**Title: Dynamics of growth and overweight transitions in a pediatric cohort from South India.**

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**Abstract**

**Background:** There is paucity of information regarding overweight time trends from rapidly developing economies like India. Evidence on the role of socio demographic factors in modifying these overweight trends is also limited. The aim of the study was to analyse the dynamics of growth and overweight transitions in a cohort of school children from South India.

**Methods**: A population of 25 228 children were selected using stratified random sampling method from schools in a contiguous area in Ernakulam District, Kerala, South India. Weight and height, were measured at two time points, one in 2003-04 and another in 2005-06. The paired data of 12 129 children aged 5-16 years were analysed for the study.

**Results**: The mean interval between the two surveys was 2.02 ± 0.32 years. The percentage of normal weight, overweight and obese children in the year 2003-04 were 95%, 3.7%, and 1.3% respectively. The corresponding figures in year 2005-06 were 93.5%, 4.8% and 1.7% respectively. During the study period, weight showed marked increase in comparison to height. Conversion of normal weight to overweight status predominated in urban area, private schools and boys when compared to their counter parts. Among the overweight children in 2003-04, 26.7% migrated to normal weight status, 6.4% became obese and 56.9 % retained their overweight status. Of the obese children in 2003-04, 16.2 % improved to normal weight status, 25.3% improved to overweight status and 68.5% remained as obese in 2005-06.

While there was significant difference in trends between the socio demographic subgroups regarding conversion of normal weight to overweight status, no significant difference was found when conversion of overweight status to normal weight status was analysed.

**Conclusion**: The pediatric population is witnessing an explosion of overweight burden due to rapid growth, heavily influenced by socio demographic factors. Socio economic status appears to be the predominant factor influencing this growth transition. The favourable conversion of

overweight to normal appears to be due to unidentified factors. Identification of these beneficial factors is critical to the success of future overweight prevention programs.

**Background**

Obesity in children is considered as an emerging global epidemic. Studies from across the globe have confirmed a rapid increase in prevalence of childhood overweight and obesity [1-3]. The proportion of school age children affected is predicted to double by 2010 compared with the most recently available surveys from the late 1990s up to 2003 [3]. This alarming trend is demonstrated even in developing economies like India, China and Brazil [4-6]. Obesity is known to promote clustering of cardiovascular risk factors even from early childhood [7,8]. Studies have demonstrated that childhood obesity tracks into adulthood [9]. Obesity significantly contributes to cardiovascular risk in adulthood [10]. There is evidence of a demographic, epidemiological and nutritional transition in India amplifying the burden of chronic diseases and obesity [11].

The relationship of socioeconomic status and obesity shows interesting asymmetry [12]. The urban poor of developed economies are particularly vulnerable to childhood obesity in contrast to developing nations where the urban rich are extremely at risk for the same [13]. While the former group appears vulnerable due to poor diet and decreasing physical activity, the latter remains at risk probably due to an increased affinity towards a western type of lifestyle [14-17]. A recent systematic review demonstrated that associations between physical environmental variables and obesity differ by gender, age, socio economic status and population density [18]. Cohort studies have demonstrated that social patterning of overweight varies between and within populations over time [19]. National surveys from China have demonstrated the rapidity of overweight progression as well as the differential growth of overweight in terms of varying levels of urbanization [6]. Studies from India have also stressed the role of socio economic

status and urbanization in promoting childhood obesity [5,20]. The aim of this study was to examine the dynamics of growth and overweight transitions in school children from a selected population in South India and to assess the influence of socio demographic factors in the same.

**Methods**

A contiguous area with a population of approximately 1.37 million was selected from Ernakulam district, in central Kerala, South India. Sampling was done by stratified random sampling method. Schools in the area were stratified into 5 groups according to the strength of children and a representative sample of 46 schools with a cumulative population of 25 228 children was randomly chosen. Anthropometric measurements, which consisted of height and weight, were recorded for 24 842 children of age group 5-16 years in 2003-04. The same set of measurements was repeated in the selected schools in 2005-06 covering a total of 20 263. Personnel specifically trained for the study recorded the anthropometric measurements. One trained person was dedicated for recording weight and another for height, to avoid inter observer error. Intra observer error was within acceptable limits for both height and weight measurements as documented by the co-efficient of reliability (R >0.99). Height was measured to the nearest 0.5 centimeter by a wall-mounted stadiometer. Weight was measured to the nearest 0.5 kilogram by mechanical weighing scale. Both equipments were standardized at regular intervals. A total of 12 129 children had two sets of measurements, one in 2003-04 and other in 2005-06. Paired data of these children were used for studying dynamics of childhood overweight and obesity in the study population. Children with Body Mass Index (BMI) more than or equal to 85$^{th}$ percentile of reference data were considered overweight and those having more than or equal to 95$^{th}$ percentile were considered obese [21]. The reference data used to identify the BMI cut offs as well as conversion of weight and height to Z scores were taken from CDC 2000 data set for growth parameters in children and adolescents [22]. The cohort was divided into various subgroups for detailed analysis. Schools were divided into government and private schools. Government

