Original Article

Composition of weight gain during nutrition rehabilitation of severely under nourished children in a hospital based study from India

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Concerns are raised that rapid catch up growth during nutrition rehabilitation of severely malnourished children may be associated with disproportionately higher amounts of body fat deposition. This study examined the composition of weight gain in severely undernourished children who underwent nutrition rehabilitation in a hospital from India. Body composition of 80 severely malnourished children (age 6-60 months) was assessed using skinfold thickness measurements on admission and after 1 month of supplementary feeding. On admission, children had severe weight and height deficits and were severely wasted. The mean weight for age z score, height for age z score and weight for height z score (WHZ) were -5.0, -4.2 and -4.1 respectively. Children consumed a mixed diet and mean energy intake was 177 kcal/kg/day with a protein energy ratio of 13. Overall, the mean weight gain was 6.1 g/kg/day and fat mass contributed to about 40% of the weight gain. When the composition of weight gain was analysed in tertiles of baseline WHZ score, children in the lowest tertile of WHZ score had significantly higher weight gain and fat free mass (FFM) gain. Gain in fat mass did not differ in relation to the baseline WHZ score. The study demonstrates that it is possible to achieve rapid weight gain with recovery of lost tissue in severely malnourished children with mixed diets. Children with lowest WHZ scores at baseline gained higher FFM during nutrition rehabilitation when compared to the children with relatively higher WHZ score probably in an attempt to recover the lost tissue.

Key Words: protein energy malnutrition, nutrition rehabilitation, body composition, fat mass, fat free mass

INTRODUCTION

As per the National Family Health Survey report (NFHS 3), in India, 48% of children under 5 are stunted, 42.5% are underweight and 19.8% are wasted.[1] Among these, 6.4% of preschool children are severely wasted (weight for height z score < -3 SD) due to protein energy malnutrition (PEM). Children with PEM are at an increased risk of mortality and often require intensive feeding in a hospital or clinic. Nutrition rehabilitation of these children with generous amounts of energy and protein along with other nutrients is associated with rapid weight gain.[2-4] However, it is important to ascertain whether the treatment that induce rapid weight gain also restore reference body composition.

A number of studies have indicated that at high rates of weight gain, disproportionately higher amounts of body fat is deposited and fat free mass accretion is relatively smaller.[5-8] It is possible that resulting high fat body composition may continue in adulthood and increase the risk of metabolic syndrome and other chronic disorders related to adiposity. On the other hand, higher fat free mass, which includes muscle mass, is important for physical work capacity, recovery from acute stress, insulin sensitivity as well as a number of other physiological processes.[9]

A few studies have indicated that with adequate provision of energy, availability of proteins may be limited for full recovery of lean tissue.[3] A study in Bangladesh demonstrated that children fed with a high protein diet had higher increases in fat free mass when compared to the children fed a standard protein diet.[10]

Studies from India investigating recovery from severe PEM have focused on the weight gain per se and information on composition of weight gain is not available. This longitudinal study examined the composition of weight gain in severely undernourished children who underwent nutrition rehabilitation in a hospital.

MATERIALS AND METHODS

Eighty children aged 6-60 months admitted in the nutrition ward of a government pediatric hospital in Hyderabad, India were enrolled for this study. Children were usually admitted to the hospital for acute infections. Initial management including necessary investigations, correction of electrolyte imbalance, and treatment of infections with appropriate antibiotics was carried out in other

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wards of the hospital. The initial period of stabilization and control of infection varied from 2-7 days and there after the children were transferred to the nutrition ward for nutrition rehabilitation. All the children admitted to Nutrition Ward during the period of January 2005-December 2007 who stayed in the ward for a period of one month were included in the study. Children with congenital abnormalities were excluded.

Admission criteria was weight for height z score < -2. World Health Organization guidelines for the management of severe malnutrition[11] were followed with modifications in diet to include the foods traditionally considered appropriate for children in this area. Infections during the stay in the ward were treated with appropriate antibiotics. Routine massive vitamin A administration was done as per the WHO guidelines and children were also supplemented with multivitamins and minerals including zinc and calcium. Informed consent was obtained from parents for their children to participate in the study. The protocol was approved by institutional Ethical Review Committee.

