

# FEV1 and FVC pulmonary function reference values among 6–18-year-old children: a multi-centre study in Saudi Arabia

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## القيم المرجعية لوظائف الرئة لحجم الزفير القسري في الثانية الأولى والسعة الحيوية القسرية بين الأطفال بعمر 6-18 عاماً: دراسة متعددة المراكز في المملكة العربية السعودية

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**الخلاصة:** من المهم إقرار قيم مرجعية لوظائف الرئة لكل مجموعة سكانية. وتهدف هذه الدراسة إلى التعرف على القيم المرجعية للقياسات التنفسية لدى الأطفال والمراهقين الأصحاء في المملكة العربية السعودية، واشتقاق معادلات للتنبؤ بقيمتها. وقد أجرى الباحثون دراسة مستعرضة شملت تلاميذ وتلميذات أصحاء تتراوح أعمارهم بين 6 و18 عاماً، تم اختيارهم عشوائياً من ست مناطق إدارية في المملكة العربية السعودية. وجمع الباحثون البيانات من خلال استبيان ومن خلال الفحص المادي باستخدام المقياس التنفسي. واتضح أن قيم حجم الزفير القسري خلال الثانية الأولى والسعة الحيوية القسرية كانت أعلى بمقدار يعتد به إحصائياً لدى الذكور مما هي لدى الإناث. وقد كان الطول هو المتغير الأكثر أهمية من حيث الترابط في القياسات البشرية ذات الصلة بحجم الزفير القسري خلال الثانية الأولى (معامل الارتباط  $r = 0.61$ ) وهو أكثر قيمة لدى الذكور (معامل الارتباط  $r = 0.71$ ) منه لدى الإناث (معامل الارتباط  $r = 0.50$ ). وقد أوضح نموذج التحوُّف الخطي المتعدد المتغيرات لدى الذكور تفسير التفاوتات لدى 53.9% من حجم الزفير القسري خلال الثانية الأولى و35.1% من السعة الحيوية القسرية، أما ما لدى الإناث فقد فسّر التفاوتات لدى 25.3% من حجم الزفير القسري خلال الثانية الأولى و16.5% من السعة الحيوية القسرية. وقد كانت جميع التغيرات في مربع معامل الارتباط  $R^2$  ذات أهمية يعتد بها إحصائياً.

**ABSTRACT** It is important to establish lung function reference values for each population. This study aimed to determine the spirometric reference values for healthy Saudi Arabian children and adolescents and to derive prediction equations for these. A cross-sectional study was conducted among healthy schoolboys and girls aged 6–18 years old, selected randomly from the 6 administrative regions of Saudi Arabia. Data were collected by questionnaire and physical examinations including spirometry. Forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) were significantly higher in males than females. Height was the anthropometric variable most strongly correlated with FEV1 ( $r = 0.61$ ), more so for males ( $r = 0.71$ ) than females ( $r = 0.50$ ). In males the multivariate linear regression model explained 53.9% of FEV1 and 35.1% of FVC variations. In females it explained 25.3% of FEV1 and 16.5% of FVC variations. All changes in  $R^2$  were statistically significant.

## Valeurs de référence de la VEMS et de la CVF chez des enfants de 6 à 18 ans : étude multicentrique en Arabie saoudite

**RÉSUMÉ** Il est important d'établir des valeurs de référence de la fonction respiratoire pour chaque population. La présente étude visait à déterminer les valeurs spirométriques de référence chez des enfants et des adolescents saoudiens en bonne santé et à en déduire des équations pronostiques pour ces derniers. Une étude transversale a été menée auprès d'écoliers et d'étudiants des deux sexes en bonne santé et âgés de 6 à 18 ans, sélectionnés aléatoirement dans six régions administratives d'Arabie saoudite. Des données ont été recueillies au moyen d'un questionnaire et d'examen cliniques, y compris la spirométrie. Le volume expiratoire maximal par seconde (VEMS) et la capacité vitale forcée (CVF) étaient nettement supérieurs chez les garçons que chez les filles. La taille était la variable anthropométrique la plus fortement corrélée au VEMS ( $r = 0,61$ ), et cette corrélation était plus forte chez les garçons ( $r = 0,71$ ) que chez les filles ( $r = 0,50$ ). Chez les garçons, le modèle de régression linéaire multivariée expliquait 53,9 % des variations du VEMS et 35,1 % des variations de la CVF. Chez les filles, le modèle expliquait 25,3 % des variations du VEMS et 16,5 % des variations de la CVF. Toutes les évolutions du  $R^2$  étaient statistiquement significatives.