schools receive subsidies from the educational department enabling them to provide education at less than INR 500 per year per student (approximately US$ 12). Private schools receive no subsidies and charge students INR 5000 and above per year. Schools were also divided into rural and urban as well. Rural area was defined if more than 75 percent of adult male population was engaged in agricultural occupations along with lower levels of developmental indices. Non-rural areas were designated as urban areas.

Consent to conduct the survey on students was obtained from parents through school authorities, who arranged parent meetings in the respective schools. Verbal assent was taken from the children after demonstrating and explaining the procedure.

**Statistical analysis**

The data was analyzed using SPSS software version 15. Anthropometric transition was assessed by converting the corresponding parameters to Z scores and comparing their means. Paired samples test was used for comparing individual subgroup time transitions. Independent samples test was used for comparing time transitions of inter subgroup differences. Pearson Chi square test was used for comparing transitions from normal weight status to overweight status and vice versa. Significance was assigned for a P value $<0.05$.

**Results**

Descriptive data of the cohort based on the two periods 2003-04 and 2005-06 is given in Table 1. The mean interval between the two surveys was 2.02 ± 0.32 years. The percentage of normal weight, overweight and obese children in the year 2003 were 95%, 3.7%, and 1.3% respectively. The corresponding figures when the cohort was examined two years later were 93.5%, 4.8% and

1.7% respectively. The difference in categories of weight status between 2003 and 2005 appears to be statistically significant (P<0.0001).

Among the 11522 normal weight children in 2003-04, 11207 (97.3%) remained normal, 288 (2.5%) became overweight and 27 (0.2%) became obese when screened during 2005-06. Among the 445 overweight children in 2003-04, 119 (26.7%) migrated to normal weight status, 73 (16.4%) became obese and 253 (56.9 %) retained their overweight status. Of the 162 obese children in 2003-04, 10 (6.2 %) improved to normal weight status, 41 (25.3%) improved to overweight status and 111 (68.5%) remained as obese in 2005-06.

The anthropometric parameters (height, weight and BMI) were converted to their respective z scores based on reference population values [22] and analyzed (Table 2). The cohort showed significant improvements in height, weight and BMI during the study period as documented by corresponding increases in their mean z scores. (P < 0.001). Sub-group analysis of the cohort was done to look for the influence of socio demographic factors in this anthropometric transition. The rural subgroup showed significant improvements in weight and BMI (P < 0.001). The change in height was not significant. The urban sub group showed significant improvements in all three parameters (P < 0.001). The government school subgroup showed significant improvements in weight and BMI (P < 0.001) only where as private school group showed significant improvements in all three parameters (P < 0.001). The boys sub group demonstrated an increase in all three parameters (P < 0.001) where as girls demonstrated an increase in weight and BMI only (P < 0.001). In addition girls demonstrated a significant reduction in terms of height (P< 0.001).

The inter subgroup differences between the two time points were analyzed to look for any significant trends (Table 2). While the rural urban difference for height increased significantly during the study period (P < 0.001), the same for weight and BMI showed no significant changes. In terms of government private comparison, the difference in height increased significantly (P<0.001), while that of weight (P<0.001) and BMI decreased significantly (P<0.001). In comparing the gender subgroups, significant increase was found in height difference (P<0.001) where as weight difference showed a significant decrease. There was no significant change for difference in BMI.

For the sake of comparing demographic influences on the transition of weight status, overweight and obesity were clubbed together to form the overweight group. The details are available in Table 3.

