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Evaluation of Some Anatomical and Anthropometric Characteristics of the Chest Based on the Analysis of Digital Images of the Anterior Aspect of Trunk in Top Athletes

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SUMMARY

The aim of this research was to assess the size and shape of the chest in students and top athletes. The research involved 23 first-year students of the Faculty of Sport and Physical Education, and 23 top athletes of the Athletic Federation of Serbia. The digital images of the frontal trunk aspect were made and further analyzed in ImageJ program. The vertical and horizontal distances and as well as the angles were determined: the infrasternal angle and the angle of umbilicus (sides of the angle connect the points on the left and right). Both students and athletes were divided into three height groups (I – 165-174 cm; II – 175-184 cm; III – 185-194 cm). BMI and BI were determined (shoulder width). No statistical differences in height, weight and BMI among the groups of students and top athletes were found, which pointed to the homogeneity of the groups. All the parameters determined, the vertical and horizontal ones, except AAD, were significantly higher in top athletes (p ≤ 0.05) compared to the same parameters obtained in students of all three height groups. Acromial distance increases with height, but not statistically significantly. The above mentioned indicates a significantly better development of the bone-joint-muscle system of the chest in top athletes. The infrasternalni angle correlates with the angle of the umbilicus and it can be used to assess the shape of the chest. In our researches, analysing the individual cases, the presence of normasthenic, asthenic (elongated) and barrel-shaped chest was determined. The program ImageJ is very precise, objective and easily applicable for determining the lenghtwise parameters and angles in anatomic and anthropometric measurements. The method does not require anthropometric equipment, digital images can be made quickly and efficiently. Therefore, we consider it particularly suitable for measurements in childhood and athletes.

Key words: **anthropometric measurements, frontal aspect of the trunk, top athletes, ImageJ**

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INTRODUCTION

Chest anatomy is described as part of the trunk between the neck and abdomen, of truncated cone in shape, with a narrow base facing upwards towards the neck, and downwards towards the abdomen. Chest wall is a bone-joint-muscle system, which limits the chest cavity in which vital organs of the respiratory and cardiovascular systems are located (1, 2). The chest wall is covered with subcutaneous fatty tissue and skin. In the surface anatomy or external appearance, there is a detailed relief of the anterior, lateral and posterior walls of the chest, composed of the prominence of characteristic anatomical details, both osteoarticual and muscular in origin (3, 4). It is noteworthy that the relief is most prominent on the anterior wall of the chest. Some of these details are used as orientation in anatomy; however, in anthropometric measurements the shoulder area is attached to the chest.

Anthropometry is the science of taking quantitative measurements of the human body dimensions and consist of static, functional strength and anthropometry. Determined angles and distances or breadth are parts of static anthropometry (5). Anthropometric measurements are required in many areas of human activity such as ergonomics, anthropology, bio-mechanics, medicine and sports. Sports anthropometry has developed from the techniques and results of general physical anthropology. Continual progress in the methods of sports training, athletic performances and consequently in the changes in athletic rules and equipment have developed a need for the investigation of human biological factors such that may have a role in competitive sport performance (6).

The analytical approach in sport anthropometry has only become dominant during the past 10 years; it is applied in anthropometry for understanding the human body and posture. A large number of image processing tools are aviable, with varied capabilities. ImageJ is one such tool, which is available as a freeware. It is a public domain, Java-based image processing program developed at the National Institutes of Health (7). ImageJ was designed with an open architecture via Java that provides extensibility pluggings and recordable macros (8, 9). Downloadable distributions are available for Microsoft Windows and have a simple protocol (8).

The aim of this study is to analyse, using the ImageJ digital program, the static trunk digital image in the frontal aspect and assess the size and shape of the chest in top athletes, and to compare these results with the same parameters obtained in the first-year students of the Faculty of Sport and Physical Education in Niš, who are not included in athletic activities. Also, the distances (horizontal and vertical) and angles which define the chest were estimated as well as the differences in size and shape of the chest in top athletes and students.

METHODS

The researches were conducted at the Faculty of Sport and Physical Education in Niš and during trainings of athletes of the Athletic Federation of Serbia.

