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Original Article

Peak Expiratory Flow Rate of Healthy Sri Lankan Tamil Children in Jaffna District

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Abstract

The objective of the study was to correlate Peak Expiratory Flow Rate (PEFR) with anthropometric measurements and Tanner pubertal staging and to develop reference norms of PEFR for Sri Lankan Tamil boys and girls aged 6-18 years in Jaffna district. Age, height, weight, Tanner staging and PEFR were obtained by a cross sectional study.

Pearson's correlation of PEFR in boys with age, height and weight were: 0.863, 0.870 and 0.808 ($p<0.001$). In girls they were: 0.797, 0.813 and 0.761 respectively ($p<0.001$). Girls achieved maximum PEFR at 16 years but in boys PEFR was increasing up to 18 years. The PEFR of boys was higher than girls after the age of 14 years. Prediction equations for PEFR were obtained by multiple regression analysis. Pubertal stage correlated ($p<0.001$) with age, height, weight and PEFR. Including pubertal stage in analysis did not improve the prediction. A table of reference norm was developed for PEFR based on sex, age and height to keep in line with current clinical practice.

Introduction

Chronic respiratory diseases are increasing and deteriorate the quality of life of affected individuals. It has been estimated that about 300 million individuals worldwide have asthma; this is likely to increase to 400 million by the year 2025; respiratory diseases contribute to 4 million deaths annually; and 250,000 people die of Asthma (1). Asthma is the most common obstructive disease in children. Early diagnosis is important to reduce suffering and mortality. Burden of childhood Asthma among children aged between 6-7 and 13-14 years in Sri Lanka was estimated to be 11% and 11.7% respectively in 2014 (2).

Peak Expiratory Flow Rate (PEFR) is a convenient and reliable measurement in diagnosing and monitoring the progress of airflow limitation and evaluating the response to treatment. Various factors

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can influence PEFR. The most important ones are: age, sex, height, weight and race (3, 4). Diurnal variation in PEFR also has been reported (5). PEFR in infants, children and adults differ between different ethnic groups (6). Since the growth and development are affected by pubertal hormones, pubertal stage also is likely to affect PEFR.

Interpreting PEFR of patients depends on ethnic specific reference norms derived from healthy population. In Sri Lanka, PEFR of Sinhalese children were published from Kandy (7) and Galle (8) but no publication is available for Sri Lankan Tamil children.

The aim of the present study is to correlate anthropometric measurements and pubertal stage with PEFR and to develop reference norms for PEFR of Sri Lankan Tamil children living in Jaffna.

Methodology

This is a population based descriptive cross sectional study among Tamil boys and girls aged 6 to 18 years, living in Jaffna District. The sample size was calculated using the formula for population mean: $N=Z^2\ S^2/d^2$ (9). The targeted total sample size was 1536. It was decided to recruit 60 boys and 60 girls in each age group- a total of 1560 participants. Since education is compulsory for children in Sri Lanka and the dropout rate is minimal, the participants were recruited from schools. Cluster sampling method was applied. Each cluster was a classroom consisting of approximately 30 students. Number of clusters in each grade was selected according to percentage of total students in that grade. The classes were selected by systematic random sampling.

Ethical clearance was obtained from Ethical Review Committee of Faculty of Medicine, University of Jaffna. Permissions were obtained from Provincial director of education, each Zonal director of education and school Principals. Informed written consent was obtained from all parents and assent was obtained from adolescents aged 14 years and above. All measurements were made between 9 am and 2 pm to avoid the effect of diurnal variation.

One of the parents of each participant filled a self-administered questionnaire to obtain general information and disease history of the participant. Children with history of chronic cardio pulmonary diseases such as Asthma, Tuberculosis, Chronic heart failure and anyone who had symptoms or signs suggestive of respiratory illness such as cough, breathlessness, hemoptysis and wheezing were excluded. Anyone who had physical disability of mouth, neck, chest which can affect the procedure and those who had undergone recent thoracic or abdominal surgery were also excluded from the study.

Age was calculated in years as on the last birthday. Height and weight were measured according to a standardized protocol to the nearest 0.1 cm and 0.1 kg respectively by using portable device (Seca, Germany) and BMI was calculated.