Among the normal weight urban children, as identified in 2003-04, 3.4% migrated to overweight status in 2005-06. The corresponding figure for rural area was 1.9%. The difference between the groups was significant (P<0.001). Among the overweight urban children, 20.1 % migrated to normal weight in 2005-06. The corresponding figure for rural area was 25.4%. The difference was not statistically significant. Among the normal weight children from government schools, as identified in 2003-04, 2.2% migrated to overweight status in 2005-06. The corresponding figure for private schools was 4.9%. The difference between the groups was significant (P<0.001). Among the overweight children from government schools, 24.5% migrated to normal weight status in 2005-06. The corresponding figure for private schools was 18.7%. The difference was not statistically significant. Among the normal weight boys, as identified in 2003-04, 3.1% migrated to overweight status in 2005-06. The corresponding figure for girls was 2.4%. The difference between the groups was significant (P<0.038). Among overweight boys, as identified

in 2003-04, 21.3% migrated to normal weight status in 2005-06. The corresponding figure for girls was 21.2%. The difference was not statistically significant.

**Discussion**

The dynamics of growth transition demonstrated by the cohort appears to be heterogeneous in nature. The results clearly shows that growth is more or less restricted to increments in weight in the majority of children. A similar trend was reported by Vidal et al [23]. In short, the population is becoming heavier without exhibiting the desired increment in height. The rural as well as government school children have shown significant increment in weight and BMI but not in height. In contrast, both urban as well as private school children demonstrated significant increases in height, weight and BMI. While the private and urban school children are becoming heavier and taller, the rural and government school children are simply becoming heavier and not taller. It should be noticed that area of residence and type of school are acceptable surrogates of level of urbanization and socioeconomic status respectively in the Indian context. The findings also document that the time trend for linear growth remained stagnant in rural areas and low socioeconomic levels. It is important to note that secular trends in height demonstrated during childhood could extend into adulthood [24]. This assumes significance due to the fact that adult height exhibits inverse linear associations with mortality from coronary heart disease and stroke as well as total mortality [25].

While boys have shown improvements in height, weight and BMI, girls have shown improvements in weight and BMI along with a significant reduction in height. This implies that while boys are becoming taller and heavier with increasing age, girls are becoming heavier and shorter when compared to international reference. This disparity in growth pattern between the

genders could probably be due to the combined effects of both physiological and socio demographic influences.

In terms of height difference, all three sub group comparisons i.e. rural Vs urban, government Vs private as well as boys Vs girls increased significantly. In terms of weight difference, significant decreases were seen in government Vs private as well as boys Vs girls comparisons. In terms of BMI difference, significant decrease was seen in government Vs private comparison. The study suggests that the socio economically advanced as well as the more urbanised segments of the pediatric population are growing relatively taller than their counterparts, promoting a progressive height divide in the population. This is also happening with boys when compared to girls. It should be noted that in spite of a short gap of two years between the two surveys, there is a significant change in height status among certain segments of the study population. It is very rare to see demonstrable changes in height at a population level in such short periods. This finding clearly suggest that the study population is experiencing rapid transitions in growth that is demonstrated at different velocities among subgroups. The enhancement of gender divide in terms of height appears to be in contrast to the trend demonstrated by Vidal et al [23]**.** The results also suggest that the weight divide between the higher and lower socio economic segments of the pediatric population is diminishing with time. The same trend is seen in gender comparison, which implies that the gender divide in weight is also diminishing with time. Vidal et al reported a similar time trend of diminishing weight divide between the genders among children [23]. It is interesting to note that the difference in adiposity between comparable subgroups is showing a significant decrease with time across socio-economic status only. Combining the above findings, it becomes clear that the low socio-economic segments of the population are experiencing overweight issues that are growing at a faster rate when compared to the same in higher socio-economic segments of the pediatric population.

Even though the change in normal weight population appears small at 1.5%, the overweight sub population has grown by 29.7% and the obese sub population by 30.8% in a short span of two years. The study results indicate that the conversion of normal weight status to overweight status occurs more in urban areas, private schools, and boys in comparison to rural areas, government schools and girls respectively. In contrast, no significant influence of the same socio demographic factors was noticed in conversion of overweight population to normal weight status. In short, the beneficial conversion of overweight to normal weight appears to be due to other unidentified factors. The conversion of overweight to normal weight happening in the pediatric population could be due to multiple factors. The probable candidates promoting this beneficial conversion could be individual awareness about overweight issues, attempts at the family, school, community or individual level to reduce the burden of overweight as well as policy changes aimed at containing childhood obesity. The role of these factors as well as other unidentified ones need to be clearly identified for converting them into effective interventions aimed at reducing the burden of childhood obesity.

## Conclusions

The pediatric population is experiencing a growth transition, which appears to be heterogeneous across various segments. An explosion of overweight burden, heavily influenced by socio demographic factors seems to accompany this rapid transition. Socio economic status appears to be the predominant factor influencing this growth transition. A favourable conversion of overweight to normal appears to happen in the population probably due to unidentified factors. More studies are needed to identify these beneficial factors for the purpose of creating viable population strategies to contain childhood obesity.

