SPIROMETRIC IMPAIRMENTS IN UNDERNOURISHED CHILDREN

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Abstract : The present study elucidates the effect of undernutrition on pulmonary functions in children. The study was carried out in healthy normals, wasted, wasted and stunted children. Spirometry was performed with Vitalograph Compact-II spirometer. Wasted, wasted and stunted children showed lower lung volumes, forced mid expiratory flow time and inspiratory flow rates than healthy normals. Wasted and stunted children had lower VC, FVC and $FIF_{50\%}$ than wasted children. The reduction in lung volumes and flow rates in wasted children may be due to ventilatory muscle wasting. But in wasted and stunted children along with muscular wasting diminished skeletal growth is also a reason for lower lung functions. No airflow limitation was observed in undernourished children.

Key words : undernutrition wasted   lung volume
     wasted and stunted   flow rate

INTRODUCTION

In different forms and degrees of severity, protein-energy malnutrition (PEM) is common in most less developed countries and is the principal nutritional public health problem in the world. The body reserves of protein and calories are markedly depleted in wasted (thin) children, so that there is a danger of the development of severe PEM. The wasted and stunted (thin and short) child is suffering from acute malnutrition on a background of chronic malnutrition. Such children are not only small in stature, but also have thin limbs (1). Stunting is a slowing of skeletal growth and stature defined by Waterlow (2) as "the end result of a reduced rate of linear growth". This condition results from extended periods of inadequate food intake and increased morbidity. Weight loss is associated with wasting of skeletal muscle including the ventilatory muscles (3). Michael et al. (4) reported that changes in diaphragm contractile and fatigue properties occur as a result of the influence of malnutrition on muscle fibre cross-sectional area. Studies regarding the effect of undernutrition on pulmonary functions were very scanty in India and abroad. Arora and Rochester (5) observed reduction in respiratory muscle strength and maximal voluntary ventilation (MVV) in malnourished patients. In India a recent study (6) on lung functions in

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malnourished children demonstrated that, forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were significantly reduced. It has therefore been felt necessary to know the effect of undernutrition on lung volumes and flow rates in children.

METHODS

Subjects : A sample of 132 school children in the age range of 6 to 12 years were randomly selected from non-industrialised rural islands of Ernakulam district, Kerala. There were 78 males and 54 females. They were all non-smokers. Children having any type of respiratory as well as cardiac diseases, physically and mentally handicapped were excluded.

Design of study : The age was recorded from the school register and confirmed from parents through questionnaire. The height (cm), body weight (kg), head circumference (cm), mid upper arm circumference (cm) were measured following standard techniques and body mass index was calculated (7). Body surface area was calculated by Du Bois's formula (8). Anthropometric assessment of growth was done according to Waterlow classification (9) considering height-for-age and weight-for-height as follows:

Normal   : ≥ 90 per cent height/age
             ≥ 80 per cent weight/height

Wasted   : ≥ 90 per cent height/age
             < 80 per cent weight/height

Wasted and   : < 90 per cent height/age
stunted   < 80 per cent weight/height

WHO reference growth data (10) was used as the reference standard for above classification.

Pulmonary functions were measured with a portable PC based spirometer with printer (Vitalograph Compact-II, Buckingham). Spirometry was performed during morning hours. After calibration of the machine, the procedure of the respiratory function test were carefully explained to each child and they were made 3-5 efforts while standing and wearing a noseclip. The best of the multiple trials was recorded automatically by the spirometer at BTPS (body temperature, ambient pressure and saturated with water vapour).

Parameters studied

Lung volumes : Vital capacity (VC), forced vital capacity (FVC), forced expiratory volume at 0.5 second ($FEV_{0.5}$), forced expiratory volume at 1 second (FEV_1), ratios between forced expiratory volume in second to vital capacity, to forced vital capacity in percentage ($FEV_{0.5}/FVC\%$, $FEV_1/VC\%$, $FEV_1/FVC\%$) and maximal voluntary ventilation (MVV_{IND}).