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## Introduction

Pulmonary function tests have been widely used as an objective measure to diagnose and follow up the course of therapy in lung diseases. Their interpretation is highly dependent on reference values (1,2). Forced expiratory volume in 1 second (FEV1) is widely used to estimate the degree of pulmonary impairment in cases of asthma and other obstructive lung diseases. It has proved to be an excellent method to monitor the progress of individual patients (3).

It is important to establish lung function reference values for each population (4). Lung function differs from one population to other, depending on multiple factors including size and shape of the rib cage, respiratory muscles' strength and possibly parenchymal lung development (5). There are also other influences such as environmental pollution, socio-economic conditions, nutritional status and exercise, which have direct and indirect effects on lung function (6–8).

Currently available reference values of pulmonary functions tests are mostly based on data from European and North American populations which vary from other populations in body stature and ethnic origin (9). Having local spirometric prediction equations will enhance the reliability of the evaluation of lung function (10). It is therefore important to establish normative values relevant to the ethnic characteristics of the Saudi population.

A literature review yielded only studies among pulmonary patients or adults, but no studies from Saudi Arabia among healthy children (11–13). A study was therefore designed to determine the FEV-1 and forced vital capacity (FCV) reference values for healthy Saudi Arabian children and adolescents and to derive prediction equations for these.

## Methods

### Study design and sampling

This cross-sectional study was conducted among normal healthy schoolboys and schoolgirls aged 6–18 years. It used multistage, stratified random sampling in 6 different city regions in Saudi Arabia selected as sites of the study: Riyadh, Mecca, Dammam, Abha, Jizan and Al-Jouf. Three schools in each region were randomly selected. All children ( $n = 5196$ ) registered at the selected schools were invited to participate in the study.

### Data collection

Prior ethical approval and permission of the school health authority were obtained. A pilot study including 20 pupils in the Riyadh region was conducted to test the data collection tools and feasibility of the study. The purpose and objective of the study was explained to the pupils and parents by the school health medical staff prior to conduct of the study. The survey ran from September 2009 to April 2010.

The data were collected by well-trained school health medical staff (including Arabic-speaking physicians and nurses) using a 3-part questionnaire (in Arabic language) Part 1 was age and anthropometric measurements of height in cm and weight in kg. Part 2 focused on relevant history such as bronchial asthma, skeletal deformity, chronic bronchitis, chest injury, chest surgery cardiac disease, medical treatment for any respiratory condition in the 2 weeks prior to the study, and cigarette smoking. Part 3 was the physical examination performed by the same medical staff who obtained the history. Examinations focused on ear, nose and throat (ENT), chest, abdomen, skin, and any other relevant systems, e.g. cardiac, musculoskeletal systems.

Only Saudi Arabian nationality subjects were recruited. The exclusion criteria were bronchial asthma, chest cage deformities, previous chest injuries and/or chest operation, cardiac surgery, respiratory illness in the last 2 weeks and cigarette smoking (if 5 cigarettes or more per day).

Prior to performing spirometry, the procedure was explained and demonstrated to each child. The pulmonary function test was conducted with the child in a sitting position with the head straight. A minimum of 3 trials were allowed and the best reading was chosen for analysis based on taskforce standard series of the American Task Force standard and European Respiratory Society (14).

Each participant was instructed to take a deep breath and then blow into the mouthpiece as hard and fast as he/she could. The same spirometers were used throughout the study and the tests were performed by the medical staff who were introduced to the study and became acquainted with proper use at the spirometer.

Spirometers used in the study displayed the total valuation of lung function including FVC and FEV1.

### Statistical analysis

The data were analysed using SPSS, version 18. Absolute numbers and proportions were used to describe the sample distribution across the different cities and age groups. Means and standard deviations (SD) were used to describe age and lung functions. Independent *t*-test was used to test the statistical significance of the difference between males and females. Pearson coefficient of correlation (*r*) was used to investigate the correlation between anthropometric variables and lung functions. Multivariate linear regression model was used to produce coefficient of determination ( $R^2$ ) and prediction equations were developed. Since lung function data

from males and females were significantly different, regression analysis was applied to each sex separately.

## Results

Out of 5196 children invited to participate in the present study spirometric tests were done for 4526 (87.1%); 133 (2.6%) children refused to participate and 568 (11.0%) were excluded for health reasons [bronchial asthma (75), musculoskeletal diseases (14), smokers (227), cough (161), obesity (26) and ENT problems (34)]. Of the 4526 healthy schoolchildren who agreed to participate in the study 2226 (49.2%) were males and 2300 (50.8%) females. Table 1 shows the age and regional distribution of the children by age and sex.

