ORIGINAL ARTICLE

The influence of body posture on the impulse oscillometry system parameters in children

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ABSTRACT

Impulse oscillometry (IOS) is an alternative and supplementary method for evaluating respiratory mechanics, but whose performance technique still requires standardization. **Objective:** This study sought to analyze and compare the results of IOS parameters when done with schoolchildren in standing (orthostatic) and sitting positions. **Method:** Analytical cross-sectional study. Healthy school children of 6 to 12 years were submitted to spirometry and two exams with IOS (randomized sitting and standing). Data were analyzed with SPSS 20.0. Using the Shapiro-Wilk test and, according to the normality of the data, applying the Wilcoxon or Student *T*-tests, the postures were compared. In correlating between the anthropometric data and the oscillometric variables, the Pearson or Spearman test was used, with $p \leq 0.05$. **Results:** Participating were 72 children with a mean age of 8.42 ± 1.26. There was no difference between the oscillometric variables in the two postures. In the sitting position, there was low negative correlation between trunk height (Hetrunk) and the following variables: resistance to 20Hz (R20) ($p = 0.034$) and 5Hz (R5) ($p = 0.041$), central resistance (Rescent) ($p = 0.018$), and impedance (Z) ($p = 0.030$). In the standing position there was low negative correlation between age and peripheral resistance (Resper) ($p = 0.011$), R5 ($p = 0.014$), and Z ($p = 0.009$). **Conclusion:** There was no difference noted in comparing the oscillometric variables in the two postures. However, the airway resistance was influenced by Hetrunk, height, and age. The orthostatic position seems to be the best position to analyze Resper.

Keywords: Child, Posture, Respiratory Mechanics, Respiratory Function Tests

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INTRODUCTION

The Impulse Oscillometry System (IOS) is an instrument that measures the mechanical properties of the lungs and thorax, being useful as an alternate supplementary means of testing pulmonary function. There is an advantage to using tidal breathing volume instead of forced ventilation in determining the impedance of the respiratory system. The test is quick to apply, is very reproducible, and works with all age brackets.[1]

There has been great interest in pediatric research with IOS involving asthmatic and fibrocystic patients as well as in determining the reference levels of this system for healthy children.[2,3] The majority of studies perform the test in the seated position, in spite of there having been as yet no investigation as to the influence of this posture on the test results.[2,3]

Body posture is known to have a direct influence on the respiratory system. Changes in the body position alter the thoracic-abdominal biomechanics as well as the breathing process due to changes in the action of the diaphragm muscle. There are also changes in transpulmonary pressures and in the contractility of the respiratory muscles.[4]

As for breathing, the seated position presents a certain mechanical disadvantage compared to the standing position.[5,6] However, there are still no investigations into aspects related to the respiratory system resistance. Especially in children, whose respiratory evaluation is more complicated where growth and development aspects must be considered, little is known.

In the case of IOS, the sitting position is recommended for the exam, yet no study has been conducted comparing this and other postures regarding the performance and results of the test. Most studies up until now have involved impulse oscillometry on adult samples, most of whom had a chronic obstructive disease and were tested in the seated position.[1,2]

In this context, seeing whether there are any significant repercussions from differing body positions on the parameters of this new instrument within the pediatric age bracket could contribute to the development of clinical evaluation protocols and standardization of the oscillometry technique, in addition to adding knowledge to one more functional aspect of the infantile respiratory system. This knowledge will underpin therapeutic and diagnostic strategies for children with respiratory dysfunctions and also contribute to the quality and assistance involving the use of this instrument in pediatrics.

OBJECTIVE

The objective of this study was to analyze and compare the parameters obtained from impulse oscillometry exams on children in both the sitting and standing positions.

METHOD

This was an observational analytical study, cross-sectional and randomized, approved by the Committee on Ethics in Research of the *Universidade do Estado de Santa Catarina* - UDESC (protocol 42/2011). The data were collected from two private schools in the Greater Florianópolis area, Santa Catarina - Brazil, and included healthy children between 6 and 12 years of age.

In addition to the Terms of Free and Informed Consent (TFIC), the parents/guardians were also sent a questionnaire prepared by the researchers concerning the children's physical activities, health (history of illnesses, treatments, allergies, and number of smokers in the home), living habits (meals, hours of sleep, after-school activities), and family socio-economic conditions.