Dietary intakes

Children were initially put on a maintenance diet of about 100 kcal/kg/day, which was slowly increased up to 170-220 kcal/kg/day. A typical diet of a child weighing 7 kg consisted of 350 ml of milk (fortified with groundnut oil to increase the energy density), 250 g of kichidi (rice and dhal in 2:1 ratio with oil added), 1-2 slices of bread, 2 eggs and a banana, which provided around 170 to 220 kcal/kg/day and 3 to 4 g of protein/kg/day. Breastfed children continued to receive breast milk.

Dietary intakes of the children were measured by 24 hr recall by mother or attendant at the time of admission as well as after 1 month of admission. Nutrient intakes were calculated using food composition tables for Indian foods.[12]

Anthropometry

Children were weighed daily at a scheduled time on a digital balance (SECA, Hamburg, Germany) with a precision of 1 g. On day 1, in children ≤ 2 years, length was measured to the nearest 0.1 cm with an infantometer made in house at our institute. For children aged > 2 years, height was measured with an anthropometric rod (SECA, U.K). Weight gain was expressed in g/kg/day and was calculated as follows:

$$\frac{(\text{Final weight} - \text{Initial weight}) \times 1000}{(\text{Initial weight} \times 30)}$$

Body composition

Body composition was assessed at the time of admission and after 1 month. Body fat was estimated by skin fold thickness measurement using a formula derived by Dauncy et al.[13] Three indexes of adiposity were derived from the skinfold thickness measurements: 1) Sum of skinfold thicknesses at biceps, triceps, subscapular, suprailliac and mid-thigh regions,[14] 2) total body fat mass, and 3) percentage body fat.

Fat free mass was calculated by subtracting fat mass from the body weight. All the anthropometric measurements were carried out by trained nurses. Quality control was ensured by periodic assessment of intra and inter individual coefficient of variation CV%.

Biochemical parameters

These were measured at the time of admission and were repeated after 1 month. A fasting blood sample was drawn in the morning between 0900 to 1000 hours in all the children and the estimations of biochemical parameters were carried out using standard procedures. Hemoglobin was estimated by the Cyanmethaemoglobin method. Serum albumin[15] and serum urea (Diacetyl monoxime method) were also estimated. Serum zinc was estimated using atomic absorption spectroscopy. Serum concentrations of IGF-I were assayed using ELISA kit (R and D systems, Inc).

Statistical analyses

STATA version 10 (College Station, Texas) was used for statistical analysis. Descriptive statistics were calculated for all the anthropometric and biochemical parameters and dietary intakes of energy and protein; and demographic variables such as age. Z scores of height for age, weight for age and weight for height were calculated using WHO anthro (v2.0.4) software. Subjects were divided into tertiles of baseline weight for height z score, and body composition parameters at baseline and follow up and composition of weight gain were analyzed among these tertiles using one-way ANOVA.

RESULTS

There were 45 boys and 35 girls in the study group and a total of 14 children (17%) presented with edema on admission. The children belonged to the lowest socioeconomic strata of the society and their parents were working as domestic help, daily wage earners, agricultural laborers, home based occupations etc. At home, children were fed mainly cereal based family foods. The quality and quantity of the diet was very poor. There was near absence of milk, meat, eggs, fats etc. During the study, morbidities were frequent with 20% of the children suffering from at least one episode of diarrhea, 10% of the children had fever for varying duration, 20% of the children were diagnosed to have pneumonia, 15% were diagnosed to have tuberculosis and a few children had malaria or other infections. Three children presented with clinical signs of rickets.

Characteristics of the children and their anthropometric and biochemical parameters as well as dietary intakes at baseline and at 1 month are described in Table 1. Z scores for weight for age, height for age and weight for height indicate that the study participants had severe weight and height/length deficits and were severely wasted. There was improvement by one SD unit in weight for age z score (WAZ) and by 1.5 SD units in weight for height z score (WHZ) after one month of intervention. There was very little improvement in height for age z score (HAZ) (0.1 SD Unit). Overall mean (SE) weight gain was about 6.1 (0.5) g/kg/day. There was severe deficiency in terms of body fat mass at baseline, with average body fat percentage of 8 which increased to 13.1 at 1 month indicating fat deposition. Dietary intakes at baseline were very poor with mean (SE) energy intake of only

Table 1. Characteristics and anthropometric parameters of subjects at baseline and after one month

