

Comparison of Reference Values and Short-Term Variability for Oscillatory and Spirometric Lung Function in Healthy Korean Preschool Children

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Respiratory function measurements are important in the diagnosis and follow-up assessment of respiratory diseases. The aims of this study were to establish reference values for spirometry, to compare them with respiratory resistance and impedance by an impulse oscillometry system (IOS), and to analyze 3-month follow-up studies in healthy Korean preschool children. Six hundred seven questionnaires were distributed and 497 (82%) were returned. Lung function tests were performed in 183 healthy children of the age of 3–6 years. The 3-month follow-up studies were conducted from 19 children who visited our clinic twice. Of the 183 children who underwent both IOS and spirometry, 164 (90%) and 150 (82%) met the quality-control criteria for IOS and spirometry, respectively. The regression equations of each spirometric parameter were obtained. Height was the most consistently correlated measurement in both boys and girls. All spirometry parameters, except for FEF_{25–75}/FVC, were significantly correlated with IOS parameters. There were no significant differences in respiratory resistance at 5 Hz measured by IOS (Rrs_{IOS5}), forced vital capacity (FVC), and forced expiratory volume in 1 s (FEV₁) between the first and second sets. The intraclass correlation coefficients and relative coefficients of repeatability for FEV₁, Rrs_{IOS5}, and respiratory system reactance (Xrs)_{IOS5} were 0.90 (95% CI 0.73–0.96), 0.82 (95% CI 0.53–0.93), and 0.55 (95% CI –0.17–0.83) and 22.6%, 35.5%, and 91.8%, respectively. The obtained values and regression equations provide a reference for Korean preschool children and may be of importance in evaluating lung function of preschool children with pulmonary problems. Respiratory resistance and FEV₁ for healthy young Korean children are lower than literature reported reference values for Caucasian children. Rrs_{IOS5} appears to be more stable on repeat testing than Xrs_{IOS5}.

Introduction

RESPIRATORY FUNCTION MEASUREMENTS are important in the diagnosis, management, and follow-up assessment of respiratory diseases. Spirometry is a simple test regarded as the gold standard for assessment of airflow obstruction in school-aged children. When applied to preschool children, the reliability of spirometry depends on standardized methodology¹ and quality-control criteria.² An impulse oscillometry system (IOS), which utilizes a user-friendly commercial apparatus,³ is easier to use than spirometry or plethysmography and can measure respiratory system resistance (Rrs) and respiratory system reactance (Xrs) at various frequencies.⁴

Reference values for lung function tests are influenced by subjects' age, sex, body size, and ethnic group.^{1,5,6} Spirometry

comparisons of pulmonary function in children and adolescents with different ethnic backgrounds have shown that Asian subjects have significantly lower lung function than Caucasian subjects.^{5,6} However, no reference values for spirometry are available on Korean preschool children. It is of importance to provide spirometric reference values for Korean preschool children because Koreans are ethnically different from other Asians and Caucasians and using inappropriate lung reference values may lead to erroneous clinical categorization. Since spirometry and IOS reflect different pathophysiological aspects of airflow obstruction,⁷ it is also important to determine whether IOS measurements of Rrs and Xrs differ between Asian and Caucasian children.

The use of lung function tests to diagnose and monitor patients with respiratory diseases also requires that the

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variability for each test be established. Variability is defined as the degree of agreement between repeated individual measurements,^{1,8} including within-test and short- and long-term variability.⁸ Spirometric measurements of short- and long-term variability have been reported in healthy populations and in children with lung diseases.^{9–11} The coefficient of variation, a normalized measure of dispersion of a probability distribution, of Rrs measured by IOS (Rrs_{IOS}) in preschool children has been reported to range from 6% to 10%.^{3,12,13} The between-test variability of IOS is often used when assessing bronchodilator response measured at 1–3-month intervals.^{8,14,15}

The aims of this study were (1) to establish reference values for spirometry in healthy Korean preschool children, (2) to compare them with respiratory resistance and impedance by IOS, (3) to compare these data with those of similar groups of Caucasian and other Asian children, and (4) to analyze 3-month follow-up studies of IOS and spirometry.

Materials and Methods

Study population and recruitment procedures

The source population consisted of preschool children, aged 3 to 6 years, from 5 kindergartens located in urban areas, Seongnam, Gyeonggi province, Korea, surveyed between April and August 2009. They were originally enrolled in a study¹⁶ to assess reference values for respiratory system impedance using IOS in Korean preschool children. Their parents answered the Korean version¹⁷ of the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire.¹⁸ The questionnaire also included information on secondhand smoking exposure and a past history of chronic diseases, information used to define healthy children.¹⁹ Exclusion criteria were incomplete questionnaire replies and/or an absence of signed informed consent forms, a history of prematurity, low birth weight, ventilator care, or bronchopulmonary dysplasia, exposure to household secondhand smoking, obesity (BMI ≥ 95 percentile or ≥ 25 kg/m²), a history of chronic pulmonary disease, or anyone not considered to be “healthy” as defined by Stocks et al.¹⁹ Each subject’s parents provided written informed consent, and the study protocol was approved by the Institutional Review Board of the CHA University School of Medicine.