Children with a signed TFIC and duly completed questionnaire were included if they had no history or diagnosis of diseases of a cardiopulmonary, musculoskeletal, genetic, or neurological nature. Students were excluded if they presented a spirometric parameter of forced expiratory volume in the first second (FEV1) of less than 80% of predicted[7] or if they did some of the proposed procedures incorrectly.

Body weight was measured using a G-TECH analog scale and height, by a measuring tape. From these data the children were characterized according to Body Mass Index (BMI) and Body Surface (BS). The platform of the *Telessaúde Brasil* program was used to calculate the former,[8] and the latter according to the Dubois equation ($weight^{0.425} \times height^{0.725} \times 0.007184$).[9] The height of the trunk (Hetrunk) was also measured for all the children: the distance between the reference points of the seventh cervical and the fifth lumbar vertebrae. To collect these data, the children wore light clothes, no shoes, and remained in an erect standing posture with the head in a neutral position. The same evaluator conducted all these measurements.

In order to randomize the posture sequence of the IOS exam (sitting/standing or standing/sitting), one datum was considered: those whose resulting number was even began in the sitting position and those with an odd-numbered result began standing. All the children did the two IOS examinations on the Jaeger Pneumatograph - Master Scope IOS machine,[10] which was calibrated at the beginning of each data-collection day using a 3-liter syringe. The examinations were conducted in accordance with the recommendations of the *American Thoracic Society* (ATS).[10]

In both postures the child used a mouthpiece, a nose clip, and was instructed to breath normally and calmly without closing his throat and to keep his head in a neutral horizontal position. One assistant held the cheeks of the subject to avoid the "Upper Airway Shunt" effect during the test. In this period, 20 seconds of stable breathing were recorded and the data stored.[2,11]

While standing, the child remained as erect and straight as possible for the entire test. For the sitting posture, a chair was used with no inclination making the student remain with his column totally supported against the chair, with his hips and knees flexed at 90º and feet flat on the floor.

The following oscillometric variables were considered: respiratory impedance (Z), central respiratory resistance (Rescent), peripheral respiratory resistance (Resper), resistance measured at 5Hz (R5), resistance at 20 Hz (R20), Reactance (X), and resonant frequency (Fres).[11]

Following the IOS tests, to prevent any influence from forced maneuvers,[12] a spirometric test was conducted in accordance with the *II Consenso Brasileiro sobre Espirometria*,[13] (The Second Brazilian Consensus on Spirometry) to determine the child's health. The same machine also registered measurements of forced vital capacity (FVC), FEV_1, peak exhalation flow (PEF), and forced exhalation flow (FEF) at 25-75% of the FVC curve ($FEF_{25-75\%}$), in absolute values (liters) as well as percentages of the predicted values according to Polgar et al.[14] The same evaluator conducted the spirometry as well as the IOS.

All data were analyzed via the SPSS version 20.0 statistical program. Normality of the data was initially determined according to the

Kolmogorov-Smirnov test and the variables classified as normally distributed (Resper sitting - ResperS, Rescent sitting - RescentS, R20 sitting - R20S, R5 sitting - R5S, Z sitting - ZS, X sitting - XS, Rescent orthostatic (standing) - RescentO, R20 standing - R20O, R5 standing - R5O and Z standing - ZO) and abnormal (weight, age, height, BMI, BS, Hetrunk, Fres sitting - FresS, Resper standing - ResperO, Fres standing - FresO, and X standing - XO). The Wilcoxon test or the Student *T*-test were used to compare between the results for standing and sitting postures. The Spearman correlation test analyzed the correlation between the anthropometric data (age, weight, height, BMI, Hetrunk, and BS) and the oscillometric variables in the two postures. The data were presented via descriptive statistics and frequencies, expressed in averages and standard deviation. For all the statistical tests, $p \leq 0.05$ was adopted as significant.

RESULTS

There were 124 children evaluated; of these, 52 were excluded-22 for presenting bronchitis or asthma, one for being unable to do the IOS, and 29 for not doing acceptable and reproducible spirometric tests.

Of the 72 participating children, 40 were female and 32 were male, with an average age of 8.42 ± 1.26 years. Table 1 characterizes the sample as to age, weight, Hetrunk, BMI and BS.

The students presented spirometric parameters (average ± standard deviation) in absolute values and in percentage of predicted value for: FVC 1.99 ± 0.35L and 94.49 ± 10.73%; FEV_1 1.85 ± 0.30L and 95.80 ± 9.65%; PEF 3.75 ± 0.65L and 80.93 ± 11.78%; $FEF_{25-75\%}$ 2.36 ± 0.48L and 96.75 ± 16.47%.