Table 2 shows that while the mean age of females was higher than males [12.8 (SD 3.4) versus 12.5 (SD 3.4) years] the mean height of males was higher than females [145.9 (SD 17.4) versus 144.5 (SD 14.6) cm]. The differences were statistically significant.

FEV1, FVC and FEV1/FVC were statistically significant higher in males than females ( $P < 0.001$ ) (Table 2). The Pearson correlation coefficients between the anthropometric and pulmonary function measures are shown in Table 3. Height was the highest correlated anthropometric variable with FEV1 ( $r = 0.61$ ). This was true for both males ( $r = 0.71$ ) and females ( $r = 0.50$ ). Age and weight were also correlated with FEV1. All the correlation coefficients were higher for males than females. The same trend was also present in the correlation between anthropometric variables and FVC ( $r = 0.49$  for height, 0.40 for weight and 0.40 for age). All coefficients of correlation were statistically significantly different between males and females ( $P < 0.05$ ).

Multivariate linear regression analysis was done for the anthropometric variables and lung functions in children and adolescents (Table 4). In males the

**Table 1 Demographic characteristics of the studied sample of healthy Saudi Arabian children and adolescents, 2010 ( $n = 4526$ )**

Characteristic	Males		Females		Total	
	No.	%	No.	%	No.	%
<b>Region</b>						
Riyadh	400	18.0	426	18.5	826	18.2
Mecca	190	8.5	363	15.8	553	12.2
Dammam	394	17.7	318	13.8	712	15.7
Abha	440	19.8	419	18.2	859	19.0
Jizan	355	15.9	420	18.3	775	17.1
Al-Jouf	447	20.1	354	15.4	801	17.7
<b>Age (years)<sup>a</sup></b>						
6–9	534	24.1	480	21.0	1014	22.5
9–12	569	25.7	603	26.4	1172	26.0
12–15	591	26.7	609	26.7	1200	26.7
15–18	523	23.6	591	25.9	1114	24.8

<sup>a</sup>Age was unknown for 26 students.

model explained 53.9% of FEV1 and 35.1% of FVC variations. In females it explained 25.3% of FEV1 and 16.5% of FVC variations. In the total studied sample 37.3% of variation in FEV1 and 24.1% of FVC were explained by the model. All changes in  $R^2$  were statistically significant ( $P < 0.05$ ).

The normal values of FEV1 and FVC (between 2.5 and 97.5 percentiles) increased with increases in height in both males and females (Figures 1–4).

## Discussion

Pulmonary function tests are widely used as medical decision-making

tools. They are relatively simple and non-invasive, but their interpretation depends on reference values (15). Studies have demonstrated that reference values based on European populations may not apply in other populations (16). Development of population-specific spirometric prediction equations is essential to ensure the reliability of lung function evaluation (17).

The present study revealed that the mean FEV1 and FVC were 1.78 (SD 0.75) L and 2.19 (SD 0.98) L respectively for males and 1.46 (SD 0.68) L and 1.80 (SD 0.92) L respectively for females. A similar study in Jordan included 204 males and 224 females aged 7–18 years and found that the mean

**Table 2 Anthropometric and lung function variables among Saudi Arabian children and adolescents, 2010**

Variable	Boys ( $n = 2226$ )		Girls ( $n = 2300$ )		P-value
	Mean	(SD)	Mean	(SD)	
Age (years)	12.5	(3.4)	12.8	(3.4)	0.004
Height (cm)	145.9	(17.4)	144.5	(14.6)	0.01
Weight (kg)	44.1	(18.9)	43.3	(16.0)	0.129
FEV1 (L)	1.78	(0.75)	1.46	(0.68)	< 0.001
FVC (L)	2.19	(0.98)	1.80	(0.92)	< 0.001
FEV1/FVC	83.9	(17.2)	76.5	(30.9)	< 0.001

SD = standard deviation; FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity.

**Table 3 Correlation between anthropometric and pulmonary function variables among Saudi Arabian children and adolescents, 2010**

Variable	Correlation coefficient			P-value
	Males	Females	Total	
<b>FEV1</b>				
Height	0.714	0.496	0.611	< 0.001
Weight	0.647	0.330	0.500	< 0.001
Age	0.690	0.366	0.511	< 0.001
<b>FVC</b>				
Height	0.578	0.395	0.492	< 0.001
Weight	0.520	0.256	0.396	< 0.001
Age	0.557	0.274	0.400	< 0.001
<b>FEV1/FVC</b>				
Height	0.091	0.105	0.098	< 0.001
Weight	0.096	-0.075	-0.004	0.764
Age	0.092	0.011	0.032	0.035

FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity.