Lung function tests

Lung function was measured according to the American Thoracic Society/European Respiratory Society (ATS/ERS) criteria¹ using a commercially available device (MasterScreen IOS, Jaeger, Germany). The equipment was transported to and stationed at each of the 5 kindergartens. Impulse oscillometry and spirometric measurements were performed according to a previous study.¹ Data for the first set of IOS measures were obtained from a previously published study by our group in which healthy Korean preschool children had been examined for IOS measures.¹⁶

Validation

IOS was performed prior to spirometry to prevent any unfavorable effects of deep inhalation on IOS parameters. Real-time respiratory impedance was also monitored; data were discarded if affected by glottic closure, incomplete

seal around the mouthpiece, movement of the mouth, coughing, talking or audible noise, swallowing, obstruction of the mouthpiece by the tongue, pressure leakage resulting from an inadequate seal of the mouthpiece, or episodes of irregular breathing. Breaths were considered for analysis only when an acceptable signal persisted for 8–16 s. Disturbances from coughing or vocalization resulted in a new measurement.

Spirometric quality-control criteria were applied in accord with a previous study.¹ Flow–volume curve was considered to be the most important criterion. Thresholds chosen for acceptability included backward extrapolated volume (V_{be}) ≤ 80 mL and $\leq 12.5\%$ of forced vital capacity (FVC),² and time-to-PEF < 160 msec.²⁰ Repeatability thresholds included a difference (Δ) between the 2 best FEV₁ (Δ FEV₁) measurements of ≤ 110 mL or $\leq 10\%$ of best effort, and a difference (Δ) between the 2 best FVCs (Δ FVC) of ≤ 110 mL or $\leq 10\%$ of best effort.¹⁰ End-of-test criteria included end-expiratory volume plateau and no specific duration of forced expiration. A minimum of 3 technically acceptable measurements were performed for IOS and spirometry.

Three-month follow-up studies of IOS and spirometry

Of the 183 healthy children recruited for assessment of pulmonary function tests, 21 agreed to undergo a second set of testing 3 months later (August to October 2009, range 2–4 months). Two children were excluded due to recent respiratory tract infections, yielding a total of 19 children who underwent analysis of 3-month follow-up studies of IOS and spirometry.

Statistical analysis

Data are presented as mean $\pm$ standard deviation (SD) unless otherwise indicated. Student’s *t*-test was used for comparisons of means. Linear regression analysis was used to assess the correlation between IOS and spirometric variables. Multivariate analysis was performed to determine independent effects of sex, age, height, and weight on lung function parameters. A stepwise multiple linear regression analysis was first performed to determine which of the following independent variables [sex, age, standing height (H), and weight] significantly correlated with a given respiratory impedance parameter. Four different equations (eg, linear, multiplicative, exponential, and logarithmic) were tested to find the optimal regression model.²¹ Factors known to

TABLE 1. CHARACTERISTICS OF THE CHILDREN IN THIS STUDY

	Healthy controls	Excluded children
Subjects (n)	183	314
Male (%)	106 (57.9)	158 (53.0)
Age (months) ^a	58.6 $\pm$ 11.1	60.7 $\pm$ 10.2
Height (cm)	108.7 $\pm$ 7.5	109.6 $\pm$ 6.8
Weight (kg)	18.8 $\pm$ 3.7	19.2 $\pm$ 3.5
BMI	15.8 $\pm$ 1.9	15.9 $\pm$ 1.8

Data are presented as mean $\pm$ SD. BMI, body mass index. ^a*P* < 0.05 between 2 groups.

BMI, body mass index; SD, standard deviation.

TABLE 2. COMPARISON OF IMPULSE OSCILLOMETRY SYSTEM AND SPIROMETRIC VALUES

	Impulse oscillometry system		Spirometry	
	Success	Failure	Success	Failure
Subjects (n)	164	19	150	33
Sex (Male)	86 (52%)	11 (58%)	74 (49%)	23 (70%) ^a
Age (months)	59.25 ± 10.83	52.00 ± 10.72 ^b	59.42 ± 10.69	54.38 ± 11.63 ^c
Ht (cm)	108.90 ± 7.58	105.37 ± 5.11 ^c	108.89 ± 7.54	106.91 ± 6.78
BMI (kg/m ²)	15.80 ± 1.92	16.09 ± 1.84	15.87 ± 1.98	15.67 ± 1.37

All curves for spirometry were visually reviewed for technical acceptability by the technologist. The following thresholds were chosen for acceptability: backward extrapolated volume (Vbe) ≤ 80 mL and ≤ 12.5% of FVC, time-to-PEF < 160 ms, and repeatability: difference (Δ) between the 2 best ΔFEV₁ ≤ 110 mL or 10% of best effort, and difference (Δ) between the 2 best FVCs (ΔFVC) ≤ 110 mL or 10% of best effort.

