtained from the athletes' parents or legal guardians, club coaches, and competition organizers.

The research protocol was approved by the Bioethics Committee at the Regional Medical Council in Zielona Góra (Bioethics Committee Resolution No.17/82/2017 of 17th July 2017).

Following data collection, statistical analysis was conducted. Arithmetic means Table 1

(M), standard deviations (SD), and ranges of variability (Min-Max) were calculated for vital capacity across the respective age classes (10, 11, 12, and 13) of the tested athletes (Arska-Kotlińska et al., 2002).

The obtained results were compared to reference values derived from studies conducted by the European Respiratory Society and the Global Lung Function Initiative calculators for Spirometry, TLCO, and Lung volume, utilizing prediction equations (Hall et al., 2021):

Female:

$$VC = \exp(-9.230600 - 0.005517 * \text{age} + 2.116822 * \log(\text{height}) + \text{Mspline})$$

Male

$$VC = \exp(-10.134371 - 0.003532 * \text{age} + 2.307980 * \log(\text{height}) + \text{Mspline})$$

Utilizing the individual body height values of the tested athletes and referencing the study by the European Respiratory Society (Hall et al., 2021) and the Global Lung Function Initiative calculators for Spirometry, TLCO, and Lung volume (<http://gli-calculator.ersnet.org/>), the Lower Limit of Normal (LLN) and Upper Limit of Normal (ULN) were determined for vital capacity (VC) within the respective age classes of the athletes.

RESULTS

On average, surveyed girls aged 10 have a higher weight than boys of the same age, while at ages 11, 12, and 13, boys tend to be heavier than girls. Regarding body height, girls aged 10 and 12 are, on average, taller than their male counterparts, whereas boys aged 11 and 13 are taller than girls. Both girls' and boys' height and weight increase with age.

Numerical values for body height, body weight and BMI of the examined girls and boys

Feature	Age	Girls					Boys				
		n	M	SD	Min	Max	n	M	SD	Min	Max
Body mass [kg]	10	13	32.38	3.74	27	40.70	8	31.36	3.14	25.70	36.10
	11	18	33.38	5.01	23.10	42.20	9	35.41	4.79	28.40	43.80
	12	20	36.03	5.24	29.50	45.90	19	37.38	5.81	28.60	53.00
	13	18	43.87	6.75	34.90	59.00	11	45.24	7.46	32.40	61.40
Body height [cm]	10	13	139.77	3.31	134.00	144.00	8	137.13	4.23	128.00	142.00
	11	18	143.22	7.41	134.00	159.00	9	144.33	5.10	136.00	153.00
	12	20	148.05	5.69	141.00	162.00	19	147.05	6.71	137.00	160.00
	13	18	154.22	6.07	140.00	162.00	11	156.82	8.16	145.00	176.00
BMI	10	13	16.56	1.63	13.69	19.63	8	16.64	0.98	15.03	18.11
	11	18	16.19	1.44	12.86	17.87	9	16.92	1.34	14.08	18.71
	12	20	16.37	1.65	14.13	19.63	19	17.18	1.40	14.64	20.70
	13	18	18.34	1.78	15.41	22.48	11	18.31	1.90	13.31	18.31

Table 2:

Vital capacity VC [l] of examined trampoline gymnasts broken down by age

Age	Girls					Boys				
	n	M	SD	Min	Max	n	M	SD	Min	Max
10	13	2.20	0.27	1.68	2.60	8	2.36	0.33	1.87	2.82
11	18	2.43	0.26	1.91	2.88	9	2.57	0.22	2.32	2.98
12	20	2.51	0.35	1.87	3.19	19	2.86	0.32	2.37	3.47
13	18	3.07	0.39	2.24	3.84	11	3.28	0.51	2.60	4.24

The average BMI values for girls in each age group indicate normal body weight. However, cases of grade I underweight were observed among 10- and 13-year-old girls, and grade II underweight among 11- and 12-year-olds. Similarly, the average BMI for boys in each age group also suggests normal body weight. Instances of underweight class I were noted among 11- and 12-year-old boys, with cases of underweight class II recorded among the oldest group (13-year-olds).

In each age category, the examined boys exhibit, on average, higher vital capacity compared to their female counterparts practicing the same sports discipline. Vital capacity (VC) increases with the age of the respondents, both for girls and boys.

The graphical representation of the average (M) vital capacity of the tested athletes aged 10-13 who practice trampoline jumping is presented in Figure 1.