	Baseline		Final		*p* value
	Mean	SE	Mean	SE	
Age (Mo)	25.0	1.7			
Weight (kg)	6.33	0.24	7.42	0.25	<0.001
Length (cm)	72.4	1.11	73.6	1.1	<0.001
MAC (cm)	10.2	0.19	11.7	0.2	<0.001
WAZ	-5.0	0.1	-4.0	0.1	<0.001
HAZ	-4.2	0.2	-4.1	0.2	<0.001
WHZ	-4.1	0.1	-2.6	0.1	<0.001
Sum of skin-fold thicknesses (mm)	21.6	0.8	28.8	0.7	<0.001
FFM (kg)	5.77	0.20	6.41	0.21	<0.001
TBF (kg)	0.56	0.06	1.01	0.06	<0.001
Percent fat	8.0	0.5	13.1	0.5	<0.001
Dietary energy (kcal/kg/day)	117	8	178	7.7	<0.001
Protein energy ratio	11.3	0.3	13.0	0.1	0.115
Hemoglobin (g/dL)	10.1	0.2	9.4	0.2	<0.001
S. albumin (g/dL)	4.4	0.2	4.7	0.1	0.013
S.zinc	82.0	3.7	96.6	3.6	0.001
S.urea	18.6	1.1	21.3	1.0	0.021
IGF-1	10.7	2.3	38.5	6.3	<0.001

N for dietary intakes = 53, S. zinc = 45, S. albumin = 44, S. urea = 42, IGF = 30
WAZ, weight for age z score; HAZ, height for age z score; WHZ, weight for height z score; FFM, Fat free mass; TBF, Total body fat.

715 (50) kcal/day which increased by almost 70% during their stay in the nutrition ward, and at 15-30 days, it was ≈ 1200 (37) kcal/day. Protein energy ratio was around 11-13% during their stay at the ward. Mean hemoglobin value decreased, serum albumin increased marginally whereas serum IGF1 values increased rapidly during nutrition rehabilitation.

Composition of weight gain in relation to the severity of wasting at baseline

Children were stratified by tertiles of baseline WHZ and their characteristics and composition of weight gain were assessed in these tertiles (Table 2). The mean age was not significantly different in these groups. There was severe depletion of body fat in the lowest tertile of WHZ with mean body fat percent of only 3.8. Fat free mass (FFM) was also significantly lower in children in the lower tertiles of WHZ. Children in the lowest tertiles had significantly higher weight gain and higher increase in WHZ score at 1 month when compared to the children in the highest tertile of WHZ. However, it should be noted that even the group in the highest tertile of WHZ was severely wasted with mean WHZ of -2.6. Total weight gain in children in the lowest tertile of WHZ was almost 50% higher than that in the highest tertile. However, the higher weight gain in the lowest tertile of WHZ was contributed by FFM and increase in the sum of skinfold thicknesses and total body fat (TBF) gain did not differ in the 3 groups. Final body fat percent was therefore higher in the higher tertiles of WHZ at baseline. Dietary intakes of energy and protein were not different in the 3 WHZ groups.

DISCUSSION

This is one of the few studies which describe composition of weight gain during nutrition rehabilitation of severely undernourished children from India. It reveals differences in lean and fat mass accretion in relation to baseline severity of wasting.

The anthropometric parameters in Table 1 indicate that the children suffered from severe stunting as well as wasting. Therefore, even though there was rapid weight gain during one month of hospitalization, mean WHZ improved to only -2.6 which is still indicative of severe wasting. More than 50% children had a WHZ score of less than -4.2 with the lowest WHZ score being -6.9. The median WHZ scores reported by other studies from Africa range between -2 to -3[16-18] whereas studies from Bangladesh have indicated median WHZ score of about -4.[19] It appears that such extreme wasting is observed in the South Asian region whereas children admitted in nutrition rehabilitation centres in Africa appear to have less severe wasting. Lower birth weight and overall higher prevalence of undernutrition in the Asian countries in spite of relatively better economic status is frequently referred to as 'Asian enigma'.[20] However, the fact that a number of children presenting with infectious illnesses at government hospital suffer from extreme form of wasting has not received enough attention. It is important to note that most of these children were admitted to hospital for infectious morbidities and the physicians treating the infections referred them to the nutrition rehabilitation ward. Parents usually did not perceive that the child required treatment of undernutrition possibly because of widespread undernutrition prevalent in the poor communities. As majority of the children were still wasted after one month of hospitalization and intensive feeding, complete recovery may be prolonged. However, parents were generally unable to keep the child in hospital after 1 month because of loss of wages and the need to look after other children at home. Follow up assessment of dietary intakes and anthropometry after discharge in a few children at 6 months indicated that it was not possible for the families to maintain the intensive feeding at home due to monetary