**Competing interests:** The authors declare that they have no competing interests in this study.

**Authors' contributions:** MR conceived, designed and drafted the study. KRS did the statistical analysis and contributed to the drafting of manuscript. MP managed the data and assisted in drafting the manuscript. AS assisted in statistical analysis and in data management. RKK supervised and revised the manuscript for important intellectual content. All authors read and approved the final manuscript. MR will act as guarantor of the study.

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**Table 1 –Descriptive data of the study cohort**

| | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| **2003** | | **Height (cm)** | **Weight (kg)** | **BMI (kg/m$^2$)** | | **Height (cm)** | **Weight (kg)** | **BMI (kg/m$^2$)** |
| Age (yrs) | N | Mean | Mean | Mean | N | Mean | Mean | Mean |
| 5 | 293 | 109.7 (4.6) | 16.7 (2.2) | 13.8 (1.3) | 223 | 108.6 (5.5) | 16.3 (2.4) | 13.8 (1.5) |
| 6 | 580 | 115.5 (5.4) | 19.1 (3.2) | 14.2 (1.6) | 486 | 114.3 (5.5) | 18.6 (3.5) | 14.2 (1.8) |
| 7 | 574 | 120.7 (6.2) | 21.1 (4.1) | 14.4 (1.9) | 425 | 120.2 (5.8) | 20.8 (3.8) | 14.3 (1.8) |
| 8 | 534 | 126.6 (6.1) | 23.8 (4.6) | 14.8 (2.0) | 421 | 125.5 (6.4) | 23.4 (5.3) | 14.7 (2.2) |
| 9 | 720 | 131.9 (6.5) | 26.4 (6.0) | 15.1 (2.3) | 737 | 131.4 (6.5) | 26.4 (5.6) | 15.1 (2.3) |
| 10 | 812 | 135.9 (6.8) | 28.5 (6.9) | 15.3 (2.6) | 946 | 136.5 (7.1) | 28.8 (6.2) | 15.3 (2.3) |
| 11 | 733 | 140.5 (7.4) | 31.2 (7.5) | 15.6 (2.7) | 1059 | 142.3 (7.1) | 32.7 (7.1) | 16.0 (2.6) |
| 12 | 842 | 145.9 (7.4) | 33.9 (7.4) | 15.8 (2.5) | 1122 | 147.9 (7.2) | 36.7 (8.1) | 16.6 (2.8) |
| 13 | 556 | 152.5 (8.7) | 39.2 (9.8) | 16.7 (3.0) | 706 | 151.0 (6.7) | 39.7 (7.7) | 17.3 (2.7) |
| 14 | 197 | 155.9 (8.7) | 41.6 (9.7) | 17.0 (2.9) | 146 | 151.9 (6.1) | 40.9 (7.3) | 17.7 (2.7) |
| **2005** | | | | | | | | |
| 7 | 207 | 122.4 (5.1) | 21.3 (3.8) | 14.1 (1.8) | 163 | 122.1 (5.7) | 21.6 (5.1) | 14.4 (2.4) |
| 8 | 592 | 127.4 (5.8) | 24.5 (5.2) | 15.0 (2.3) | 489 | 126.1 (6.3) | 23.7 (4.9) | 14.8 (2.1) |
| 9 | 574 | 131.8 (6.5) | 26.8 (5.9) | 15.3 (2.4) | 454 | 131.7 (6.6) | 26.6 (5.7) | 15.2 (2.3) |
| 10 | 551 | 137.5 (6.8) | 30.1 (6.8) | 15.8 (2.6) | 406 | 138.0 (7.2) | 30.6 (7.4) | 15.9 (2.7) |
| 11 | 746 | 142.5 (7.5) | 33.3 (8.1) | 16.2 (2.8) | 763 | 143.7 (7.4) | 34.4 (8.2) | 16.5 (2.8) |
| 12 | 837 | 146.7 (8.0) | 35.9 (9.2) | 16.5 (3.0) | 989 | 148.7 (6.6) | 38.4 (8.3) | 17.2 (2.9) |
| 13 | 754 | 153.7 (8.7) | 40.7 (9.4) | 17.1 (2.9) | 1034 | 152.0 (6.0) | 41.4 (7.5) | 17.9 (2.8) |
| 14 | 836 | 160.1 (8.2) | 45.0 (9.4) | 17.4 (2.7) | 1204 | 154.5 (5.8) | 44.1 (8.6) | 18.4 (3.1) |
| 15 | 537 | 164.3 (7.4) | 49.3 (10.0) | 18.2 (2.9) | 648 | 155.2 (6.3) | 45.9 (8.4) | 19.0 (2.9) |
| 16 | 211 | 166.1 (6.7) | 52.7 (10.7) | 19.0 (3.2) | 131 | 155.3 (6.4) | 46.2 (8.4) | 19.1 (3.1) |

Figures in parenthesis are standard deviations.