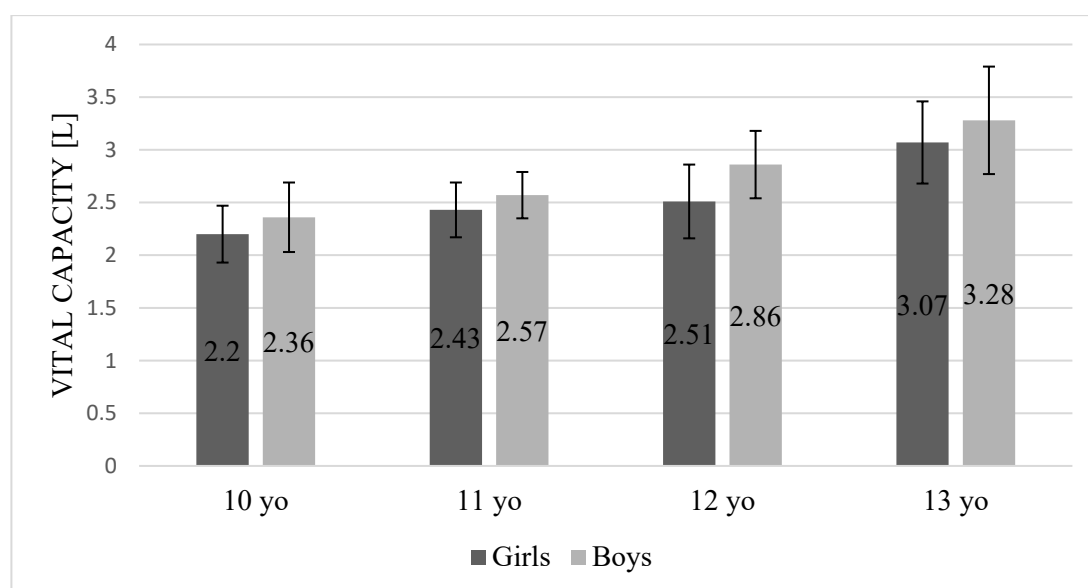


Figure 1. Graphical representation of average vital capacity of the lungs of examined girls and boys with standard deviation

Table 3

Vital capacity of the lungs of tested female athletes in relation to predicted values

Age	n	VC	Predicted	LLN	ULN	% Predicted
10	13	2.20 ± 0.27	2.39	1.95	2.83	91.97
11	18	2.43 ± 0.26	2.55	2.08	3.02	95.26
12	20	2.51 ± 0.35	2.77	2.26	3.28	90.54
13	18	3.07 ± 0.39	3.06	2.49	3.63	100.34

Table 4

Vital capacity of the lungs of the tested male athletes in relation to predicted values

Age	n	VC	Predicted	LLN	ULN	% Predicted
10	8	2.36 ± 0.33	2.45	1.98	2.94	96.38
11	9	2.57 ± 0.22	2.81	2.26	3.36	91.59
12	19	2.86 ± 0.32	2.97	2.40	3.56	96.23
13	11	3.28 ± 0.51	3.50	2.82	4.20	93.72

Based on the average body height values of the tested female athletes, as specified in the study by the European Respiratory Society (Hall et al. 2021) and the Global Lung Function Initiative calculators for Spirometry, TLCO and Lung volume (<http://gli-calculator.ersnet.org/>),

the presented results indicate that the tested 10-year-old athletes achieve 91.97% of the predicted values, 11-year-olds achieve 95.26% of the predicted values, 12-year-olds achieve 90.54%, and 13-year-olds achieve 100.34% (Table 3). In all age categories, the average vital capacity of the tested athletes

is within the reference values (between LLN and ULN) (Table 3).

The presented results indicate that the tested 10-year-old athletes achieve 96.38% of the predicted values, the 11-year-olds 91.59% of the predicted values, the 12-year-olds 96.23%, and the 13-year-olds 93.72%. In all age categories, the average vital capacity of the tested athletes is within the

reference values (between LLN and ULN values) (Table 4).

In terms of average values, both the tested male and female athletes exceeded 90% of the predicted values for VC (Figure 2). The girls stand out with higher % predicted values for VC at the ages of 11 (95.26%) and 13 (100.34%), while the boys excel at the ages of 10 (96.38%) and 12 (96.23%).