PEFR was measured with mini-Wright compatible ‘asthma plan peak flow meter’ which had a range of 50- 800 L/min and readable to the nearest 10 L/min. The measurement was made while the participant was in erect (anatomical) position. The participants were given demonstration and instructed to take maximum inspiration and to blow as hard as possible without any delay while keeping a tight seal around the mouth-piece. While the participant was performing the test he/she was observed to ensure that there was no leak around the mouth, and to avoid any hesitation and improper blowing. Likewise three readings were obtained. If the difference between largest two values was less than 10% of the highest value, the highest reading was considered for analysis. Otherwise two more attempts were given. If reproducibility was not achieved, the participant was regarded as non-respondent.

Pubertal stage was assessed by self-administered Tanner staging scale, pictures of genital organs and breast at different stages, in a confidential place, separately for males and females. Children aged less than 8 years were excluded from this assessment to avoid un-necessary embarrassment as they would not have any pubertal changes. The participants were asked to indicate their pubertal stage by recording

the number of the picture that matches with the stage of their genitals best. One of the investigators of the same sex was available to clear any discrepancies or doubts before the participant went out.

Data analysis was done using Statistical Package for Social Science (SPSS). Independent t-test was used to compare the significance of difference between means. Pearson's correlation was used to get the relationship between PEFR and height, weight, BMI and Tanner staging. Step wise multiple regression analysis was performed to derive prediction equations for PEFR.

Results

The number of study participants was 950 boys and 972 girls. Analyzed height, weight and PEFR of boys and girls in each age are given in Table I.

When analyzed for Pearson's correlation, height, weight and BMI of boys correlated positively (P<0.001) with age and the R was: 0.931, 0.817 and 0.558 respectively. In girls the respective correlations were 0.886, 0.810 and 0.629 (p<0.001).

Regarding the mean height of boys, there was an increase of about 3-4 cm per year upto the age of 12 years. Then the rate of increase was higher (6 cm) until the age of 15 years. Beyond this age the rate of growth decreased. The rate of increase in weight was about 2 kg per year until the age of 10 years followed by a higher weight gain (3-5 kg) until 17 years. In girls, the rate of increase in height was higher (4-7 cm) upto the age of 12 years. Beyond this age the rate of growth decreased to about 1-3 cm per year. When considering the weight of girls, there was about 2-3 kg increase in weight per year upto the age of 10 years. Then the rate of increase was higher (4-6 kg) until the age of 14 years. Beyond this age the rate of increase was lower, which is about 2 kg per year.

When the PEFR of boys was analyzed, the increase from one age group to the next is statistically significant (P<0.05) in each age group except 11 and 12 year age groups. In girls this increase was statistically significant (P<0.05) until the age of 10 years and 11 to 14 years: the difference between 10 and 11 years and beyond 16 years was not significant statistically.

In boys, Pearson's correlations (R) for PEFR were with age - 0.863, height - 0.870, and weight - 0.808. In girls the respective correlations were 0.797, 0.813 and 0.761. All these were statistically significant (p<0.001).

In multiple regression analysis, the correlation coefficient (R^2) of PEFR for boys with age, height, and weight individually were 0.748, 0.759 and 0.656

TABLE I: Mean(SD) of height, weight and PEFR of boys and girls in each age group.

	Boys Mean (SD)				*Girls Mean (SD)*				*P for Sex difference*
Age	*n-No*	*Ht -cm*	*Wt-kg*	*PEFR L/min.*	*n-No*	*Ht-cm*	*Wt-kg*	*PEFR L/min*	*of PEFR*
6	61	119.3 (4.9)	18.2 (2.7)	139 (24)	63	120.1 (4.8)	18.7 (3.2)	132 (21)	0.083
7	79	123.7 (5.6)	20.6 (4.5)	157 (37)	75	123.9 (4.6)	20.4 (3.8)	142 (27)	0.005
8	75	129.5 (3.9)	23.6 (5.2)	176 (34)	79	128.1 (4.6)	22.9 (5.8)	163 (27)	0.011
9	81	132.1 (4.8)	25.3 (6.0)	190 (33)	79	132.5 (4.9)	26.0 (6.0)	177 (34)	0.017
10	71	135.1 (5.0)	27.0 (6.9)	207 (40)	77	136.4 (6.6)	28.0 (5.5)	200 (29)	0.178
11	76	141.4 (7.3)	32.6 (9.4)	232 (35)	83	141.4 (7.1)	32.2 (7.0)	209 (42)	0.001
12	76	145.3 (7.7)	34.9 (9.6)	235 (35)	72	148.2 (7.5)	37.7 (10.3)	226 (37)	0.106
13	76	151.4 (8.2)	38.5 (8.1)	268 (48)	78	151.2 (7.2)	38.9 (7.7)	247 (39)	0.003
14	72	157.6 (8.6)	43.5 (10.8)	294 (56)	84	154.2 (6.3)	43.5 (9.4)	262 (44)	0.001
15	92	163.6 (6.8)	47.6 (10.0)	330 (62)	99	155.9 (6.4)	45.1 (8.1)	267 (39)	0.001
16	84	166.5 (6.9)	50.6 (11.3)	365 (54)	77	157.9 (5.7)	48.6 (7.9)	285 (56)	0.001
17	56	169.0 (6.9)	55.1 (11.7)	394 (76)	60	156.9 (6.1)	46.9 (8.3)	285 (44)	0.001
18	51	171.4 (6.1)	56.9 (8.8)	423 (58)	46	158.8 (5.3)	50.0 (8.6)	287 (44)	0.001