Table 2. Subject characteristics and components of weight gain in tertiles of baseline weight for height Z score

	T1		T2		T3		*p* Value
	Mean	SE	Mean	SE	Mean	SE	
Age	24.6	3.0	24.0	2.6	26.5	3.3	0.644
Baseline weight (kg)	5.16	0.25	6.17	0.30	7.58	0.50	<0.001
Final weight (kg)	6.53	0.36	7.20	0.35	8.46	0.52	0.002
Weight gain (kg)	1.45	0.16	1.03	0.10	0.93	0.11	0.005
Weight gain (g/kg/d)	8.9	1.0	5.6	0.5	4.1	0.4	<0.001
Baseline FFM (kg)	4.96	0.25	5.68	0.28	6.62	0.40	<0.001
Increase in sum of skinfolds (mm)	8.6	1.1	6.9	0.7	6.1	0.8	0.126
FFM gain (kg)	1.00	0.11	0.62	0.06	0.57	0.07	<0.001
Baseline TBF (kg)	0.19	0.03	0.50	0.04	0.96	0.12	<0.001
TBF gain (kg)	0.50	0.06	0.45	0.05	0.47	0.06	0.808
Baseline %BF	3.8	0.5	8.0	0.7	11.8	0.9	<0.001
Final %BF	10.2	0.6	13.0	0.7	15.9	0.9	<0.001
Baseline WHZ	-5.5	0.1	-4.2	0.1	-2.6	0.2	<0.001
Final WHZ	-3.4	0.2	-2.7	0.1	-1.7	0.2	<0.001
Improvement in WHZ	2.1	0.3	1.5	0.2	0.9	0.2	<0.001

T1 ≤ -4.6, T2 = -4.6 to -3.7, T3 ≥ -3.7
WAZ, weight for age z score; HAZ, height for age z score; WHZ, weight for height z score; FFM, Fat free mass; TBF, Total body fat; % BF, per cent body fat.

and time constraints and therefore, weight gain after discharge from the hospital was significantly lower.

Before admission to the hospital, children were consuming only about 700 kcal/day (117 kcal/kg/day) when compared to the recommended dietary allowance of about 1000-1400 kcal/day for this age-group. This caloric intake was just enough to maintain their weight before admission to nutrition ward and caloric intakes rapidly improved within a week of admission. Mean protein intake ranged from 3.6 to 6.1 g/kg/day with an average protein energy ratio of 13% which was slightly higher than the other studies as children had access to liberal amounts of cereal-pulse preparations, eggs as well as milk. The foods offered to children in the nutrition ward were locally available and were traditionally considered appropriate for children, so that mothers could maintain similar feeding at home. Biochemical parameters indicated that there was improvement in serum albumin and serum zinc whereas no significant increase in blood urea levels was observed in spite of the high protein diets. As expected there was significant increase in IGF-1 levels indicating stimulation of growth.

Since there was wide variation in the severity of wasting at baseline and as improvement in the WHZ scores during nutrition rehabilitation was related to the baseline WHZ score, components of weight gain were assessed in tertiles of baseline WHZ score (Table2). The mean (SE) age of the children in the 3 groups was not different. There was severe deficit of both FFM and TBF in the lower tertiles of WHZ. Body fat percent of the children in the lowest tertile was only 3.8% which is an estimated amount of fat necessary for survival.[21] Acknowledging the measurement errors possible in body composition estimates using skin fold thickness measurement, nevertheless, one can conclude that these children had body fat percentage that was just enough for survival. It is interesting to note that the TBF gain was similar in the tertiles of WHZ scores but FFM gain was significantly different in the 3 groups.

The children in the lowest tertile had significantly higher weight gain as well as FFM gain when compared to the children in the upper tertiles while consuming similar amounts of dietary energy and proteins. To our knowledge, the relationship of baseline severity of wasting and composition of weight gain has not been reported to date.

