CLINICS

CLINICAL SCIENCE

Variation of the Anthropometric Index for *pectus excavatum* relative to age, race, and sex

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OBJECTIVES: To determine possible variations in the Anthropometric Index for *pectus excavatum* relative to age, race, and sex in individuals free of thoracic wall deformities.

METHODS: Between 2002 and 2012, 166 individuals with morphologically normal thoracic walls consented to have their chests and the perimeter of the lower third of the thorax measured according to the Anthropometric Index for *pectus excavatum*. The participant characteristics are presented (114 men and 52 women; 118 Caucasians and 48 people of African descent).

RESULTS: Measurements of the Anthropometric Index for *pectus excavatum* were statistically significantly different between men and women (11–40 years old); however, no significant difference was found between Caucasians and people of African descent. For men, the index measurements were not significantly different across all of the age groups. For women, the index measurements were significantly lower for individuals aged 3 to 10 years old than for individuals aged 11 to 20 years old and 21 to 40 years old; however, no such difference was observed between women aged 11 to 20 years old and those aged 21 to 40 years old.

CONCLUSION: In the sample, significant differences were observed between women aged 11 to 40 years old and the other age groups; however, there was no difference between Caucasian and people of African descent.

KEYWORDS: Anthropometry/Methods; Thoracic Wall/Abnormalities; Funnel Chest/Diagnosis.

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INTRODUCTION

Among all of the congenital deformities of the thoracic wall, *pectus excavatum* (PEX) is the most common. It is characterized by a depressed sternal region relative to the frontal rib cage (1).

Treatment of PEX is based on functional (2), aesthetic (3) psychological (4), and quality of life (5) considerations. Treatment can be either conservative (6) or surgical (7), involving pre-sternum filling without bone mobilization or bone mobilization with prosthetics (1,8–10) or without (1,11).

Consensus has not been obtained regarding the methods used to assess this deformity, and evaluation remains subjective (7) or objective (12–16). The Anthropometric Index (AI) for PEX (15,17–19) purports to provide the physician with a method for clinically verifying PEX. The AI is a quickly administered and low-cost clinical assessment, which does not induce adverse effects and is not vulnerable to environmental influences.

We compared the AI to the Haller index (HI) (14) and the lower vertebral index (VI) (13). The operational characteristics that were drawn from our data bank produced highly accurate curves and superimposable values for the three indices, relative to the diagnosis of PEX. The AI, HI, and VI cut-off points that differentiated PEX patients from healthy subjects were 0.12, 3.1, and 0.25, respectively. The AI was thus validated, although the HI and VI were once considered among surgeons the gold standards informing the treatment of this illness (15). However, previous reports have not examined differences in the results due to age, race, or sex; such inferences would not be appropriate given the sample sizes of these studies. Thus, the purpose of the present study was to consider effects of age, race, and sex on AI.

OBJECTIVE

The objective of this study was to determine variations in the IA for PEX due to age, race, and sex in individuals who were free of congenital defects of the thoracic wall.

No potential conflict of interest was reported.

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METHODS

The period of this investigation was 2002 through 2012. The study was undertaken at Ambulatório de Cirurgia Torácica and Ambulatório de Alergias do Instituto da Criança do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Ambulatório de Cirurgia Torácica da Prefeitura de Piracicaba, Instituto Formar de Piracicaba.

The subjects were male and female patients, both Caucasian and of African descent, belonging to the following age ranges: 3 – 10 years old; 11 – 20 years old; and 21 – 40 years old (20).

This study was approved by the Comissão de Ética para Análise de Projetos de Pesquisa do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo under #658/01 and #0122/06.

The inclusion criteria were: a) absence of congenital or acquired defects of the thoracic wall; b) aged between 3 and 40 years old; and c) body mass index (BMI) less than 25.

The exclusion criteria were: a) individuals with breast implants; b) lactation; and c) presence of any condition that might interfere with the normal architecture of the thorax, such as trauma leading to alteration of the chest, kyphosis and/or lordosis, cardiopathy, and pneumopathy.

Clinical measurements were obtained with the patient lying in the supine position on a flat table parallel to the floor during deep inhalation. The measurement instruments were: a) an articulated square; b) a rigid ruler coupled to a level (the measuring device); c) a pinned limiting device; and d) a conventional ruler.