Participants

The researches involved a group of athletes, including 23 male subjects with outstanding results in the respective disciplines, aged 18 to 21 years. Another group of examinees were the first-year students of the Faculty of Sport and Physical Education in Niš who were involved in recreational sports and their regular activities at the university, also aged 18 to 21 years. This group was also used as control group. In both groups, the participants were divided into three groups according to body height: I (165-174 cm), II (175-184 cm) and III (185-194 cm).

Instruments

The following instruments were used: weighing scales, digital camera, "Cassio FX", digital Image J program that is freely available and is taken from the website http>//en. Wikipedia.org /wiki/ImageJ.

Procedures

The weight of each examinee was measured using the classical scales and was expressed in kg; height was determined with antropometer and expressed in cm.

Then, static digital photos were made in the anterior anatomical position using the camera, which was set to the optimal distance and to the optimum height in relation to the subjects. The subjects were always photographed under the same conditions, and the photographs were 2816x1872 pixels in size. At the same time, the length (200cm) was photographed under absolutely identical conditions, and was used to calibrate the system before each ImageJ in order to determine the distance, using the option "set scale".

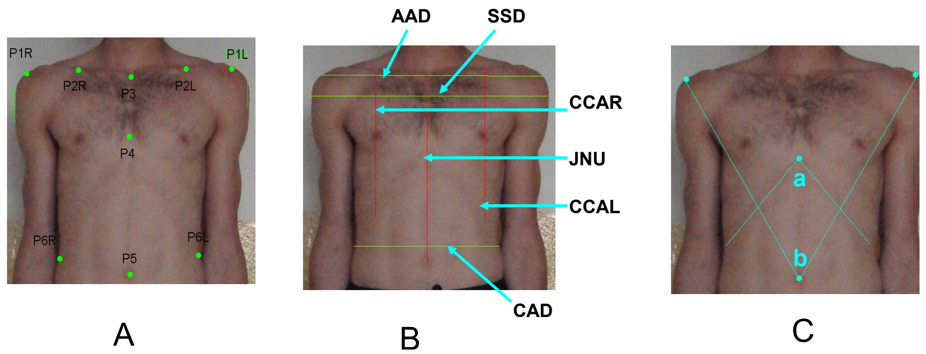
ImageJ program and a set of digital images in the frontal aspect were set to "desktop" for easy manipulation. From the software system, the option "distance" was used to express length and "angle" for angles, whose values were directly expressed in centimeters for length and degrees for angles.

First, they selected and fixed the points, namely: acromial (left-P1L and right-P1R), the middle point of the clavicle (left-P2L and right-P2R), a narrow point on the jugular notch (P3), a place where the xiphoid extension joins the sternum (P4) i.e. where the rib arches and umbilicus (P5) begin, as well as the lowest point on the rib arch (the frontal aspect) to the left - P6L and right - P6R (Figure 1A). The determined distances were divided into vertical (three) and horizontal (three) ones. The horizontal ones were: acromio-acromial distance (AAD), the width of the shoulders SSD) and the line connecting the lowest points on the arch rib on the left and right sides (CAD). The vertical ones were: the length between the jugular notch and umbilicus (JNU) and left and right distances on the medioclavicular line where it crosses the rib arch (CCAL and CCAR) (Figure 1B). As for the angles, we determined the infrasternal angle (a) and angle of umbilicus (b) in which the angular point matches umbilicus and sides connect the acromial points on the left and right.

Biomass index (BMI) was determined according to the National Heart, Lung and Blood Institute - UnitedStates(http://www.nhlbisupport.com/bmi/bmi-m.htm).

Also, the BI - index was determined as the ratio between AAD and height, which is expressed in %; average shoulder width was determined according to the standard (10).

Statistical processing of the obtained data was done using the SPSS10 program. The mean value and standard deviation were determined, and statistical significance was tested by the t-test for small independent samples; the correlation between the angles was determined as well. All data were presented in tables and figures.