During IOS measurements, individual measurements were visually inspected. Measurements were excluded if there was an incomplete seal around the mouthpiece, or if there was movement of the mouth, swallowing, glottic closure, leakage, coughing, talking, or audible noise.

^aP=0.036, ^bP=0.008, ^cP=0.018, and ^dP=0.005.

FVC, forced vital capacity; Ht, height; IOS, impulse oscillometry system.

influence lung function, such as an environmental tobacco exposure or a history of chronic lung disease, were excluded from analysis because those who might have been affected by these factors were excluded prior to the present study. A 2-sided type 1 error of <0.05 was considered statistically significant. The intraclass correlation coefficient was calculated as the between-subject variance divided by the total variance.³ Three-month follow-up studies were conducted as described previously.¹ Coefficients of repeatability are expressed as absolutes or relative to baseline as percentages. The absolute coefficients of repeatability were calculated as 2 × SD of differences, and the relative coefficients of repeatability were calculated as 2 × SD of the differences between measurement sets as a percentage of the mean of the 2 measurements.²² The calculation of relative coefficient of repeatability allows a significant percentage change from baseline to be defined.²² Data were analyzed using PASW statistical software (version 18.0; PASW Statistics; Chicago, IL).

Results

Characteristics of the subjects

A total of 607 questionnaires were distributed to the parents, and 497 (82%) were returned. The remaining 298 children were excluded according to the exclusion criteria.

Another 16 children were excluded because their parents did not agree to have their child perform the tests, yielding a total of 183 subjects. The first set of pulmonary function testing was performed in 183 children. The characteristics of the 183 subjects are shown in Table 1. There were no significant differences in sex, height, weight, and BMI between included and excluded children, except that excluded children were significantly older than those included ($P < 0.05$, Table 1).

Feasibility and validation

Table 2 shows the comparison and validation of IOS and spirometry. Of the 183 children, 164 (90%) fulfilled the quality-control criteria for IOS, whereas 150 (82%) fulfilled the quality-control criteria for spirometry ($P = 0.024$). The success rate increased with age ($P = 0.008$) and height ($P = 0.05$). When the 3 variables were controlled, age was found to be significantly correlated with success rate. There was no difference in height or BMI between children who did and did not meet the quality-control criteria for spirometry. Of the 150 and 33 subjects who did and did not meet the quality-control criteria for spirometry, 74 (49%) and 23 (70%), respectively, were boys, indicating that the failure rate was significantly higher in boys than in girls ($P = 0.036$).

TABLE 3. SPIROMETRIC REGRESSION EQUATIONS FOR PREDICTING LUNG FUNCTION PARAMETERS BASED ON STANDING HEIGHT, GENDER, AND AGE IN HEALTHY KOREAN PRESCHOOL CHILDREN

	Regression equations	SEE	R ²
FVC (L) Ht	-2.020 + (0.029 × Ht)	0.13686	0.710
+ Gender	-1.910 + (0.028 × Ht) - (0.050 × G)	0.13507	0.720
+ Gender + Age	-1.632 + (0.024 × Ht) - (0.058 × G) + (0.045 × A)	0.13254	0.732
FEV ₁ (L) Ht	-1.691 + (0.025 × Ht)	0.11946	0.709
+ Gender	-1.578 + (0.025 × Ht) - (0.051 × G)	0.11717	0.722
+ Gender + Age	-1.280 + (0.02 × Ht) - (0.06 × G) + (0.048 × A)	0.11354	0.741
FEV _{0.5} (L) Ht	-1.088 + (0.018 × Ht)	0.10404	0.619
+ Gender	-1.023 + (0.018 × Ht) - (0.029 × G)	0.10337	0.627
+ Gender + Age	-0.735 + (0.013 × Ht) - (0.038 × G) + (0.047 × A)	0.09946	0.657
FEV _{0.75} (L) Ht	-1.457 + (0.022 × Ht)	0.11439	0.680
+ Gender	-1.385 + (0.022 × Ht) - (0.045 × G)	0.11257	0.692
+ Gender + Age	-1.057 + (0.017 × Ht) - (0.054 × G) + (0.049 × A)	0.10870	0.715

Ht, height (cm); G, Gender (Male=1, female=2); A, Age (years); FEV_x, forced expiratory volume in x second; SEE, standard error of the estimate.