Flow rates : Peak expiratory flow rate (PEF), forced mid expiratory flow rate ($FEF_{25-75\%}$), forced mid expiratory flow time (FMFT), forced late expiratory flow rate ($FEF_{75-85\%}$), forced expiratory flow rate at 25%, 50% and 75% of FVC ($FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$). Peak inspiratory flow rate (PIF), peak inspiratory flow rate at 75%, 50% and 25% ($FIF_{75\%}$, $FIF_{50\%}$, $FIF_{25\%}$). Vital capacity was recorded by doing separate manoeuvre but all the measurements were obtained

while subject performed a forced vital capacity (FVC) manoeuvre.

Data analysis : Statistical analysis of results were carried out using unpaired 't' test (i) to find the significance of anthropometric characters between normals and different types of undernourished school children and (ii) to find the significance of lung volumes and flow rates between normal, wasted and wasted and stunted children.

RESULTS

Among 132 children, normals were 41.67% (n = 55), wasted 47.72% (n = 63) and wasted and stunted 10.61% (n = 14).

Anthropometric measurements

When comparison was made between different classes of undernourished children with normals, wasted children were significantly lower in weight, MUAC, BMI and BSA (P<0.001). Wasted and stunted children showed a clear-cut lower value in height (P<0.005), weight (P<0.001), head circumference (P<0.05), MUAC, BMI and BSA (P<0.001). The wasted and stunted children showed significant decrease in height than wasted (P<0.01) (Table I).

Lung volumes

Lung volumes, viz. VC (P<0.001, <0.001), FVC (P<0.005, <0.001), $FEV_{0.5}$ (P<0.01, <0.01), FEV_1 (P<0.005, <0.001), MVV_{IND} (P<0.005, 0.001) were significantly lower in wasted, wasted and stunted than normal children respectively. $FEV_{0.5}$/FVC% was significantly higher in wasted and stunted than normals (P<0.001). No significant difference was noticed in FEV_1/VC%, FEV_1/FVC% between normal and different types of undernutrition. Wasted and stunted children had decreased VC and FVC (P<0.05) than wasted children (Table II).

TABLE I : Comparison of anthropometric measurements between normals and undernourished school children (Mean ± SD).

Anthropometric indices (units)	Normal (1) n = 55	Wasted (2) n = 63	Wasted and stunted (3) n = 14	P< 1 vs 2	1 vs 3	2 vs 3
Age (yrs)	9.28±1.97	9.05±1.79	9.62±2.35	NS	NS	NS
Height (cm)	132.30±10.43	129.63±9.37	121.55±10.84	NS	0.005	0.01
Weight (kg)	25.82±5.72	20.31±3.39	18.42±3.86	0.001	0.001	NS
Head circumference (cm)	52.04±1.54	51.50±1.46	50.91±1.35	NS	0.05	NS
MUAC (cm)	18.04±1.71	16.01±1.15	15.87±1.23	0.001	0.001	NS
BMI (kg/m²)	14.56±1.61	12.03±1.05	12.56±1.03	0.001	0.001	NS
BSA (m²)	0.98±0.14	0.87±0.10	0.81±0.13	0.001	0.001	NS

MUAC – Mid upper arm circumference
BMI   – Body mass index
BSA   – Body surface area
NS   – Not significant

TABLE II : Comparison of lung volumes between normals and
undernourished school children (Mean ± SD).