A:
P1R - acromial point right
P1L – acromial left
P2R – middle of clavicule point right
P2L - middle of clavicule left
P3 - jugular notch
P4 - top body of sternum
P5 - umbilicus
P6R - the lowest point costal arch right
P6L – the lowest point costal arch left

B:
AAD – acromio-acromial distance
SSD – schoulder-schoulder distance
CCAR – middle of clavicule - costal arch right
JNU – jugular nocht umbilicus
CCAL- middle of clavicule - costal arch left
CAD – the lowest point costal arch right and left

C:
a – infrasternal angle
b – angle by umbilicus

Figure 1. *Display of procedure using ImageJ analysis: A - points, B - lines, C - angles*

RESULTS

The results are presented in tables, and figures showing the shapes of the chest.

Table 1 shows the basic measures: height, weight and BMI of the examinees. Testing the mean values by using the t-test showed that there was no statistical significance between the students and top athletes, or between the groups. Given that the groups are composed according to body height, statistically significant differences can not be expected. As for weight and BMI, statistically significant differences were not found because those were young people of approximately the same age who were physically active.

Concerning weight and BMI, the groups were mainly homogenous, suggesting that other parameters examined would not be affected by height and weight.

Table 2 shows the vertical and transverse (horizontal) distances of the anterior wall of the trunk in students and top athletes in II height group. All vertical diameters were statistically significantly higher ($p \leq 0.05$), indicating that the chest wall in athletes was more elongated compared to students. Horizontal distances, except for AAD, were also significantly greater ($p \leq 0.001$) in athletes compared to students, showing that in this height group the width of the chest was greater compared to the students. Increased shoulder width on the deltoideus can be explained by better development of the deltoid muscle in athletes, both on the left and right sides. Statistically significantly greater CAD points to the wider CAD bottom opening of the chest, and thus the better development of the skeletal system in top athletes.

Table 3 shows the vertical and transverse (horizontal) distances of the anterior chest wall in students and top athletes in II height group. All vertical diameters were statistically significantly greater ($p \leq 0.001$), indicating the elongation of the chest in athletes in relation to the students. Horizontal distances, except for AAD, were also significantly greater ($p \leq 0.001$) in athletes compared to students, which pointed to greater chest width in this height group compared to students. Greater shoulder width of the deltoideus can be explained by better development of the deltoid muscle in athletes, both on the left and the right sides. Statistically significantly greater CAD suggests the wider lower opening of the chest, and thus the better development of the skeletal system in top athletes.

Table 4 shows the vertical and transverse (horizontal) distances of the anterior chest wall in students and top athletes in III height group. All vertical diameters were significantly greater ($p \leq 0.05$), which pointed to the elongation of the chest in athletes in relation to the students. Horizontal distance, except for AAD, was also significantly greater ($p \leq 0.001$) in athletes compared to students, indicating that in this height group the shoulder width was also greater in respect to the students. CAD points to greater lower opening of the chest, and thus the better development of the skeletal system in top athletes, as evidenced by the I and II height groups.

Table 5 demonstrates the infrasternal angle, which is expressed in degrees for students and top athletes in the three height groups. The size of the infrasternal angle was significantly bigger ($p \leq 0.05$) in top athletes in I and II height groups ($p \leq 0.001$), whereas in III height group statistically significant differences were not found. There was a correlation between ISA and AU, which indicated that the measurement of AU can be used to assess the shape of the thorax.

As for the angle of the umbilicus there were no statistically significant differences between students and top athletes.

BI Index showed that the students of I height group included the individuals with broad shoulders, while II and III groups involved the subjects with average width of the shoulders (acromial width). Among the top athletes of I and II groups are individuals with broad shoulders, and group III involved the subjects with average width of shoulders. Neither in students nor in top athletes is the average shoulder width in the category of narrow shoulders; it ranges from averagely broad to broad shoulders which indicates a good chest development, because the values are compared within the height groups.

Using the analysis of the angle of umbilicus in all individual cases, both in the students and top athletes, it can be perceived that when the angle approaches or equates 60° then the corners of acromial points to the left and right equate 60°, and the triangle formed on the anterior wall of the chest is equilateral; then, the rib cage has the normostenic somatotype (Figure 2A).