TABLE 4. THREE-MONTH FOLLOW-UP STUDIES OF IMPULSE OSCILLOMETRY SYSTEM AND SPIROMETRY

	1st set mean (SD)	2nd set mean (SD)	Mean difference (95% CI)	P value	SDw	ICC (95% CI)	Coefficients of repeatability	
							Absolute	Relative (%)
Spirometry								
FVC (L)	1.14 (0.22)	1.09 (0.24)	-0.047 (-0.098 to 0.003)	0.064	0.08	0.95 (0.86 to 0.98) ^a	0.22	19.7
FEV _{0.5} (L)	0.84 (0.14)	0.85 (0.18)	0.014 (-0.048 to 0.076)	0.637	0.09	0.81 (0.50 to 0.93) ^a	0.25	29.3
FEV _{0.75} (L)	0.97 (0.17)	0.98 (0.20)	0.011 (-0.052 to 0.073)	0.727	0.09	0.86 (0.64 to 0.95) ^a	0.25	25.4
FEV ₁ (L)	1.03 (0.18)	1.02 (0.22)	0.002 (-0.057 to 0.061)	0.941	0.08	0.90 (0.73 to 0.96) ^a	0.23	22.6
FEV ₂₅₋₇₅ (L/sec)	1.46 (0.34)	1.61 (0.37)	-0.15 (-0.343 to 0.049)	0.131	0.30	0.51 (-0.27 to 0.81)	0.83	54.0
IOS								
Rrs _{IOS5} (kPa·s/L)	0.97 (0.29)	0.93 (0.24)	-0.044 (-0.038 to 0.127)	0.272	0.12	0.82 (0.53 to 0.93) ^a	0.34	35.5
Rrs _{IOS10} (kPa·s/L)	0.97 (0.20)	0.76 (0.17)	0.130 (-0.137 to -0.015)	0.017	0.10	0.81 (0.50 to 0.93) ^a	0.29	35.6
Xrs _{IOS5} (kPa·s/L)	-0.34 (0.08)	-0.24 (0.09)	-0.101 (-0.148 to -0.054)	<0.001	0.10	0.55 (-0.17 to 0.83)	0.27	91.8
Xrs _{IOS10} (kPa·s/L)	-0.18 (0.08)	-0.16 (0.08)	0.019 (-0.019 to 0.582)	0.304	0.06	0.68 (0.17 to 0.88) ^a	0.16	91.1
AX	2.34 (1.12)	1.99 (1.21)	-0.145 (-0.791 to 0.500)	0.634	0.8	0.67 (-0.04 to 0.89)	2.1	97.2
Rf	20.9 (2.4)	17.2 (4.4)	-3.274 (-5.93 to -0.62)	0.019	4.23	-0.04 (-1.87 to 0.62)	11.7	61.9

FEV_{0.5}, 0.75, and 1 s; FEF₂₅₋₇₅ forced expiratory flow at 25% to 75% of FVC; Rrs_{IOS5} and 10, reactance at 5 and 10 Hz; Xrs_{IOS5} and 10, reactance at 5 and 10 Hz; AX, low-frequency reactance area; Rf, resonant frequency; SDw, Within-subject standard deviation; ICC, Intraclass correlation coefficient. In bold are comparisons attaining at least a 0.05 level of significance.

Two sets of measurements were performed in 19 healthy preschool children at 3-month intervals. SDw, Within-subject SD (SD of the mean difference between the 2 measurements divided by $\sqrt{2}$); ICC, intraclass correlation coefficient (between-subject variance divided by the total variance); CR-A, absolute of coefficient of repeatability (2 SD of the mean difference between 2 sets of measurements); CR-R, relative coefficients of repeatability (2 SD of the differences between measurement sets as a percentage of the mean of the 2 measurements).

Overall, success increased with age ($P=0.018$) and was higher in females ($P=0.036$). Of the 183 children who performed the first set of both IOS and spirometry testing, 7 (3.8%) failed to meet the quality-control criteria for both IOS and spirometry. There was no difference in sex, age, or height between those who failed to meet the quality-control criteria for both IOS and spirometry and those who met the quality-control criteria for either (Table 2).

Spirometric regression equations for predicting lung function parameters

Table 3 shows the regression equations of each spirometric parameter for both boys and girls using standing height, gender, and age. Among them, the regression equations of FVC and FEV₁ had the highest R² than FEV_{0.5}, and FEV_{0.75} ($P<0.001$).