Two clinical measurements were recorded: **measurement A** and **measurement B.** Measurement A was the longest measured anteroposterior distance from the tangential coronal plane relative to the dorsal region and the tangential coronal plane to the highest point of the chest at the distal third of the sternum (DT). This measurement was obtained with the patient in the supine position, while laying over one of the segments of the articulated square. Measurement A was defined as the intersection between the vertical scale of the other segment of the articulated square and the rigid ruler (the measuring instrument), coupled to the level running tangentially over the highest point of the anterior chest wall at the DT (Figure 1).

Measurement B, or the deepest point of the chest defect, was defined as the distance between the tangential plane and the highest point of the anterior chest wall and the plane over the deepest point of the pre-sternum region at the DT, when both planes were parallel to each other. This measurement was obtained with the rigid ruler (the measuring instrument) coupled to the level running tangentially over the highest point of the chest. The vertical shaft was then introduced through the center of the ruler until the tip touched the skin over the sternum at the DT. The segment of shaft from the pre-sternum region to the ruler indicated the vertical distance (Figure 2).

In addition, a metric tape measure was used to assess the circumference of the thorax at the DT.

In these individuals, the Anthropometric Index for PEX (AI) (15,17) was defined as measurement B divided by measurement A (AI = B/A). Weight, height, and thorax circumference at the DT were statically analyzed using Prism software, version 5.2 (Graphpad Prism, USA).

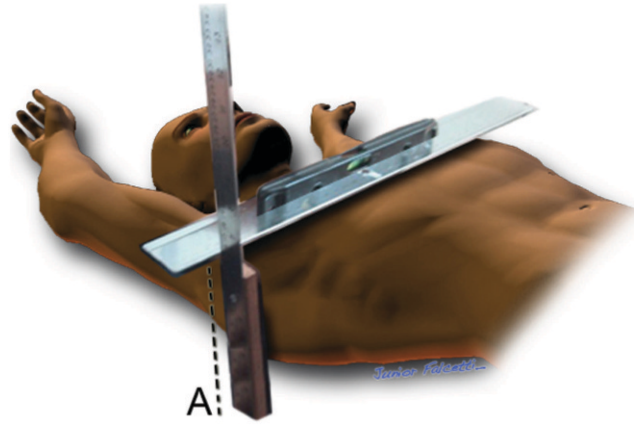

Figure 1 - Measurement A) The maximum anteroposterior measurement at the level of the distal third of the sternum.

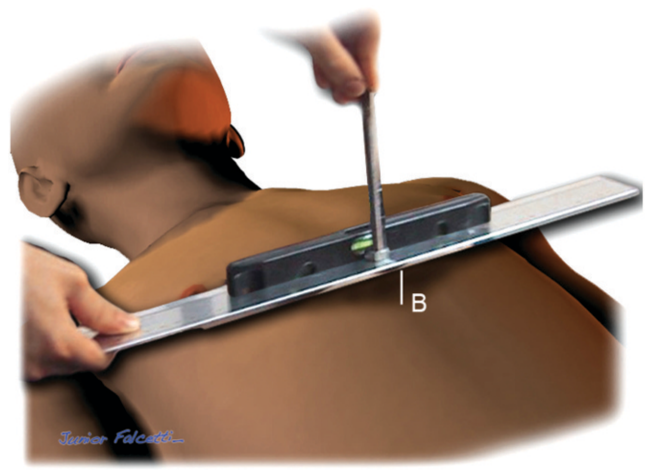

Figure 2 - Measurement B) The lowest depth of the defect, using the highest point of the anterior chest wall and the deepest point of the pre-sternum region at the DT as reference points.

'The normality of the sample distribution was tested using the Shapiro-Wilk test. Correlations were assessed via Spearman's rank-order correlation test, and comparisons between sexes and races were performed using the Mann-Whitney U test. Comparisons between sexes and age groups were conducted via ANOVA. p-values<0.05 indicated statistical significance.

RESULTS

Between 2002 and 2012, 166 individuals with normal chest morphology were assessed. The group of subjects was enrolled by the Ambulatório de Cirurgia Torácica and the Ambulatório de Alergias do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, the Ambulatório de Cirurgia Torácica da Prefeitura de Piracicaba, and the Instituto Formar de Piracicaba/São Paulo.