In elongated or asthenic chest, the angle of umbilicus is less than 60°, and angles of acromial points greater than 60°; the equilateral triangle is formed with the base (AAD) smaller than the arms (Figure 2B).

When the angle of the umbilicus is greater than 60° and the angles of acromial points less than 60°, a triangle is equilateral with the base (AAD) greater than arms (distance between acromial points and umbilicus); the chest is barrel-shaped or picnic (Figure 2C).

Table 1. *Presentation of height (in cm), weight (in kg) and BMI among students and athletes within height groups*

By using the t-test, statisticially significant difference between students and athletes was not found

Height Groups	**I (165-174)**				**II (175-184)**				**III (185-194)**			
Variables	**Students**				**Students**				**Students**			
	N	**X**	±	**SD**	**N**	**X**	±	**SD**	**N**	**X**	±	**SD**
Height	7	172	±	2,236	16	180	±	2,205	5	191	±	5,805
Weight	7	71	±	6,824	16	74	±	8,232	5	86	±	9,808
BMI	7	24			16	23			5	24		
Variables	**Athletes**				**Athletes**				**Athletes**			
	N	**X**	±	**SD**	**N**	**X**	±	**SD**	**N**	**X**	±	**SD**
Height	6	170	±	3,061	8	180	±	3,357	5	188	±	3,395
Weight	6	63	±	7,711	8	68	±	3,988	5	82	±	5,754
BMI	6	22			8	21			5	23		

Table 2. *Transverse and longitudinal parameters of the anterior trunk wall in students and top athletes in the first height group (165-174cm) expressed in cm*

Variables	Students				Athletes			
	N	X	±	SD	N	X	±	SD
JNU	7	38	±	1,063	6	46	±	1,329**
CCAL	7	30	±	1,676	6	33	±	2,563*
CCAR	7	30	±	2,193	6	33	±	2,757*
AAD	7	41	±	1,414	6	42	±	1.366
SSD	7	44	±	0,976	6	56	±	1,211**
CAD	7	27	±	1,134	6	34	±	2,000**

athletes vs students: p≤0,05*; p≤0,001**

JNU: jugular notch - umbilicus
CCAL: the middle of clavicule - to costal arch left
CCAR: the middle of clavicule - to costal arch right
AAD: acromialno - acromialna distance
SSD: shoulder - shoulder distance (on deltoid)
CAD: the lowest points on costal arch right and left

Table 3. *Transverse and longitudinal parameters of the anterior trunk wall in students and top athletes in the second height group (175-184cm) expressed in cm*

Variables	Students				Athlets			
	N	X	±	SD	N	X	±	SD
JNU	16	39	±	1,844	8	47	±	2,900**
CCAL	16	31	±	2,221	8	36	±	0,945**
CCAR	16	30	±	2,097	8	36	±	0,945**
AAD	16	40	±	1,459	8	42	±	1,768
SSD	16	44	±	1,862	8	58	±	2,532**
CAD	16	28	±	0,588	8	35	±	2,167**

Table 4. *Transverse and longitudinal parameters of the anterior trunk wall in students and top athletes in the third height group (185-194cm) expressed in cm*

Variables	Students				Athlets			
	N	X	±	SD	N	X	±	SD
JNU	5	41	±	1,304	9	47	±	3,745**
CCAL	5	33	±	1,817	9	37	±	3,790*
CCAR	5	33	±	1,140	9	37	±	1,312*
AAD	5	43	±	2,302	9	43	±	3,082
SSD	5	47	±	2,387	9	57	±	4,460**
CAD	5	29	±	1,924	9	36	±	2,445**

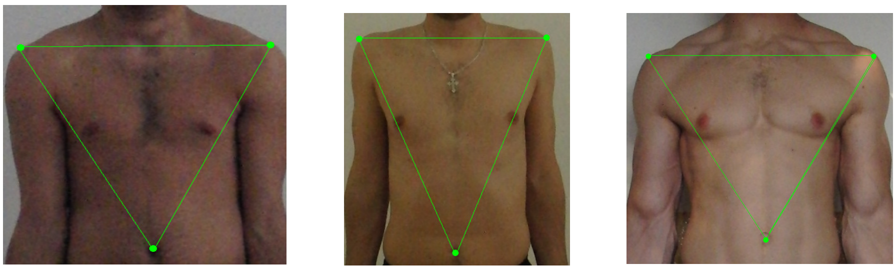
Table 5. *Presentation of infrasternal angle, angle of umbilicus and BI index in students and top athletes by high groups*