Parameters (units)	Normal (1) n = 55	Wasted (2) n = 63	Wasted and stunted (3) n = 14	P<		
				1 vs 2	1 vs 3	2 vs 3
VC (L)	1.36±0.33	1.14±0.32	0.93±0.27	0.001	0.001	0.05
FVC (L)	1.38±0.30	1.20±0.30	1.02±0.26	0.005	0.001	0.05
$FEV_{0.5}$ (L)	0.99±0.20	0.89±0.21	0.83±0.21	0.01	0.01	NS
$FEV_{0.5}/FVC\%$	72.30±7.83	75.86±11.74	82.14±10.41	NS	0.001	NS
FEV_1 (L)	1.29±0.27	1.14±0.28	0.99±0.29	0.005	0.001	NS
$FEV_1/VC\%$	96.56±10.22	99.76±14.26	102.16±24.87	NS	NS	NS
$FEV_1/FVC\%$	94.25±4.32	94.68±7.60	91.00±14.62	NS	NS	NS
MVV_{IND} (L/min)	48.72±10.24	42.58±11.14	36.14±10.71	0.005	0.001	NS

NS – Not significant

TABLE III : Comparison of flow rates between normals and
undernourished school children (Mean ± SD).

Parameters (units)	Normal (1) n = 55	Wasted (2) n = 63	Wasted and stunted (3) n = 14	P<		
				1 vs 2	1 vs 3	2 vs 3
PEF (L/min)	145.69±37.36	139.49±40.81	133.71±44.71	NS	NS	NS
$FEF_{25-75\%}$ (L/s)	1.74±0.44	1.64±0.45	1.44±0.78	NS	NS	NS
FMFT (s)	0.40±0.08	0.36±0.10	0.32±0.07	0.05	0.001	NS
$FEF_{75-85\%}$ (L/s)	0.92±0.30	0.89±0.28	0.94±0.33	NS	NS	NS
$FEF_{25\%}$ (L/s)	2.33±0.61	2.20±0.68	1.95±0.81	NS	NS	NS
$FEF_{50\%}$ (L/s)	1.89±0.45	1.79±0.48	1.71±0.69	NS	NS	NS
$FEF_{75\%}$ (L/s)	1.08±0.32	1.03±0.31	1.08±0.36	NS	NS	NS
PIF (L/s)	1.71±0.47	1.47±0.53	1.21±0.47	0.05	0.001	NS
$FIF_{75\%}$ (L/s)	1.54±0.46	1.25±0.54	0.98±0.46	0.005	0.001	NS
$FIF_{50\%}$ (L/s)	1.56±0.50	1.32±0.52	0.98±0.53	0.05	0.001	0.05
$FIF_{25\%}$ (L/s)	1.36±0.47	1.16±0.50	1.02±0.47	0.05	0.05	NS

NS – Not significant

Flow rates

Inspiratory flow rates, viz. PIF (P<0.05, <0.001), $FIF_{75\%}$ (P<0.005, <0.001), $FIF_{50\%}$ (P<0.05, <0.001) and $FIF_{25\%}$ (P<0.05, <0.05) were higher in normals than wasted, wasted and stunted respectively. A reduction in FMFT was observed in wasted (P<0.05), wasted and stunted (P<0.001) than normals. $FIF_{50\%}$ was significantly decreased (P<0.05) in wasted and stunted than wasted (Table III).

DISCUSSION

This study demonstrated that anthropometric measurements, lung volumes and inspiratory flow rates were significantly lower in wasted, wasted and stunted children than healthy normals.

Wasted and stunted children had significantly lower VC, FVC and $FIF_{50\%}$ than wasted children.

Maintenance of ventilation depends on the ability of the inspiratory muscles to generate force (11). The inspiratory and expiratory capacity depends upon endurance and strength of the respiratory muscles and bony cage (6). Malnutrition did result in significant atrophy of type I and II fibres in the diaphragm. Fibre atrophy was most apparent for type II fibres of the diaphragm. As a result of fibre atrophy, the force-generating capacity of the diaphragm would be greatly reduced. Severe malnutrition has been associated with a decrease in muscle protein anabolism and enhanced protein breakdown. Type II fibres are unlikely to be recruited during normal quiet inspiratory efforts and thus may be more susceptible to the catabolic influence of severe nutritional deprivation (12).