Three-month follow-up studies of IOS and spirometry

Table 4 shows the 3-month follow-up studies of IOS and spirometry. There was no significant difference in age, height, or BMI between the 183 children who participated in the first set of pulmonary function tests and the 19 who participated in both sets (Supplementary Table S1; Supplementary Data are available online at www.liebertpub.com/ped). Of the 19 subjects who completed both the initial and 3-month follow-up pulmonary function studies, the vast majority were female (14/19, 74%, $P=0.013$). The mean (SD) Rrs_{IOS5} values during the first and second sets of measurements were 0.97 (0.29) and 0.93 (0.24) kPa·s/L, respectively (mean difference, -0.044 kPa·s/L; 95% CI, -0.038 to 0.127 kPa·s/L; $P=0.27$), and the mean (SD) FEV₁ values during the first and second sets of measurements were 1.03 (0.18) and 1.02 (0.22) L, respectively (mean difference, 0.002 L; 95% CI, -0.057 to 0.061 L; $P=0.941$). The intraclass correlation coefficients and the coefficients of repeatability of the 2 sets of measurements for absolute and relative relationships are shown in Table 4. A Bland-Altman plot showed no relationship between successive measurements and the magnitude of the mean difference of the 2 sets, except for Xrs_{IOS5}, Rrs_{IOS10}, and resonant frequency (Supplementary Fig. S1A, B).

Comparison of IOS measures and spirometric measures

Table 5 shows the correlation between IOS and spirometry. All spirometry parameters, except for FEF₂₅₋₇₅/FVC, were significantly correlated with IOS parameters. Of these IOS parameters, Rrs_{IOS5} and Rrs_{IOS10} showed strong and significant correlations with FEF₂₅₋₇₅, with coefficients of determination (R²) of 0.24 and 0.23, respectively. Other spirometric parameters showed a correlation with IOS parameters comparable with FEV₁ and FEF₂₅₋₇₅ (Supplementary Fig. S2).

Discussion

Our study has successfully established reference equations for the spirometric pulmonary function parameters in ethnic Korean preschool children. We suggest using reference equations for boys and girls based on standing height alone for preschool children of Korean ethnicity. Spirometry parameters were found to be significantly correlated with

TABLE 5. COEFFICIENTS OF CORRELATION OF SPIROMETRY AND IMPULSE OSCILLOMETRY SYSTEM ($N=136$)

	Rrs_{IOS5}	Rrs_{IOS10}	Xrs_{IOS5}	Xrs_{IOS10}	AX	Rf
FVC (L)	-0.39	-0.34	0.39	0.28	-0.29	-0.23
FEV ₁ (L)	-0.45	-0.40	0.44	0.36	-0.36	-0.28
FEF ₂₅₋₇₅ (L/sec)	-0.50	-0.49	0.38	0.49	-0.54	-0.52
FEV ₁ /FVC (%)	-0.15 ^a	-0.18 ^a	0.20 ^a	0.28	-0.30	-0.23 ^a
FEF ₂₅₋₇₅ /FVC	-0.12 ^b	-0.16 ^b	0.02 ^b	0.22	-0.27	-0.37

All values were $P < 0.001$ except ^a $P < 0.05$ and ^b $P > 0.05$.

The coefficients of determination (R^2) of FEF₂₅₋₇₅ for Rrs5 and Rrs10 were 0.24 and 0.23, respectively.

FEV₁, Forced expiratory volume in 1 second; FEF₂₅₋₇₅, forced expiratory flow at 25% to 75% of FVC; Rrs_{IOS5} and Rrs_{IOS10} , resistance at 5 and 10 Hz; Xrs_{IOS5} and Xrs_{IOS10} , reactance at 5 and 10 Hz.

IOS parameters. In comparison with the spirometric parameter values of different ethnic groups, the preschool children in our study had relatively lower spirometric values than those of Caucasian children,^{9,23} a similar finding reported by previous studies on school children and adults, but higher than those of Taiwanese children²⁴ (Fig. 1A). On 3-month follow-up of preschool children, Rrs_{IOS5} appears to be more stable than Xrs_{IOS5} .

FEV₁ and Rrs likely reflect different pathophysiological aspects of airflow obstruction.⁷ Low frequency values in IOS parameters, especially Rrs, were highly correlated with FEF₂₅₋₇₅, suggesting that both low frequency values in IOS

and FEF₂₅₋₇₅ in spirometry represent small airways. FEV₁/FVC, which represents expiratory obstruction,²⁵ was weakly correlated with IOS parameters, whereas FEF₂₅₋₇₅/FVC ratio, which reflects small airway size relative to lung size,²⁶ was not correlated with IOS parameters. These findings suggest that indirect measurements of airway caliber and the degree of airway limitation by spirometry cannot be replaced by measurements of Rrs by IOS.