Age - age at the last birthday
No - number of participants in each age group
Ht - height, Wt - weight

respectively. When the age and height were combined, the R^2 was 0.779. When weight was added, the R^2 was 0.789.

In girls R^2 values for age, height, and weight individually with PEFR were 0.636, 0.662 and 0.579 respectively. When the age and height were combined, the R^2 was 0.689. When weight was added, the R^2 was 0.694.

The prediction equations for PEFR derived from the above analysis including age, height and weight for boys and girls are given below:

PEFR (boys) = 11.32 × Age (years) + 1.69 × Ht (cm) + 1.23 × Wt (kg) – 167.07

R^2 = 0.789, SEE = ± 44.94

PEFR (girls) = 5.92 × Age (years) + 1.7 × Ht (cm) + 0.83 × Wt (kg) – 122.93

R^2 = 0.694, SEE = ± 35.49

Table II gives the reference norm for PEFR based on age, sex and height as in current practice. For each age group, PEFR of 25th, 50th and 75th percentiles of height were calculated.

Tannerpubertal staging and the mean age, height and PEFR for each pubertal stage are given in Table III.

Girls achieved pubertal changes at younger age when compared to boys. When the difference of PEFR between the stages of the same sex was analyzed, the increase at each stage was statistically significant ($P<0.05$) in boys and girls except for the difference between stage 4 and 5.

Pearson's correlation of Tanner staging with age, height weight and PEFR are given in Table IV.

Both boys and girls have significant strong positive correlation of Tanner scales with PEFR in addition to age, height and weight.

TABLE II: Reference values of PEFR according to age, sex and height.

		Boys		*Girls*	
Age	*Height percentile*	*Height (cm)*	*PEFR Mean (SD) (L/min)*	*Height (cm)*	*PEFR Mean (SD) (L/min)*
6	25th	<115.9	118 (22)	<116.6	119 (19)
	50th	115.9-122.9	140 (20)	116.6-123.9	128 (17)
	75th	>122.9	159 (18)	>123.9	154 (14)
7	25th	<119.6	133 (17)	<121.1	122 (22)
	50th	119.6-127.9	156 (32)	121.1-127.4	149 (21)
	75th	>127.9	163 (17)	>127.4	152 (31)
8	25th	<127.1	152 (28)	<125.1	150 (20)
	50th	127.1-131.4	181 (32)	125.1-130.4	160 (23)
	75th	>131.4	190 (33)	>130.4	181 (30)
9	25th	<130.1	170 (24)	<130.1	164 (31)
	50th	130.1-135.4	192 (32)	130.1-134.9	184 (30)
	75th	>135.4	214 (31)	>134.9	191 (39)
10	25th	<131.6	199 (44)	<131.6	181 (23)
	50th	131.6-137.9	209 (35)	131.6-140.2	200 (24)
	75th	>137.9	215 (43)	>140.2	219 (30)
11	25th	<136.3	219 (38)	<136.1	186 (24)
	50th	136.3-146.4	228 (30)	136.1-145.9	205 (36)
	75th	>146.4	251 (36)	>145.9	237 (48)
12	25th	<141.7	212 (28)	<143.1	197 (33)
	50th	141.7-149.3	237 (25)	143.1-153.3	229 (30)
	75th	>149.3	256 (45)	>153.3	250 (32)
13	25th	<144.7	256 (40)	<147	219 (43)
	50th	144.7-157.7	259 (48)	147-156	259 (36)
	75th	>157.7	296 (46)	>156	248 (26)
14	25th	<151.1	262 (51)	<151.6	253 (44)
	50th	151.1-163.9	292 (46)	151.6-158.9	258 (43)
	75th	>163.9	332 (55)	>158.9	276 (46)
15	25th	<159.1	298 (52)	<151.6	252 (30)
	50th	159.1-167.8	334 (59)	156.6-160.4	263 (35)
	75th	>167.8	355 (65)	>160.4	292 (43)
16	25th	<162.1	346 (46)	<153.9	272 (47)
	50th	162.1-170.9	370 (59)	153.9-161.9	279 (55)
	75th	>170.9	377 (51)	>161.9	306 (61)
17	25th	<165.7	388 (97)	<153.1	263 (37)
	50th	165.7-173.7	388 (73)	153.1-161.4	292 (42)
	75th	>173.7	411 (60)	>161.4	298 (49)
18	25th	<167.6	411 (45)	<155	292 (67)
	50th	167.6-174.9	421 (52)	155-162.5	288 (38)
	75th	>174.9	437 (76)	>162.5	282 (36)