Height Groups	**I (165-174)**				**II (175-184)**				**III (185-194)**			
Variables	**Students**				**Students**				**Students**			
	N	**X**	±	**SD**	**N**	**X**	±	**SD**	**N**	**X**	±	**SD**
ISA	7	67°	±	8,124	16	68°	±	8,195	5	61°	±	8,228
AU	7	48°	±	2,563	16	49°	±	5,902	5	47°	±	2,302
BI index	23,8% (23% and more) broad shoulders				22,5% (22% and less) averagely broad shoulders				22,5% (22% - 23%) averagely broad shoulders			
Variables	**Athletes**				**Athletes**				**Athletes**			
	N	**X**	±	**SD**	**N**	**X**	±	**SD**	**N**	**X**	±	**SD**
ISA	6	57°	±	3,204*	8	57°	±	3,523**	5	60°	±	4,684
AU	6	51°	±	2,168	8	52°	±	2,866	5	51°	±	2,297
BI index	24,7% (23% and more) broad shoulders				23% (23% and more) broad shoulders				22,8% (22% - 23%) averagely broad shoulders			

athletes vs students: $p \leq 0,05$*; $p \leq 0,001$**

ISA: infrasternal angle
AU: angle of umbilicus

Correlation between ISA and AU in students =0,71 $p<0,05$
Correlation between ISU and AU in athletes =0,45 $p<0,05$



A B C

A. Angle by umbilicus is 60o, the equilateral triangle with the side 45cm - normasternical form

B. Angle by umbilicus is 45o, the isosceles triangle with the side AAD = 40cm, 51cm AUD = - asteničan form

C. Angle by umbilicus is 65o, the isosceles triangle with the side AAD = 58cm, 54cm AUD = - barrel shape

Figure 2. *Display of triangle of the anterior trunk wall, which defines the appearance of the chest*

DISCUSSION

From the results obtained it is evident that there were no statistically significant differences in height, weight and BMI in athletes and students, indicating that the groups are homogenous, and the analysis of other anthropometric parameters should be considered valid. Smaller average body weight by height groups in top athletes was recorded, which is logical given the programmed diet and exercise. Vertical parameters were statistically significantly greater in all three height groups in athletes compared to students; CAD parameter on the left and right sides shows the same average values on the right and left sides, which points to the symmetry of the chest. Among horizontal parameters, AAD was greater in athletes, but not statistically significantly. The width of the shoulders in athletes was significantly greater in all three height groups, which is reasonable because this parameter covers the deltoid muscle, and therefore, depends on the development of that muscle. It is certain that the deltoid muscle is developed in athletes who have programmed trainings, strictly in accordance with the requirements of the sport they do. CAD parameter, which connects the lowest point on the rib arches on the right and left, indirectly indicates the size of the lower opening of the chest. This parameter is statistically significantly greater in athletes compared to students, suggesting that the rib cage, and therefore the thoracic cavity, are larger and more developed in athletes with top results. This may suggest a better functional activity, particularly the respiratory one, which vastly depends on the size and elasticity of the chest walls (11, 12).

BI index indicates the broad shoulders of the students and athletes of I and II groups, while in other groups the shoulder width category reaches average values. This index indirectly indicates the barrel-shaped chest, i.e barrel-shaped and normasthenic; it should be emphasized that we speak about average values (10).