The experimental semi-starvation studies in adults have indicated that the proportion of total body energy mobilized as protein (referred to as P-ratio) during weight loss is conserved during weight recovery.[22] It is not possible to have similar information for children because the measurements before weight loss leading to acute severe malnutrition are not possible. However, the body fat percent of the children in the lowest tertile of WHZ were just enough for survival and probably they had significant loss of FFM as well. It is reassuring to note that with intensive feeding of diets that contains good quality proteins, children are able to put on as much as 1 kg of FFM during the period of 1 month. It is uncertain whether they would be able to achieve similar gains in FFM in the absence of diets with liberal amounts of animal proteins such as milk and eggs.

It has been debated whether rapid weight gain and upward centile crossing in childhood may contribute to adiposity and the metabolic syndrome in later life. A longitudinal study in a cohort of Swedish adolescents who were followed prospectively from birth indicated that rapid weight gain in infancy and early childhood was a risk factor for adult adiposity and obesity.[23] On the other hand, a large prospective cohort study in Delhi which sequentially measured more than 1500 men and women from birth till 21 yrs of age demonstrated that higher body mass index (BMI) gain in early childhood was associated with a greater increase in adult lean mass than in adult adiposity.[14] On this background, the present study demonstrates that rapid weight gain in severely malnourished children treated with mixed diets is associated with increase in lean body mass. However, long term follow

up of these children is necessary to examine the body composition and the risk factors for the metabolic syndrome in adulthood.

Some limitations of this study need to be acknowledged. We assessed the body composition of the children by skinfold thickness measurements using Daucey's formula. Dauncey's method was developed on non-Indian infants and it has not been validated in Indian population. However, our primary interest was assessing the increments in the body tissues i.e., fat mass and lean mass and the measurements were made using the same method at baseline and after one month. Therefore, it is unlikely that any possible measurement error may have influenced the major findings of the study i.e., an association between the degree of baseline wasting and subsequent tissue gain. Moreover, analyses using the sum of skinfold thickness without any prediction formulae also confirmed this relationship. We recognize that our findings need to be confirmed with more precise methods of assessing body composition such as total body electrical conductivity, bio-electrical impedance, dual energy x-ray absorptiometry or air displacement plethysmography.

This study thus indicates that it is possible to achieve rapid weight gain with recovery of lost tissue in severely malnourished children with ad libitum feeding of milk, eggs and cereal pulse diets that can be continued at home. However, since the newly formed muscle tissue may not have optimal structure,[24] it is necessary to ensure that the children receive treatment before the severe wasting sets in. Further studies are necessary to explore dietary interventions that can enhance lean mass deposition during nutrition rehabilitation.

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AUTHOR DISCLOSURES

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印度某醫院嚴重營養不良孩童在營養恢復期增加體重之組成

嚴重營養不良的孩童在營養恢復期快速地成長的現象已引起關切，這也許與不成比例地大量的身體脂肪沉積有關。這個研究是調查在印度一個醫院裡那些嚴重營養不良的孩童，當他們經歷營養恢復期，所增加的體重及其組成。藉由測量入院以及餵食補充品一個月後的皮脂厚度來評估 80 位嚴重營養不良孩童的身體組成(年齡為 6-60 個月)。在入院時，孩童有嚴重的體重和身高不足以及極度消瘦。平均體重對年齡的 z 分數、身高對年齡的 z 分數以及體重對身高的 z 分數(WHZ)分別為-5.0、-4.2 以及 -4.1。給予孩童混合飲食，平均攝取熱量為每天每公斤體重 177 大卡，蛋白質佔總熱量的 13%。整體來看，孩童平均體重增加為每天每公斤 6.1 公克，其中脂肪量約佔 40%。當以基礎 WHZ 分數的三分位來分析體重增加的組成時，分數最低組有明顯較高的體重增加以及非脂肪量增加。但脂肪量的增加則與基礎 WHZ 分數無關。本研究顯示，對於嚴重營養不良的孩童，給予混合飲食可以快速增加體重及恢復耗損的組織。與相對較高的 WHZ 分數組相比，WHZ 分數最低組的孩童在營養復原期有較高的非脂肪量增加，也許是試著使受損的組織恢復。

關鍵字：蛋白質熱量營養不良、營養復原、身體組成、脂肪量、非脂肪重量