Age - age at the last birthday
No - number of participants in each age group

Discussion

When the height of boys and girls were compared, boys of 6-8 years were marginally taller than the girls of same age. But girls of 9-12 years became marginally taller than the boys of same age suggesting that these girls are undergoing pubertal growth spurt at this age. Boys were observably taller

TABLE III: Mean (SD) of age, height and PEFR according to Tanner staging.

Stages	Boys							
	Pubic Hair				Penile Development			
	No	Age (SD)	Height (SD)	PEFR (SD)	No	Age (SD)	Height (SD)	PEFR (SD)
Stage 1	275	10.8 (1.5)	139.9 (9.0)	221 (45)	173	10.7 (2.0)	138.4 (10.2)	220 (54)
Stage 2	90	12.6 (1.8)	148.2 (11.9)	252 (66)	166	11.7 (1.7)	141.2 (8.2)	241 (50)
Stage 3	106	13.5 (1.8)	153.6 (11.7)	290 (61)	147	13.6 (2.0)	150.1 (7.2)	291 (75)
Stage 4	216	16.0 (1.3)	166.4 (7.2)	365 (72)	177	15.7 (1.6)	156.1 (6.3)	357 (77)
Stage 5	53	16.5 (1.3)	169.9 (7.1)	388 (70)	77	16.4 (1.1)	156.8 (5.9)	380 (70)
	Girls							
Stages	Pubic Hair				Breast Development			
	No	Age (SD)	Height (SD)	PEFR (SD)	No	Age (SD)	Height (SD)	PEFR (SD)
Stage 1	136	9.8 (1.1)	134.7 (6.4)	187 (35)	99	9.8 (1.1)	132.7 (5.9)	185 (40)
Stage 2	135	11.1 (1.2)	145.0 (10.4)	213 (40)	115	10.5 (1.2)	138.5 (6.3)	201 (33)
Stage 3	97	12.9 (1.5)	150.1 (7.1)	240 (45)	118	12.2 (1.6)	148.7 (7.7)	232 (44)
Stage 4	256	15.0 (1.6)	165.1 (8.2)	270 (45)	320	14.9 (1.8)	155.1 (6.5)	266 (47)
Stage 5	131	15.9 (1.6)	169.0 (6.5)	278 (47)	103	15.9 (1.5)	157.1 (6.4)	280 (45)

TABLE IV: Correlation (R) of Tanner scale for puberty and age, height, weight and PEFR.

	r			
	Boys		Girls	
	Pubic hair	Penile development	Pubic hair	Breast development
Age	0.833*	0.824*	0.889*	0.889*
Height	0.814*	0.812*	0.840*	0.866*
Weight	0.734*	0.730*	0.789*	0.836*
PEFR	0.779*	0.748*	0.745*	0.751*

*indicates P<0.001

than the girls of the same age again after 13 years which was statistically significant. This finding suggests that the boys attained growth spurt later than girls.