It has been reported that malnutrition resulted in a significant reduction in diaphragm weight and was affected proportionately in the same way as the other skeletal muscles. Malnutrition reduced the cross-sectional area of fast-twitch muscle fibres to a greater extent than that of slow-twitch fibres which would have considerable impact on both contractile and fatigue properties of the diaphragm (4). Another recent study (11) demonstrated that diaphragm mass and thickness were related to body weight. The diaphragmatic fibre atrophy observed in their study suggests that the force generated by the muscle under basal conditions may be largely unaffected by undernutrition but any increment in force above the basal level,

however, may be severely reduced. Conditions that stress the respiratory muscles and require large efforts may be significantly comprised.

Recent evidence (5) indicates that undernutrition seriously affect the pulmonary functions. The consequence of respiratory muscle weakness in the undernourished patients include reduced VC, increased RV and reduced MVV. The reduction in VC was in proportion to the loss of respiratory muscle strength. MVV was reduced in proportion to the degree of respiratory muscle weakness. Another recent observation in Indian undernourished children (6) stated that respiratory function would be affected in the presence of protein-energy malnutrition and reported reduced FVC, FEV_1 and PEFR in undernourished children. They pointed out that PEFR and FEV_1 decreased proportionately as a result of poor endurance and strength of respiratory muscles.

On the basis of above conclusions, the present study can be evaluated. Our observations suggest that different degrees of undernutrition have its effect on pulmonary functions. The reduction in lung volumes and flow rates may be due to ventilatory muscle wasting. Another observation was that even though the study showed reduction in expiratory efforts, which were not significant, more affected was inspiratory efforts. That means inspiratory muscles couldn't generate greater force to maintain a normal forceful inspiration as in case of healthy normals. It is suspected that muscular atrophy, especially type II fibres of the diaphragm in undernourished children may be the

reason for decreased pulmonary functions. Along with the diaphragm other ventilatory muscles are also suspected of wasting. As stated above (5), the reduction in vital capacities and MVV_{IND} can be explained on the basis of decreased muscle strength and poor muscle endurance. Another point of the study was that the ratios between timed volumes and vital capacities were in normal or above normal limit. That indicates no airflow limitation was produced by poor nutritional status. The ratios were normal because the values decreased proportionately. This pattern of pulmonary functions is seen in restrictive diseases (13). $FEF_{25-75\%}$ didn't show any significant change in wasted, wasted and stunted than healthy normals. FEF$_{25-75\%}$ is relatively effort independent and it describes the status of the small airways, reflect early airway obstruction (13). So it was clear that no airway obstruction was seen in wasted, wasted and stunted children. But suspect a restrictive ventilatory impairment. Reduced VC, FVC and $FIF_{50\%}$ in wasted and stunted than wasted children indicate that as degrees of undernutrition increases, impairment of pulmonary functions also increases. In case of wasted children only muscular wasting is the reason for decreased pulmonary functions. But in wasted and stunted children along with muscular wasting, linear growth also plays a role in reduced lung functions. The ventilatory muscle wasting and decreased skeletal growth velocity may be the reason for lower pulmonary functions than healthy normals and wasted children. Lower $FIF_{50\%}$ of wasted and stunted than wasted children indicate severe fibre atrophy and muscular weakness of inspiratory muscles.

In the present study, normal children showed comparatively higher FVC, FEV_1 and PEF than reported by Faridi et al. (6). Pande and Pande (14) reported lower FEV_1, higher FVC and PEFR than our study. The mean values of VC and MVV were lower than the predicted value by Jain and Ramiah (15). But FEF$_{25-75\%}$ was higher than the predicted. The difference in lung function in normal population may be due to ethnic origin, physical activity, environmental conditions, altitude, age, height, sex and socio-economic status (16, 17).

Thus in conclusion it appeals that, wasted, wasted and stunted children have lower lung volumes and inspiratory flow rates than healthy normals.

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