Data of children in age group 15 years in 2003 (n=6) and age group 6 years in 2005 (n=2) are not shown in the table, as the number of children in the same is very low

**Table II- Trends in Z scores of Anthropometric parameters**

| Group | | Z-height | | | Z-weight | | | Z-BMI | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | 2003 | 2005 | sig* | 2003 | 2005 | sig* | 2003 | 2005 | sig* |
| | | Mean | Mean | | Mean | Mean | | Mean | Mean | |
| **All** | 12129 | -0.81 (1.02) | -0.79 (0.99) | <0.001 | -1.31 (1.27) | -1.09 (1.25) | <0.001 | -0.80 (0.88) | -0.67 (0.88) | <0.001 |
| | | | | | | | | | | |
| **Rural** | 5240 | -0.94 (0.99) | -0.94 (0.95) | 0.823 | -1.57 (1.18) | -1.36 (1.18) | <0.001 | -0.97 (0.75) | -0.83 (0.77) | <0.001 |
| **Urban** | 6889 | -0.72 (1.03) | -0.68 (1.01) | <0.001 | -1.12 (1.31) | -0.90 (1.26) | <0.001 | -0.67 (0.94) | -0.54 (0.94) | <0.001 |
| sig** | | **<0.001** | | | **0.416** | | | **0.887** | | |
| **Govt** | 9358 | -0.96 (0.98) | -0.96 (0.94) | 0.488 | -1.54 (1.20) | -1.31 (1.19) | <0.001 | -0.94 (0.76) | -0.79 (0.78) | <0.001 |
| **Pvt** | 2771 | -0.31 (0.96) | -0.24 (0.95) | <0.001 | -0.54 (1.22) | -0.38 (1.19) | <0.001 | -0.33 (1.06) | -0.25 (1.05) | <0.001 |
| sig** | | **<0.001** | | | **<0.001** | | | **<0.001** | | |
| **Boys** | 5847 | -0.79 (1.02) | -0.74 (1.02) | <0.001 | -1.38 (1.34) | -1.15 (1.29) | <0.001 | -0.84 (0.92) | -0.71 (0.94) | <0.001 |
| **Girls** | 6282 | -0.83 (1.01) | -0.85 (0.97) | <0.008 | -1.25 (1.21) | -1.05 (1.20) | <0.001 | -0.76 (0.83) | -0.63 (0.83) | <0.001 |
| sig** | | **<0.001** | | | **0.008** | | | **0.602** | | |

Figures in parenthesis are standard deviations.

* Significance of paired sample test value

** Significance of independent sample test value

Govt- government schools, Pvt- private schools

**Table 3- Trends in weight status by socio demographic factors**

| 2003 status | | | 2005 status | | | | |
|---|---|---|---|---|---|---|---|
| | | Total | Normal | % | OW | % | P value |
| NW | Urban | 6412 | 6195 | 96.6 | 217 | 3.4 | 0.000 |
| | Rural | 5110 | 5012 | 98.1 | 98 | 1.9 | |
| OW | Urban | 477 | 96 | 20.1 | 381 | 79.9 | 0.194 |
| | Rural | 130 | 33 | 25.4 | 97 | 74.6 | |
| NW | Govt | 9093 | 8897 | 97.8 | 196 | 2.2 | 0.000 |
| | Private | 2429 | 2310 | 95.1 | 119 | 4.9 | |
| OW | Govt | 265 | 65 | 24.5 | 200 | 75.5 | 0.082 |
| | Private | 342 | 64 | 18.7 | 278 | 81.3 | |
| NW | Boys | 5518 | 5349 | 96.9 | 169 | 3.1 | 0.038 |
| | Girls | 6004 | 5858 | 97.6 | 146 | 2.4 | |
| OW | Boys | 329 | 70 | 21.3 | 259 | 78.7 | 0.987 |
| | Girls | 278 | 59 | 21.2 | 219 | 78.8 | |

NW- Normal weight

OW- Overweight (inclusive of overweight and obesity)

Govt-Government schools