We excluded children with asthma, allergic disorders, a family history of allergy, and those exposed to environmental factors such as secondhand smoking, which may influence lung function.^{1,18,20} The lung function values of

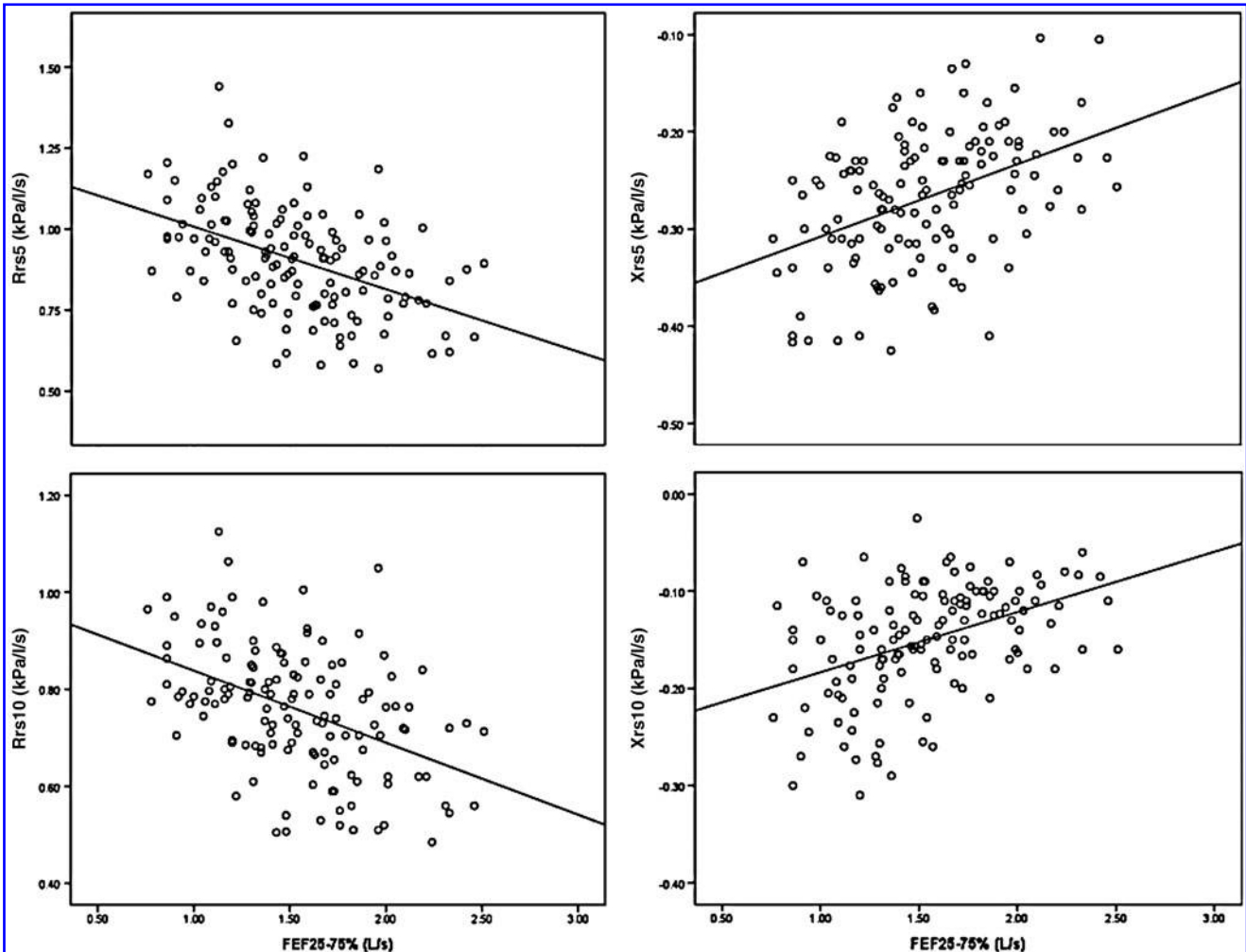


FIG. 1. The relationship between FEF₂₅₋₇₅ and impulse oscillometry system parameters. FEF₂₅₋₇₅, forced expiratory flow at 25% to 75% of forced vital capacity.