Table 2 gives descriptive data on the IOS variables, for sitting and standing, and the results of the comparison. There was no statistically significant difference in any oscillometric variable, according to the Wilcoxon test (Resper and Fres) and the Student *T*-test (Rescent, R20, R5 and Z), between the sitting and standing postures.

In the sitting posture, a correlation was observed between the anthropometric variable of Hetrunk and the oscillometric variables of Rescent (p = 0.018), R20S (p = 0.034), R5S (p = 0.041), and ZS (p = 0.030). While in the standing (orthostatic) posture there was a relationship between age and the data for ResperO (p = 0.011), R5O (p = 0.014), and ZO (p = 0.009), as well as between the height and ResperO (p = 0.003) and ZO (p = 0.040). The Hetrunk showed correlations with RescentO (p = 0.004), and R20O (p = 0.020). The BS showed a correlation with the same variables (RescentO p = 0.037, and R20O p = 0.027) (Table 3). According to Baquero,[15] all the correlation coefficients were low and negative.

Table 1. Data distribution of the sample characterization variables

	Minimum	Maximum	Average	Standard Deviation
Age (years)	6	11	8.42	1.264
Weight (Kg)	19	57	33.097	9.2837
Height (m)	1.13	1.56	1.3465	0.09419
Hetrunk (cm)	18.6	55.0	34.822	5.5479
BMI (Kg/m²)	12.4	29.41	17.9987	3.66714
BS (Kg/cm²)	0.77	1.48	1.1058	0.17432

BMI = Body mass index; Hetrunk = height of trunk; BS = Body surface.

Table 2. Distribution of the data on oscillometric variables, on sitting and standing postures, and resulting from comparisons between the two postures (*p* value)

	Minimum	Maximum	Average	SD	*p* value
ResperS	1.02	7.65	4.2642	1.33790	0.370*
ResperO	2.55	7.14	4.4271	1.23694	
RescentS	0.9	5.60	3.4418	1.10573	0.488**
RescentO	0.84	6.78	3.5368	1.12630	
FresS	1.68	26.24	15.0932	6.58416	0.170*
FresO	1.66	27.15	14.3935	7.16645	
R20S	2.72	7.39	5.0701	1.05366	0.065**
R20O	2.41	9.87	5.2869	1.18790	
R5S	3.16	10.96	6.8118	1.54700	0.271**
R5O	3.92	11.71	7.0060	1.65994	
ZS	3.16	11.23	6.9946	1.56842	0.241**
ZO	3.95	11.79	7.1992	1.65994	
XS	-2.94	0.21	-1.4656	0.66479	-
XO	-3.38	3.37	-1.4008	0.86665	

ResperS = Peripheral resistance sitting; ResperO = Peripheral resistance orthostatic (standing); RescentS = Central resistance sitting; RescentO = Peripheral resistance orthostatic (standing; FresS = Resonant frequency sitting; FresO = Resonant orthostatic frequency (standing; R20S = Resistance 20Hz sitting; R20O = Resistance 20Hz orthostatic (standing; R5S = Resistance 5Hz sitting; R5O: Resistance 5Hz orthostatic (standing; XS = Reactance sitting; XO = Reactance orthostatic (standing; ZS = Impedance sitting; ZO = Impedance orthostatic (standing; * = Wilcoxon test (< 0,05); ** = Student *T*-Test (< 0.05); *p* = statistical significance; SD = Standard Deviation.

For its being a simple method, IOS is an important instrument in evaluating children's lungs, supplementing the classic test methods.[16] It is an examination that measures the respiratory resistance from the central zone to the periphery of the trachiobronchial tree as well as the respiratory impedance based on the flow volume,[2] which allows differentiation between the proximal and distal components of the respiratory system.[11]

The present study compared the parameters of the IOS between sitting and standing postures in a sample of school children. There was concern among the investigators as to the characterization of the sample, with control of the spirometric variables for inclusion of the participants, which guaranteed that these accurately present pulmonary function. Adaptation of the biometric data (weight, height, BS, and BMI) for the corresponding age bracket reinforced the compatibility of the group studied.