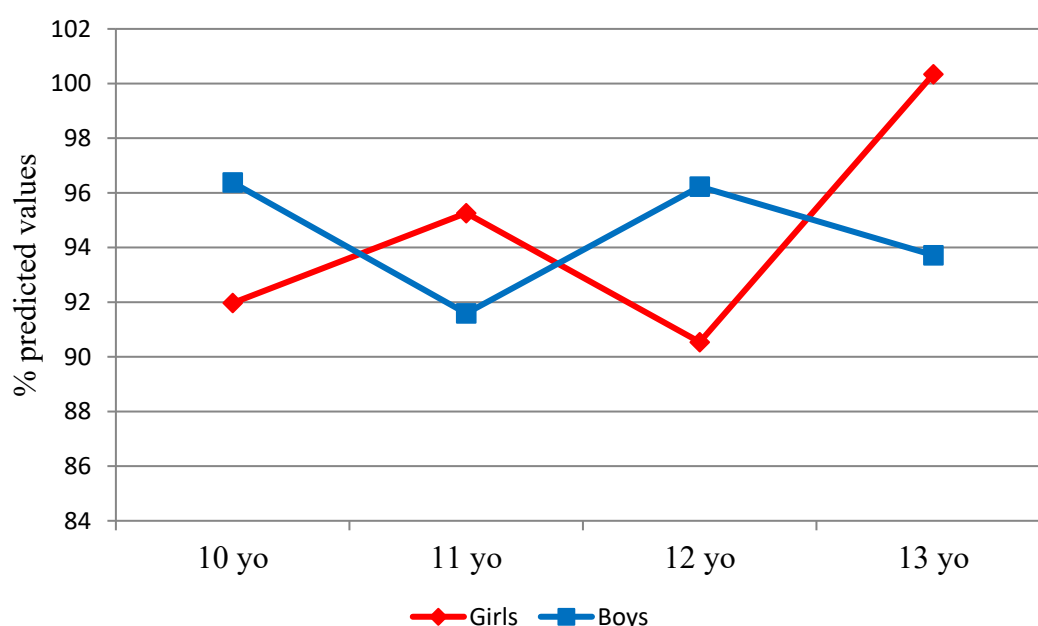


Figure 2. The graphical representation of the achieved % predicted values for VC of the tested athletes

DISCUSSION

Trampoline jumping is a technical discipline that naturally requires specific physical predispositions such as strength, power, motor coordination, speed, and stamina. While not categorized as an endurance discipline due to the nature and duration of the exercise, trampoline sports demand adaptation of the respiratory system to the effort exerted. A typical trampoline routine lasts approximately 30-60 seconds, including preparatory jumps. This necessitates an efficient respiratory system,

as athletes must inhale and exhale at precise moments or hold their breath when necessary, all while executing complex stunts. Research by Hes & Asienkiewicz (2020) has demonstrated that children aged 7-9 who engage in sports acrobatics and trampoline jumping generally exhibit superior physical fitness compared to non-training peers, except in hand grip strength. However, they typically excel particularly in flexibility (Seredyński & Polak, 2015), which indirectly relates to lung capacity.

Observations from spirometric examinations of trampoline athletes indicate

that, on average, boys in each age category exhibit higher vital capacity compared to their female counterparts in the same sports discipline. Research by Todorov (1982) highlights gender differences in vital capacity, with men generally demonstrating higher values."

The tested female athletes achieve predicted values of VC ranging from above 90% to 100.34%, with results ranging from 90.54% for 12-year-olds to 100.34% for 13-year-olds. Similarly, the tested athletes, on average, achieve predicted values of VC above 90%, albeit with a slightly narrower range, from 91.59% for 11-year-olds to 96.38% for 10-year-olds..

These findings indicate that while trampoline jumping competitors maintain VC values within the reference range (between LLN and ULN values - see Table 3.4), they do not consistently reach 100% of the predicted VC values, except for girls aged 13.

These results align with existing literature, underscoring the role of sports training in shaping lung function, a phenomenon influenced by the nature of the sport practiced. The adaptation of the cardiovascular and respiratory systems to various types of sports training and the reversibility of this process following the cessation of training in adults is a well-known phenomenon (Amann, 2012). It is well-established that physical training enhances lung function parameters, including vital capacity of the lungs (VC) (Durmic, 2017). Additionally, individuals actively engaged in sports exhibit higher VC compared to sedentary individuals (Tulin et al., 2012). Studies have consistently shown increased lung functional parameters in athletes compared to sedentary controls (Miller et al., 2005; Guenette et al., 2007, Myrianthefs et al., 2014). Research by Mazic

et al. (2015) demonstrated that basketball players, water polo contestants and rowers, exhibited statistically higher vital capacity (VC), forced vital capacity (FVC), and forced expiratory volume in one second (FEV1) compared to healthy sedentary individuals.

Research on vital lung capacity among athletes in technical sports, including gymnastic disciplines, is limited. However, Zhao et al. (2019) conducted a study analyzing VC among athletes in various sports, including basketball, judo, fencing, swimming, table tennis, and volleyball, with participants under the age of 15. The study revealed that table tennis players exhibited significantly lower vital lung capacity compared to athletes in other sports examined in the study.