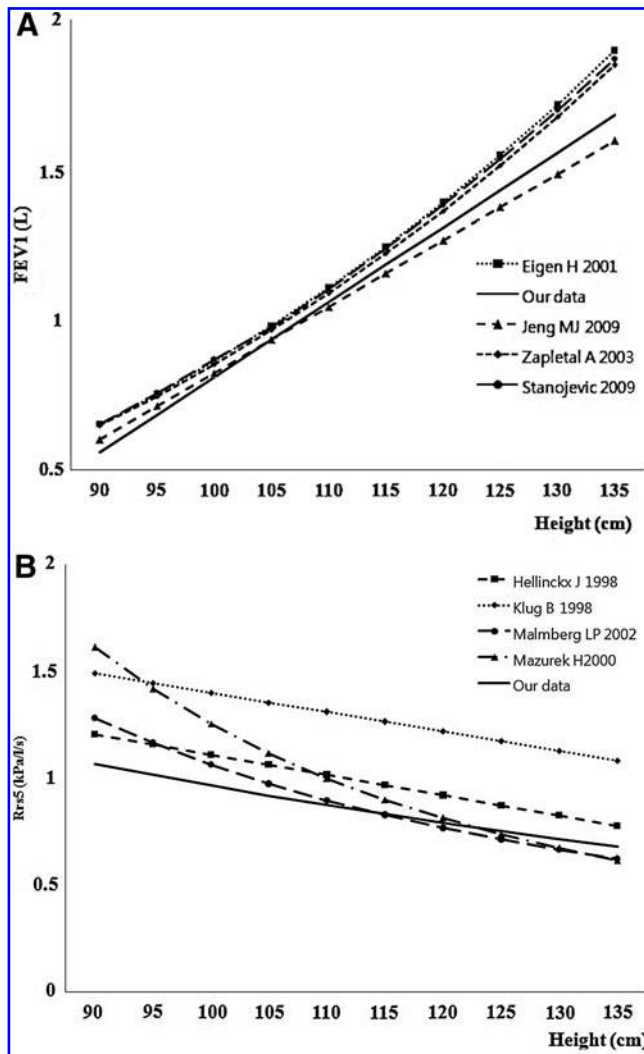


FIG. 2. Forced expiratory volume in 1 s (A) and respiratory resistance (B) compared with reference data from previous studies.

these preschool children would be higher than those of other Asians^{5,24} but lower than Caucasian children.^{27,28} Although we found difference in FEV₁ between Korean and Caucasian children, FEV₁ of taller Korean children was greater than that of Taiwanese children²⁴ but less than that of Caucasian children (Fig. 2A).^{9,23} In contrast, Rrs_{IOS5}, which represents lung resistance, was lower in shorter Korean than in Caucasian children (Fig. 2B).^{12,13,21,29} In taller Korean and Caucasian children, however, the difference in Rrs_{IOS5} diminished, which is in contrast to previous findings.²¹ The finding of the mean FEV₁ being greater in Korean than in Taiwanese children may be due to the inclusion of only healthy children, ethnic differences, spirometer, body posture, and techniques. These results indicate that, despite the difference in FEV₁ between Korean and Caucasian children, there is little difference in lung resistance.

Although IOS has been considered more feasible than spirometry, IOS was regarded as having greater variability than spirometry. We found that within-subject standard deviation for Rrs_{IOS5} was 0.12 kPa·s/L, close to the short-term variability of within-subject standard deviation for Rrs_{IOS5} of 0.039 kPa·s/L¹² and 0.13 kPa·s/L¹³ and the short-

term variability of within-subject standard deviation for Rrs_{FOT6} of 0.10 kPa·s/L.²² Our finding on the within-subject standard deviation for Xrs_{IOS5} of 0.10 kPa·s/L was also close to previous results for the within-subject standard deviation for Xrs_{IOS5} of 0.046 kPa·s/L³⁰ and 0.10 kPa·s/L¹³ and the within-subject standard deviation for Xrs_{FOT6} of 0.85 kPa·s/L.²² These findings indicate that there is little difference between short- and long-term variability of Rrs_{IOS5} and Xrs_{IOS5}. In contrast, the intraclass correlation coefficients for Rrs_{IOS5} and Xrs_{IOS5} were 0.82 and 0.55, respectively, and their relative coefficients of repeatability were 36% and 92%, respectively. Similarly, studies assessing the long-term between-test variability of forced oscillation technique (FOT) and spirometry and comparing weekly variations in school-aged children³¹ and adults³² showed that the variations in Rrs_{FOT} were much greater than those in FEV₁. We found that the intraclass correlation coefficient of Rrs_{IOS5} was lower than that of FEV₁ but close to those of FEV_{0.5} and FEV_{0.75}. In general, the intraclass correlation coefficients of all IOS parameters showed acceptable concurrence rates. These findings indicate that Rrs_{IOS5} is more stable on repeat testing than Xrs_{IOS5}, reactance area, or resonant frequency. Moreover, when assessing the concurrence between Xrs_{IOS} and spirometry, it was hard to obtain acceptable values for Xrs_{IOS}, thus demonstrating that Rrs is more stable than Xrs on 3-month follow-up studies of children. Taken together, there are variations between initial and follow-up studies of lung function tests performed at intervals of several months. Therefore, it is important to be aware that there exist variations in lung function measures when interpreting data obtained from longitudinal studies.

There is a limitation to this study. A recent study by Quanjer et al.³³ reported that age and height are the most important explanatory variables in spirometry reference equations and that heights should be recorded to 1 mm accuracy and ages should be recorded in months, not in whole years. Much to our regret, we measured height, weight, age at the first set of lung function, but did not measure them at the second set of lung function. This led us to speculate that growth between the 2 time points may have influenced IOS measures.