In the adopted method, the average BMI for the children (17.99 ± 3.66 Kg/m²) was monitored and was considered suitable to reach a percentile of 85.[8] This being the case, the sample was shown to be worthy of analysis when the objective was the comparison of the parameters between body postures. This attention to the sample's character is due to the fact that obesity could influence the results of the tests on pulmonary function. This is because in this condition there can be a compression of the adipose tissue on the thoracic cavity

Table 3. The results of correlation tests between the anthropomorphic data and the oscillometric variables

	Age	Height	Weight	BMI	Hetrunk	BS
ResperO	0.899	0.245	0.433	0.892	0.087	0.539
ResperO	0.011*	0.003*	0.149	0.970	0.071	0.912
RescentS	0.113	0.333	0.350	0.457	0.018*	0.659
RescentO	0.301	0.182	0.138	0.366	0.004*	0.037*
FresS	0.355	0.890	0.498	0.224	0.148	0.799
FresO	0.899	0.153	0.551	0.916	0.315	0.401
R20S	0.147	0.296	0.459	0.850	0.034*	0.134
R20O	0.063	0.117	0.322	0.865	0.020*	0.027*
R5S	0.062	0.106	0.319	0.756	0.041*	0.888
R5O	0.014*	0.066	0.627	0.561	0.105	0.184
ZS	0.079	0.101	0.292	0.720	0.030*	0.912
ZO	0.009*	0.040*	0.470	0.691	0.074	0.193

ResperS = Peripheral resistance sitting; ResperO = Peripheral resistance orthostatic (standing); RescentS = Central resistance sitting; RescentO = Peripheral resistance orthostatic (standing); FresS = Resonant frequency sitting; FresO = Resonant orthostatic frequency (standing); R20S = Resistance 20Hz sitting; R20O = Resistance 20Hz orthostatic (standing); R5S = Resistance 5Hz sitting; R5O: Resistance 5Hz orthostatic (standing); XS = Reactance sitting; XO = Reactance orthostatic (standing); ZS = Impedance sitting; ZO = Impedance orthostatic (standing; * = statistical significance.

and those structures involved in pulmonary expansion, thereby altering the breathing mechanics, which compromises the compliance between the thoracic cavity and the lungs. These alterations lead to the diminution of pulmonary volume and capacity, especially when there is an accumulation of adipose tissue in the abdominal region leading to an increase in peripheral resistance.[17]

As to the main focus of the study, the relationship between the postures and the IOS parameters, the literature has already presented some discussions. Some studies show higher spirometric values for some parameters (FEV_1, FEV_1/FVC, FEF_{max}),[5,6] when the test was performed in the standing position. The researchers ascribed these results to the mechanical breathing advantages in the standing position over the sitting position, which carries greater transpulmonary pressures. This is why the interaction between the thoracic cavity and the lungs makes the lungs expand in all directions when inhaling-especially the diaphragm, which contracts uniformly, moving down so as to increase thoracic capacity.[18] In the sitting posture, the hip flexion brings increased contents into the abdomen, which interferes with the "ideal" stretching of this muscle. Additionally, if the individual leans back against the chair during the test, this contact with the chair back and the thorax could bring a slight restriction to thoracic expansion.[4]

In most of the IOS studies the participant adopts a seated posture for the execution of the test[3,16] and, up until now, only one study conducted the test in the standing position.[19] The studies that use a seated posture base themselves on recommendations by the ATS/ERS (European Respiratory Society) for performing the forced oscillation technique, however, the IOS does not involve forced breathing maneuvers and therefore doubt is cast on the need to adopt a seated posture for this test.[10]

In spite of these concepts, the present study did not find any significant differences between the sitting and standing postures, nor in any of the oscillometric parameters analyzed (Resper, Rescent, Z, R5, R20, Fres, and X).

The variables Resper, Rescent, Z, R20, and R5 showed higher values in the standing position than in the sitting position. This poorer performance of the variables related to the resistance of the respiratory system (Resper, Rescent, R20, and R5) showed a numerical superiority among standing students, but it was not statistically significant and could be attributed to the annulment of abdominal and resistive components present in the seated position. Perhaps in the pediatric population this event has less influence on the test results, for there are less abdominal contents and adipose tissue in this age group. The same investigation deserves to be done in an adult population to confirm this, since this data could alter the recommendation as to the posture for doing this test.