Of the 166 subjects, 114 were male (13 of whom were between 3 and 10 years of age, 52 were between 11 and 20 years of age, and 49 were between 21 and 40 years of age), and 52 were female (8 of whom were between 3 and 10 years of age, 22 were between 11 and 20 years of age, and 22 were between 21 and 40 years of age). One hundred eighteen of the 166 individuals were Caucasian, and 48 individuals were of African descent.

The results of the Shapiro-Wilk test for AI values indicated that the sample was normally distributed. Spearman's test found no correlations between the AI for PEX and weight, height, or thoracic circumference. However, the AI values were significantly different between male and female subjects as evidenced by results of the Mann-Whitney test ($p<0.0001$). The AI values between Caucasian individuals and those of African descent were not significantly different ($p=0.311$). We compared the sexes within each age group using ANOVA; the mean values and standard deviations for the 3- to 10-year-old, 11- to 20-year-old, and 21- to 40-year-old groups are displayed in Tables 1, 2, and 3, respectively. These values exhibited large variability in the female subjects belonging to the 11- to 20-year-old and the 21- to 40-year-old groups, which was evident both in their means and corresponding standard deviations (Figure 3).

When assessing the AI according to age group we observed that:

a) There was no difference among male subjects from the 3- to 10-year-old, 11- to 20-year-old, and 21- to 40-year-old groups ($p>0.05$).
b) There was no difference between female subjects from the 11- to 20-year-old and 21- to 40-year-old groups ($p>0.05$).

Table 1 - The number of individuals, means, and standard deviations of female and male subjects aged 3–10 years old.

Sex	n	Mean	SD
Male	13	0.035	0.015
Female	8	0.030	0.019

NOTE: n = number of individuals; SD = standard deviation.
Mean = average value of the AI for PEX.

Table 2 - The number of individuals, means, and standard deviations of female and male subjects aged 11 – 20 years old.

Sex	n	Mean	SD
Male	52	0.031	0.012
Female	22	0.057	0.026

NOTE: n = number of individuals; SD = standard deviation.
Mean = average value of the AI for PEX.

Table 3 - The number of individuals, means, and standard deviations of female and male subjects aged 21 – 40 years old.

Sex	n	Mean	SD
Male	49	0.033	0.012
Female	22	0.063	0.027

NOTE: n = number of individuals; SD = standard deviation.
Mean = average value of the AI for PEX.

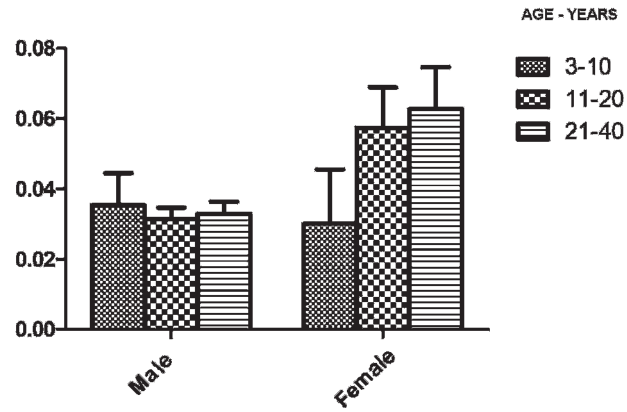

Figure 3 - This figure presents the mean AI values and their corresponding confidence intervals for male and female subjects aged 3–10 years old, 11–20 years old, and 21–40 years old.

c) There were differences between the female subjects aged 3 – 10 years old and those aged 11 – 20 years old or 21 – 40 years old ($p<0.01$ and $p<0.0001$, respectively).

DISCUSSION

A number of methods by which to assess PEX have been reported in the literature. Didactically, these methods can be classified as objective or subjective. Among the objective methods, which were the focus of the present investigation, clinical methods and those that use imagery are the most effective.

Our sample exhibited significantly different AI values between male subjects of all age groups and female subjects of all age groups ($p<0.0001$). We believe that the breasts accounted for this difference, because measurements A and B were collected using gauging devices that run across the chest. This belief is supported by no difference being found between male and female subjects of preteen ages (3–10 years of age) (Figure 3), when the breasts have not yet developed.