Research conducted among children and adolescents consistently demonstrates higher vital lung capacity (VC) values in individuals engaged in various sports disciplines compared to those who lead sedentary lifestyles. Kurkcu & Gokhan (2011) observed that 10-13-year-old handball players exhibited higher VC compared to non-sporting peers. Similarly, Nikolic & Ilic (1992) found that athlete students, with an average age of 15 years, had slightly higher VC values than non-athletes (4.9 and 4.57 l, respectively). reported higher VC and forced vital capacity (FVC) values, along with lower resting heart rate and blood pressure, in schoolchildren engaging in sports compared to sedentary students. This suggests that physical training strengthens respiratory muscles. Additionally, research by Sharma (2023) indicates that 8 weeks of speed and agility training (SAQ) in school-age children (13-17 years old) enhances VC. Ramesh & Venkatachalapathy (2022) demonstrated significant improvements in respiratory

indicators, including vital capacity, following strength and endurance training. Similar findings were reported by Velmurugan (2019) and Dinesh et al. (2020) after strength and circuit training. Furthermore, Khosravi et al. (2013) concluded that endurance training leads to a significant increase in vital capacity.

It is worth contemplating why the examined trampoline athletes did not achieve vital capacity levels above 100% of predicted values despite their considerable training efforts. This raises questions about the nature of the athletes' training regimen, which primarily focuses on refining technique and mastering new maneuvers. While motor preparation, including endurance and strength training, is also integral, its intensity may not be sufficient to elicit significant physiological adaptations in young athletes. Therefore, future studies should delve into the relationship between lung vital capacity and trampoline performance. Additionally, attention should be given to the balance between strength and endurance exercises in training and their role in shaping respiratory function in young trampolinists.

According to the Global Lung Function methodology, body height serves as a primary determinant when calculating predicted VC values, as it is closely associated with lung capacity. However, numerous studies suggest correlations between vital capacity and other somatic characteristics and indicators, such as body weight, chest volume, and BMI (Pavlica et al., 2010; Durmic et al., 2015).

Male and female trampoline jumpers typically exhibit a slim body structure, low body weight, and low BMI. This observation is supported by research conducted by Hes & Asienkiewicz (2020) among children aged 7-9, as well as by Seredyński & Polak (2018)

among girls aged 11-12, and by Hes and Nowacka-Chiari (2019), which assessed BMI index according to the classification by Cole et al. (2000, 2007) among girls and boys aged 11-13 engaged in trampolining.

The low values of body height and body mass observed among the studied female and male athletes are further supported by reference to centile grids of the Polish population. In each age category, both among girls and boys, these somatic traits fall below the 50th percentile (Kułaga et al., 2015). Specifically, the lowest values relative to the Polish population for body height were recorded among girls and boys aged 12 years (between the 25th and 10th percentile), while for body mass, the lowest values (between the 10th and 25th percentile) were observed among girls aged 11 and 12 and boys aged 12.

The slim body build, low body weight, and low BMI of the examined individuals may influence their vital capacity. Therefore, exploring the relationships between lung function parameters and various somatic features among gymnastic athletes warrants further investigation.

CONCLUSIONS

In each age category, the studied boys exhibit, on average, higher vital capacity compared to their female counterparts. The average vital capacity levels for girls aged 10, 11, 12, and 13 were 2.2 liters, 2.45 l, 2.54 l, and 3.02 l, respectively. Meanwhile, the average vital capacity levels for boys aged 10, 11, 12, and 13 were 2.36 liters, 2.56 l, 2.89 l, and 3.33 l, respectively.

These research findings indicate that trampoline jumpers achieve vital capacity values within the reference range (between LLN and ULN values). Notably, girls demonstrate higher % predicted values for

VC at the ages of 11 years (95.26%) and 13 years (100.34%), while boys excel at the ages of 10 years (96.38%) and 12 years (96.23%).

The failure of respondents to achieve 100% predicted values for VC (except for girls aged 13), despite significant training volumes, may be attributed to their slim body structure, low body mass, and low BMI. Therefore, exploring the relationships between lung function parameters and various somatic features among gymnastic athletes warrants consideration.

LIMITATIONS

This study is subject to several limitations that may impact the representativeness and interpretation of the results. Firstly, the small number of participants in each age category may limit the generalizability of the findings. Moreover, the diverse sports levels among athletes within the analyzed age categories introduce additional variables that could potentially interfere with result interpretation.

Furthermore, it is important to acknowledge that the sports level of trampoline jumpers in Poland may not be as high compared to European and global standards. This discrepancy could impact the overall lung function outcomes observed in the study.

Given these limitations, there is a need for further research incorporating a more detailed analysis of lung functions among gymnastics athletes. This analysis should consider various somatic features that may influence lung function outcomes, thereby providing a more comprehensive understanding of respiratory health in this population

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