FEV1 ranged from 1.2 to 4.0 L, while FVC ranged from 1.2 to 4.5 L among children (18). Trabelsi et al. in Tunis reported that the mean FVC was 2.37 (SD 0.81) L and the mean FEV1 was 2.08 (SD 0.7) L for Tunisian children and adolescents aged 6–16 years (19). The variation in mean values as well prediction equations is widely accepted and attributed to age, sex, body stature, ethnic, genetic and environmental differences (20).

FEV1 and FVC were higher in males than females in the present work. Studies in different parts of the

world agreed with this finding. A study conducted at The Aga Khan University Hospital in Pakistan found that mean FEV1 and FVC were higher in males than females in all age groups (9). Manzke et al. reported that the growth pattern is different in males than females and expected that lung function prediction equations should be different for both sexes (21). Their finding was in agreement with the present study results whereby males and females had 2 different prediction equations. Also Thurlbeck in the early 1980s studied the lung morphometry

of 36 boys and 20 girls aged 6 weeks to 14 years and found that boys tended to have larger lungs per unit of stature and that the total number of alveoli was greater in males than females (22).

The relationship of anthropometric measurements and values of FEV1 and FVC was assessed by linear logarithmic and power models, but simple linear models were found to be the best predictive equations for lung functions. The present study revealed that height was positively associated with reference values of pulmonary function in children and adolescents. Consistent with this finding Barcala et al. in Spain found that height was the independent variable with the greatest predictive power for lung function (23). Also Vijayan et al. in India reported that among 7–19-year-olds height influences the prediction equations to a greater extent in males than females, but that weight had a greater influence in girls (24). In Hong Kong a study among Chinese children and adolescents has noted that the most important variable affecting the spirometric variables values was height (25). The effect of height may be attributed to the fact that during childhood the lungs increase in proportion to the increase in height and the increase in height leads to an increase in lung volume and

**Table 4 Multiple regression analysis for lung function parameters among Saudi Arabian children and adolescents, 2010**

Dependent variable	Intercept	Height	Weight	Age	R <sup>2</sup>
<b>Males</b>					
FEV1	–	0.343	0.187	0.255	0.539
FVC	-1.21	0.288	0.136	0.205	0.351
FEV1/FVC	78.45	0.001	0.063	0.046	0.010
<b>Females</b>					
FEV1	-2.49	0.650	-0.129	-0.074	0.253
FVC	-2.71	0.566	-0.109	-0.108	0.165
FEV1/FVC	-30.70	0.506	-0.375	-0.135	0.080
<b>Total</b>					
FEV1	-2.31	0.587	0.039	-0.009	0.373
FVC	-2.38	0.039	0.020	-0.043	0.241
FEV1/FVC	19.51	0.377	-0.209	-0.135	0.033

FEV1 = forced expiratory volume in 1 second; FVC = forced vital capacity.