Knutson (21), who also conceived a clinical method of evaluating PEX based on the topography of the chest, reported difficulty in applying his method in women due to increased breast tissue. Similarly, Horst et al. (22) found differences between men and women when gauging the chest by means of his optical methodology and Moiré's topography. Using this approach to measure the thorax, Horst et al. did find differences between the sexes, but they were not so large as to prevent differentiating PEX patients from non-PEX patients among both men and women. This study also validated the AI, despite significant differences between sexes, it and effectively and objectively differentiated patients with PEX from those without PEX among both men and women (15).

Daunt et al. (23) electronically calculated the HI in 275 men and 282 women, according to what Haller et al. proposed in 1987. The HI was defined as being the ratio between the longest latero-lateral distance and the anteroposterior distance to the surface of the board of the sternum, relative to the anterior portion of the vertebral body at the DT, as measured by computerized tomography of the thorax (14). Daunt et al. recorded higher values in female subjects than in male subjects who were aged either between 0 and 6 years old or between 12 and 18 years old. Our results differ from those of Daunt's 0- to 6-year-old group; we found no significant differences between our male and female 3- to 10-year-old individuals. We must consider, however, that the age groups between these two studies do not completely coincide and that the sample size of our 3- to 10-year-old group was small (13 boys and 8 girls). The results obtained by Daunt et al. for the 12-to 18-year-old group were similar to ours; our female 11- to 20-year-old group had higher AI values than male subjects of the same ages.

Nakahara et al. (24) examined PEX patients and normal individuals and conceived a measurement for chest depression in PEX. It was defined as the ratio between the anteroposterior internal distance of the left parietal pleura and the parietal pleura at the level of the greatest deformity and the distance from the surface of the sternum board to the anterior portion of the vertebral body at the same level. In Nakahara's investigation, the degree of chest depression in normal individuals was lower in patients over 15 years of age. These results differed from ours; we did not find any significant difference in male subjects across all of the age groups. That the formula for the degree of depression does not account for any soft tissue must be considered. Still, the results remain controversial in light of the findings reported by Backer et al. (12) and Derveaux et al. (13), who did not observe alteration of the VI from the age of 6 years old or 10 years old, respectively. Regardless, the IV, like the depression degree, measures the internal architecture of the thorax.

Backer et al. (12) examined 88 subjects with PEX and 445 normal individuals, and Derveaux et al. (13) examined 54 subjects with PEX and 250 normal individuals. They calculated VI similarly as the ratio between the vertebral diameter and the thoracic sagittal diameter of the posterior portion of the vertebral body, relative to the posterior board of the sternum, both of which were measured using simple X-rays of the profile of the thorax at the DT. Backer et al. (12) did not find any significant differences between sexes. This finding is compatible with the AI if the increase in AI values in women is attributable to increased breast tissue; the VI calculation does not account for soft tissue, whereas the AI does because it is calculated using measurements of the external part of the thorax. Regarding age, both authors demonstrated that there was no variation from the age of 6 years old (12) or 10 years old (13), which supports our hypothesis that the internal anteroposterior architecture of the thorax does not change until at least 10 years of age. Therefore, changes in the AI (external architecture) between men and women should be attributed to breast growth beginning at approximately 11 years of age.

Male and female subjects aged 3 to 10 years old had lower mean AI values, which were statistically different from those of female subjects aged 11 to 40 years old. There was no significant difference between the mean AI values of Caucasians and subjects of African descent.

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AUTHOR CONTRIBUTIONS

Rebeis EB developed the study protocol, formulated the measurements used for all of the study subjects at all of the clinics, created the database, performed the literature review, statistical analyses, and discussion of the study results, devised the scientific methodology of the second study, and edited the current report for language. Campos JR reviewed the study protocol, realized the measurements in the sample of the Clinic of Thoracic Surgery of the HCFMUSP, and discussed the results and study goals. Moreira LF performed the statistical analyses and database generation and maintenance. Pastorino AC obtained approval of the study protocol at the Children's Institute and the HCFMUSP, participated in the measurements performed at the Clinic of Allergy at the same institution, and participated in discussion of the pediatric study. Pêgo-Fernandes PM discussed the theoretical basis of the study and participated in the final review of the manuscript. Jatene FB discussed the study design and participated in the final review of the manuscript.

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