In conclusion, this study provides acceptable reference values of spirometry for healthy Korean children aged 3–6 years. The obtained values and regression equations can be used to provide reference data for Korean preschool children and may help in evaluating the pulmonary function of preschool children with possible respiratory problems. We also found that spirometry parameters are highly correlated with IOS parameters, that FEV₁ and Rrs in these children are lower than those of Caucasian children, and that 3-month follow-up studies of IOS show greater variability than that of spirometry. Among IOS parameters, Rrs_{IOS5} appears to be more stable on repeat testing than Xrs_{IOS5} on 3-month follow-up studies of preschool children and is strongly correlated with FEF_{25–75} on spirometry.

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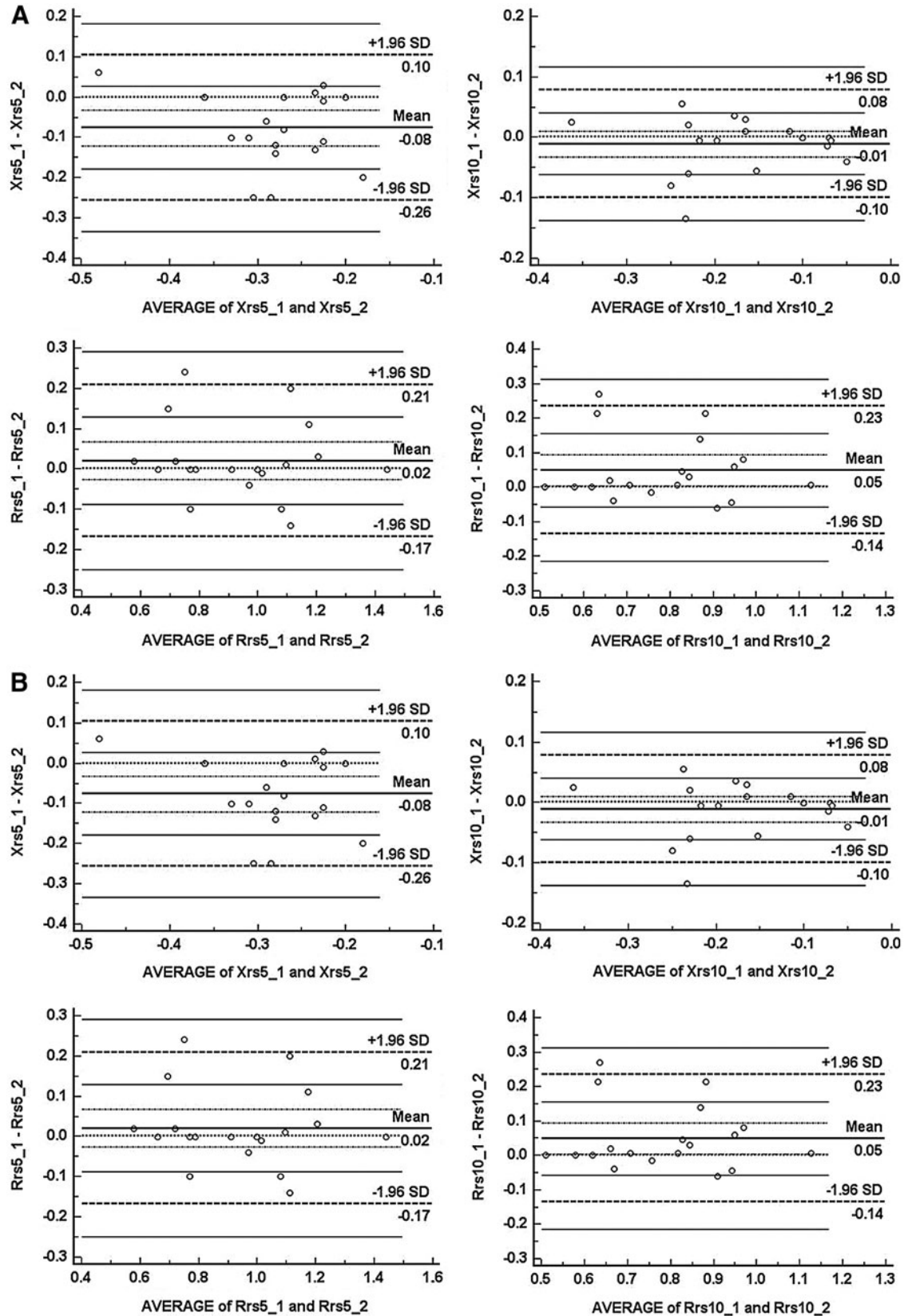
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Supplementary Data



SUPPLEMENTARY FIG. S1. (A, B) Bland–Altman plot showing relationship between successive measurements and the magnitude of the mean difference of the 2 sets.