Regarding the standing posture, it was confirmed that the height of the students influences the oscillometric measurements since children with shorter stature present greater peripheral resistances.[3,20] This fact could be due to shorter children characteristically having a proportionally shorter thorax than those taller,[21] which leads to having smaller airways which, for Decker et al.[3] is the main justification for this relationship between resistance and height. This event is also in accordance with Poiseuille's Law, which states that resistance is inversely proportional to the radius of the airways.[22]

Another variable that, in standing posture, interfered in the results of R5, Resper, and Z was age. Very young individuals are known to have increased airway resistance.[23] Since the studied population included children, these presented greater peripheral resistance the younger they were.[20] However, this finding was confirmed only in standing posture, perhaps because this was a neutral posture that showed regional differences arising from different sizes stemming from their ages.

The Z parameter, which represented complex respiratory resistance and included both resistance and reactance,[11] also showed a correlation with age and height in standing posture. Since it is a variable that encompasses the two essential elements of the oscillometry system, this relationship reinforces the above-mentioned findings: the influence of age and of height on the resistance in the standing posture.

Finally, in the standing posture, a relationship appeared between BS and the resistances (R20 and Rescent). The formula used to calculate the BS of each child was the same applied by other researchers in pediatric populations.[3,24] However, in the works conducted with IOS, BS was evaluated only to characterize the sample, without investigating its relationship with the other oscillometric variables,[3,25] which restricts discussions along these lines.

Regarding the results obtained in the sitting posture, the values for Fres and X were greater in this position than in the standing; however, none of these differences was significant. Defined as a value of the frequency when the reactance had a value of zero, the Fres is described as the point at which elastic and inertial reactance are equal.[11] Considering that these values were numerically greater, the sitting posture probably facilitated the starting point of the elastic component of the pulmonary structures, since the action of gravity in this position is minimized in relation to the individual's height.

Today it is known that the relationship between respiratory function and the seated posture is that, due to gravity, this position allows greater ventilation in the dependent regions of the lungs than in the independent regions.[26] There is generally a diminution in the abdominal breathing pattern with the predominance being thoracic, thereby causing a greater variation in thorax volume.[27] As to the execution of evaluations of the respiratory system in this position in comparison to other positions, especially the standing position, little has been investigated.[6,28]

It is important to point out that in both postures a relationship can be seen between Hetrunk and the R20 and Rescent variables, since these two oscillometric parameters represent the central resistance in the airway.[16] Being a negative relationship, the greater the Hetrunk, the lower the resistance value. Considering that, anatomically, a larger thoracic cavity can hold a larger bronchial trunk and the bigger the trunk, the better the accommodation of the central structures, the correlations shown here are very representative of the respiratory anatomy. Corroborating this idea, Willians et al.[29] report that children have more respiratory system resistance than adults do owing to the smaller dimensions of their lungs and upper airways. These findings indicate a good geographical representation of IOS, also because the Hetrunk doesn't change with the posture, as verified in the present study.

Lastly, no significant differences were seen among the oscillometric parameters between the postures adopted for running this test, which demonstrates that sitting or standing had no influence on the IOS results from the children. The fact of this examination not needing forced ventilation maneuvers nor requiring respiratory muscle effort, but simply tidal breathing[1] may be responsible for this postural independence. Nonetheless, some of the results seen here should be considered when choosing a technique for conducting this test. The resistance of the airways was influenced by the Hetrunk, height, and age, and orthostatism (standing posture) appears to be the best posture for analyzing Resper.

The importance of these findings owes itself to the growing clinical applicability of IOS, which has been used with diverse objectives such as the following: detection of respiratory problems, monitoring patients with chronic obstructive disease, evaluating infantile respiratory mechanics, studies on newborns, monitoring of patients on mechanical ventilation, and monitoring and diagnosis of sleep apnea.[1,2,30]

This being the case, the ideal posture to be adopted while running the test must be carefully evaluated, as it could influence the outcome. This is why further research analyzing the influence of body positioning on oscillometric variables deserves to be studied in this age group.

CONCLUSION

The oscillometric parameters analyzed in the sitting and standing postures showed no significant differences among the schoolchildren tested. Variables such as Rescent, Resper, R20, and R5 were numerically higher in the standing position, which suggests a certain influence from the abdominal and resistive components when the technique is carried out sitting. The airway resistance was shown to be influenced by the height of the subject's trunk as well as their height and age via a negative correlation with each of these anthropometric variables. Orthostatism also appears to be the best posture for analyzing the resistance of peripheral airways.

The possible mechanical disadvantage of the seated posture compared to standing deserves further careful investigations involving the IOS technique in the pediatric age bracket.

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