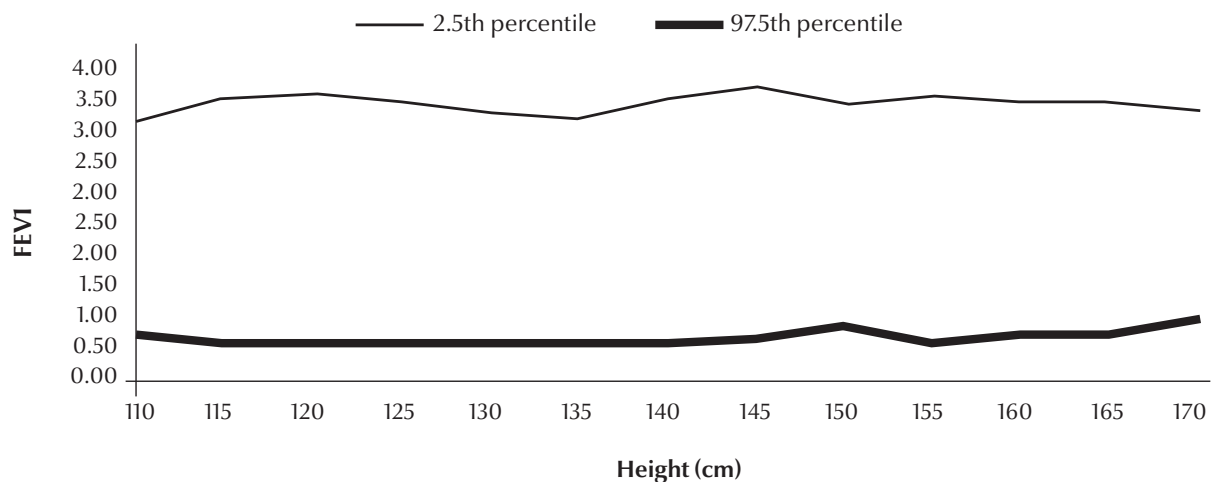


Figure 1 Forced expiratory volume in 1 second (FEV1) chart for Saudi Arabian male children aged 6–18 years old

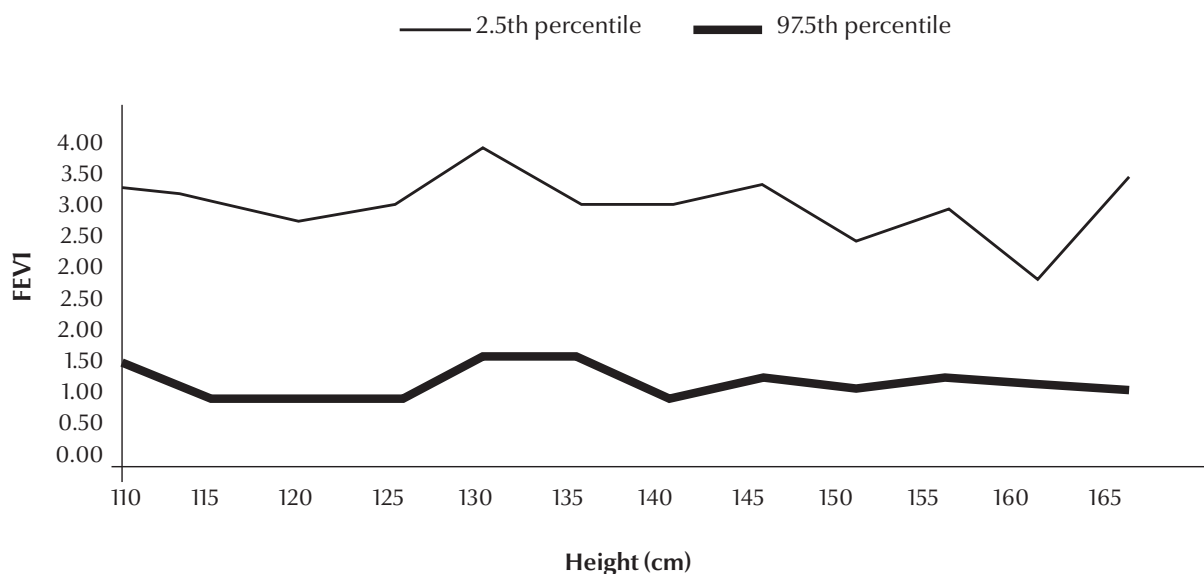


Figure 2 Forced expiratory volume in 1 second (FEV1) chart for Saudi Arabian female children aged 6–18 years old

capacity. Furthermore, height can be accurately measured without the use of special equipment or techniques (26).

The present work shows that age was one of the determinants of spirometric values. Chatterjee and Saha in India reported that age and height were significant predictors of FEV1 and FVC (27). Borsboom et al. studied the pubertal curves of ventilator function and reported that age improved the power of prediction equations

because it was correlated with growth and development, particularly the strength of intercostal muscles (28).

The present study had some limitations. It only developed reference values for 2 lung function parameters (FEV1 and FVC). Although 3 schools were selected from each city the number of participants was not equal across cities due to variations in exclusions due to morbidity and refusal to participate among school-children.

## Conclusion

In conclusion, this study has developed normal FEV1 and FVC values and prediction equations for Saudi Arabian children and adolescents (6–18 years). These national reference values need to be used and tested by health-care providers in Saudi Arabia. A prospective study using repeated measures and including all lung function parameters is recommended among Saudi children.