The weight and height of boys and girls increased with age but they were not increasing in parallel: increasing height did not reflect in weight gain. The difference in weight became statistically significant only after the age of 16 years. Even though the correlation between age and height, weight and BMI were statistically significant at p<0.001, variation in the age of onset of pubertal growth spurt, nutritional and developmental factors may have affected the correlation.

As shown in Table I, the PEFR of boys increased with age. This increase was not statistically significant in 11 and 12-year age groups. This coincides with the age of onset of puberty according to the Tanner staging. Therefore onset of growth spurt may have affected the PEFR of this age group. In girls increase in PEFR is not statistically significant between the ages of 10 and 11 years, which is difficult to explain. The rate of increase in PEFR declines after age of 14 years, which may indicate approaching adulthood. Girls achieved maximum PEFR at 16 years but the PEFR of boys kept on increasing until 18 years. This agrees with the fact that the PEFR depends on lung elasticity, recoil of thoracic cage, strength of respiratory muscles and airway caliber, which increase until the person becomes adult (10). All these can affect the increase in PEFR with age.

PEFR of boys and girls may be expected to be similar during the pre pubertal period. But boys in 7 and 8-year age groups had a higher PEFR (about 15 L/min) which was statistically significant in spite of the height of boys and girls being similar. Uduphille has reported similar finding in 1994 (7). Boys may have developed muscles better than girls due to fetal secretion of androgen and cultural encouragement to involve in strenuous activities: we could not find

any evidence for this assumption. This may have contributed to higher PEFR of boys than the girls of the same age. However, this 15 L/min sex difference in PEFR may not be clinically significant. Markedly higher PEFR in boys compared to girls after the age of 14 years coincides with the difference in height caused by pubertal growth spurt. In addition, better development of muscles of respiration due to testosterone in males could be another reason.

Our study shows good correlation of PEFR with age, height and weight individually. It is in line with other studies reported in Sri Lankan Sinhalese, Indians, Iranians, Malaysian and British populations (8, 11, 12, 13, and 14). Highest correlation of PEFR with height in the present study agrees with the finding the other studies (4, 7, 10).

Since the study population is aged between 6 and 18 years, the influence of pubertal changes cannot be ignored. Pubertal development stages correlated well individually with age, height, weight and PEFR. Inclusion of Tanner staging in to the multiple regression analysis did not show considerable improvement in correlation and statistical significance. But the pubertal staging correlated well with height and therefore it may indirectly be represented through height.

Tanner staging of puberty by direct inspection by the researchers was considered embarrassment to the participants which could not be justified for this study. Therefore pictures of pubic hair and penile size were used for boys and breast development and pubic hair were used for girls. This may have caused certain amount of error. Participants below 8 years were excluded from staging as they were unlikely to enter into pubertal development and showing pictures of genitals could be avoided. The pubertal staging correlated well with height and therefore it may indirectly be represented through height.

Neve *et al* (15) reported that the girls' lung development is completed at menarche. The present study did not record the age at menarche because we considered that the menarche is incidental depending on the cyclical hormonal secretions resulting in significant development and disintegration of endometrium and it can occur at any time during puberty. Girls in Jaffna generally attain menarche at the age of 11 to 13 years. Girls of this age are at Tanners stage 2 and 3. Girls achieved maximum PEFR in 16 years, after stage 5. This suggests that lung development occurred even after menarche and continued until they reached adulthood. This does not agree with the finding of Neve et al. Continuous increase of PEFR from 6-18 years in boys agrees with the suggestion of Neve et al that the male lung development occurs throughout puberty (15).

When the PEFR was adjusted to age and height, our values were lower than the other reported studies in Sri Lankan Sinhalese (7, 8), British (14), and Indians (12). This may be due to ethnic or genetic difference or may be due to the developmental problems resulting from residual effects (nutritional deficiencies and stress) of the war situation that prevailed for about 30 years until 2009. It is almost closer to the values reported for South Indians (16).

Conclusion

Age and height showed highest correlation with PEFR and reference norms were developed for easy interpretation in clinical practice. Prediction equations for PEFR based on age, height and weight have been developed separately for boys and girls. The pubertal staging was not included in these as the inclusion of this factor did not show considerable improvement in the correlation.

Boys seemed to show pubertal changes at the age of 11-12 years and continue up to 16 to 18 years. Girls appeared to commence puberty at 10-11 years and continue until 15-16 years.

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