Aaccording to anatomic principles, the infrasternal angle is the measure of the chest shape. When this angle is markedly sharp the chest is elongated or asthenic; it is obtuse when the chest is barrel-shaped; when approaching sixty degrees the chest is considered to be normostenic. The shape of the chest is in line with the constitution i.e.somatotype; therefore, the asthenic chest corresponds to the ectomorphic type, normostenic chest correspons to the mesomorphic somatotype, while the barrel-shaped chest corresponds to the endomorphic somatotype (13, 14). The endomorphic-mesomorphic constitution dominates in the generations of students enrolled in 1997 and 2007 (15), while mesomorphic somatotype i. e. athletic constitution is typical of the athletes who participated at the Olympic games (13).

The angle at umbilicus correlates with the infrasternalnim angle, and as it can be measured easily and reliably on digital frontal photographs in ImageJ program, we believe that it can be used to evaluate the chest type, of course, with further researches required.

CONCLUSION

The obtained results have shown that there are no statistically significant difference in height, weight and BMI between groups in students and in top athletes, indicating the homogeneity of the groups.

All the parameters determined, the vertical and horizontal ones, except for AAD in top athletes, are statistically significantly higher compared to the same parameters obtained in students of all three height groups who are not engaged in athletic activities. Acromial distance increases with height, but not statistically significantly. The aforesaid points to significantly better development of bone-joint-muscle system of the chest in top athletes.

Infrasternal angle correlates with the angle of the umbilicus, and it can be used to evaluate the shape of the chest. In our researches, by analysing the individual cases, normostenic and asthenic chest types dominate, while only individual cases have a barrel-shaped (picnic) chest. BI index shows that the shoulder width varies from broad to moderately broad, while narrow shoulders were not recorded.

The program ImageJ is very precise, objective and easily applicable for the determination of length parameters and angles in anthropometric measurements. The method does not require anthropometric equipment, and digital images quickly and efficiently can be done, therefore, we consider it suitable for measurements in children and athletes.

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PROCENA NEKIH ANATOMSKIH I ANTROPOMETRIJSKIH KARAKTERISTIKA GRUDNOG KOŠA ANALIZOM DIGITALNE SLIKE PREDNJEG ASPEKTA TRUPA KOD VRHUNSKIH ATLETIČARA

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Sažetak

Cilj istraživanja bio je da se proceni veličina i oblik grudnog koša kod studenata i vrhunskih atletičara. Istraživanja su sprovedena na 23 studenta prve godine Fakulteta sporta i fizičkog vaspitanja i 23 vrhunskih atletičara Atletskog saveza Republike Srbije. Načinjene su digitalne fotografije frontalnog aspekta trupa, koje su analizirane u ImageJ programu. Određivane su vertikalne i horizontalne distance i uglovi: infrasternalni i ugao sa temenom kod umbilikusa (kraci ugla spajaju akromijalne tačke levo i desno). I studenti i atletičari podeljeni su u tri visinske grupe (I: 165-174cm; II: 175-184cm; III: 185-194 cm). Određivan je BMI i BI (širina ramena). Nema statističkih razlika u visini, težini i BMI između grupa kod studenata i kod vrhunskih atletičara, što ukazuje na homogenost grupa. Svi određivani parametri, vertikalni i horizontalni, osim AAD, su kod vrhunskih atletičara statistički značajno veći (p 0,05) u odnosu na iste parametre kod studenata u sve tri visinske grupe. Akromijalno-akromijalna distanca se povećava sa visinom, ali ne statistički značajno. Napred navedeno ukazuje na značajno bolju razvijenost koštano-

zglobno-mišićnog sistema grudnog koša kod vrhunskih atletičara. Infrasternalni ugao korelira sa uglom kod umbilikusa, te se može koristiti za procenu oblika grudnog koša. U našim istraživanjima, analizom pojedinačnih slučajeva, utvrđeno je prisustvo normosteničnog, asteničnog i bačvastog oblika grudnog koša. Program ImageJ je veoma precizan, objektivan i lako primenljiv za određivanje dužinskih parametara i uglova u anatomskim i antropometrijskim merenjima. Metoda ne zahteva antropometrijsku opremu, a digitalne slike se mogu brzo i efikasno uraditi, te smatramo da je posebno pogodna kod merenja u dečijem uzrastu i kod sportista.

Ključne reči: **antropometrijska merenja, prednja strana trupa, vrhunski atletičari, ImageJ**