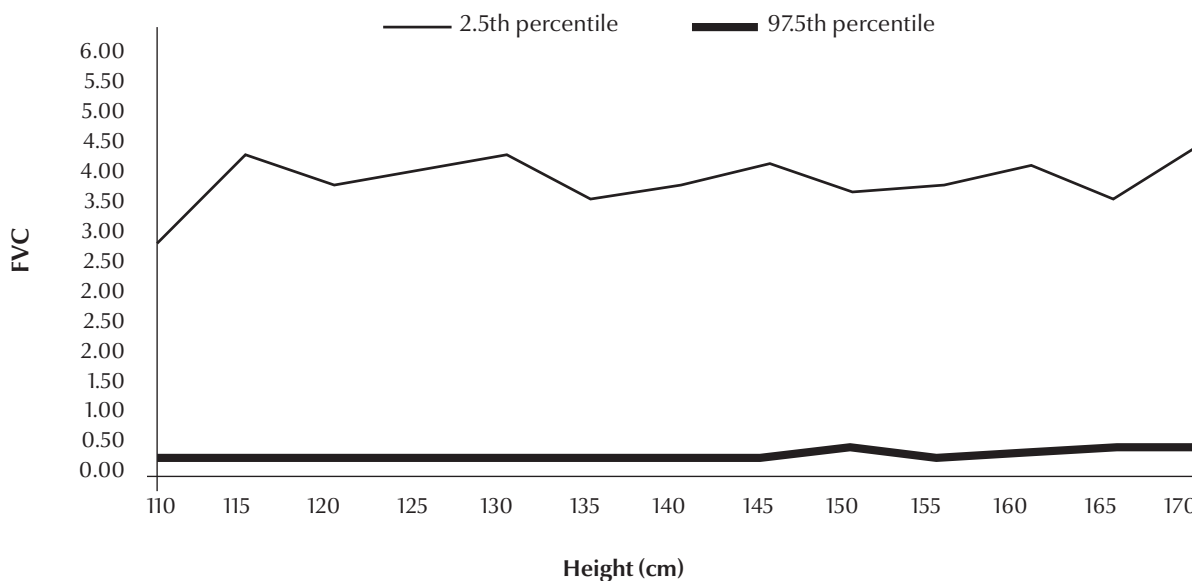


Figure 3 Forced vital capacity (FVC) chart for Saudi Arabian male children aged 6–18 years old

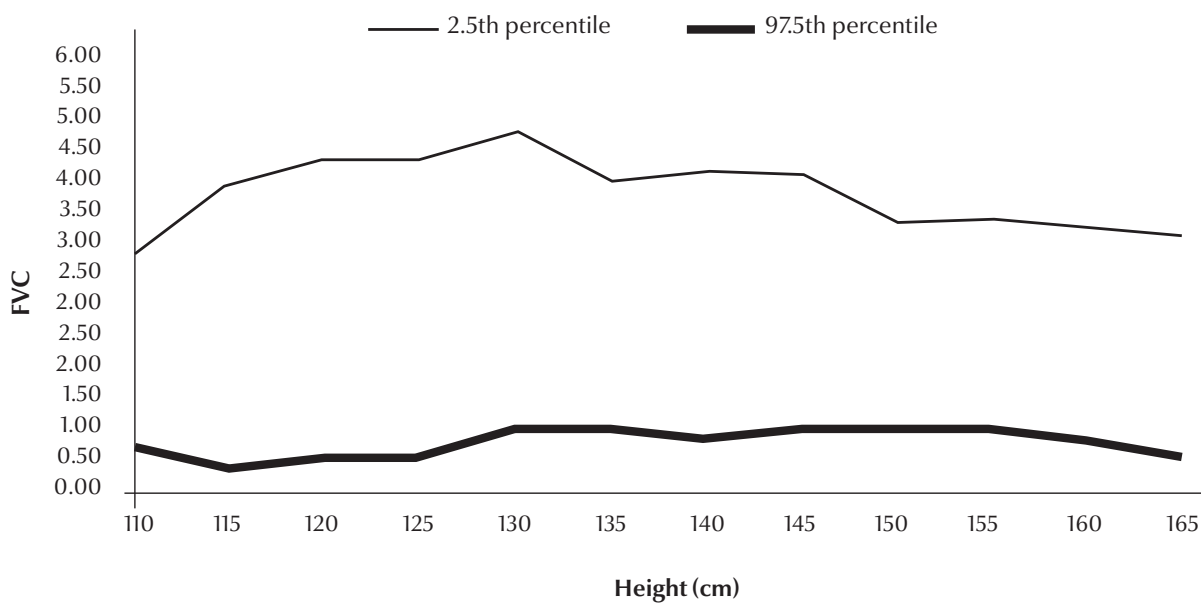


Figure 4 Forced vital capacity (FVC) chart for Saudi Arabian female children aged 6–18 years old

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