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Growth curves of Pacific Children living in Auckland, New Zealand

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Abbreviations

CDC Centres for Disease Control

FFM fat free mass

FM fat mass

LMS the skew (L), the median (M) and the coefficient of variation (S) parameters

PIF Pacific Islands Families

WHO World Health Organisation

What is already known about this subject

In children the prevalence of obesity increases with age

Pacific Island children have very high prevalence of overweight and obesity

Pacific people in New Zealand have a high prevalence of non-communicable diseases and poor health outcomes

What this study adds

From a contemporary longitudinal cohort of Pacific children objective evidence is provided that:

for Pacific children the rate of weight gain from 2 to 10 years is more rapid than in reference populations.

early identification and management of rapidly growing children is necessary to slow the weight gain in this population

Abstract

Background: Since 2000, the longitudinal Pacific Island Families study has measured weight, height and body mass index (BMI) in children aged 2 to 10 years.

Objective: To establish the changing prevalence of obesity through modelling centiles of age-related increases in body size and comparing these with clinical reference growth curves.

Methods**:** Measurements at the 2, 4, 6 and 9 year collection phases from 582 girls and 643 boys of weight, standing height and body mass index BMI were analysed. Using the LMS method gender-specific age-related centile curves were derived for weight, height and BMI. The 50^{th} centiles from the World Health Organisation's growth reference for 2 to 5 year olds and the Centres for Disease Control (CDC) for 5 to 10 year olds were compared. Overweight and obesity were defined by the CDC BMI 85^{th} and 95^{th} centiles.

Results**:** The proportion of children whose weight and height were above the reference 50^{th} centiles increased with age. At age 10 years, using CDC criteria, more than half the children were be classified as obese and 70% overweight.

Conclusions: These growth trajectories support the need to prioritise interventions for Pacific families, starting from before pregnancy, to address childhood obesity. The curves could help assess relative growth of Pacific children in general and inform identification of children for further assessment and treatment.

Introduction

From birth, children whose parents originate from the Pacific Islands have greater body weight than other ethnicities in New Zealand (NZ)[1]. Furthermore across the lifecycle, these children increase in weight-for-height faster than other ethnic group in the country. In a nationwide survey in 2006/2007,[2] Pacific boys and girls age 5-14y were at least 1.5 times more likely to be obese than boys and girls from the general population. The same survey also highlighted Pacific men and women to have 3 times the prevalence of diagnosed diabetes and rates of obesity 2.5 times higher than men and women from the general NZ population. Since the year 2000, the Pacific Island Families (PIF) study has been assessing child and family development and wellbeing since birth, in 1398 Pacific families, at Middlemore Hospital, South Auckland, NZ[3].

Previous research undertaken amongst the PIF study cohort found that at birth, the average child was 3.7±0.5 (mean, SD) kg; z-score 0.6 units heavier than the World Health Organisation (WHO) standard[4]. At 2- and 4 years, average z-scores for weight were +1.11 and +1.77 units greater, and for body mass index (BMI) +1.70 and +97 higher than WHO standard respectively[4]. At age 6 children in the PIF cohort with highest birth weights were heaviest[5] while for the children with the smallest birth weights weight gain over their first 6 years was more rapid than other children in the cohort. Furthermore, an Auckland sample from the National Children's Nutrition Survey showed Pacific girls and boys, aged between 5 to 14 years, increased in fat free mass (FFM) and fat mass (FM) faster than their European or Māori counterparts[6].

Rapid childhood growth is associated with adult obesity[7] and associated complications including non-communicable disease.[8] The PIF study presents a unique opportunity to investigate the trajectories of body weight and height from birth. Hence the aim of this study was to use empirical data to construct growth curves that describe the trajectory of increase in

the weight, height and BMI of Pacific children from 2 to 10 years and compare their measurements to both national guidelines and international standards.

Methods

Subjects

Initial study design and methodology have been reported elsewhere[9]. Briefly, 1398 live children born at Middlemore Hospital, South Auckland to 1376 mothers between 15 March and 17 December 2000 were recruited to the study. This area contains the highest density of Pacific Island residents in NZ (Manukau City, 2001 Census)[10] and the sample represents between a quarter and one third of all the eligible children born in the region. An infant was deemed eligible if at least one parent identified themselves as being of Pacific Island ethnicity and was a permanent resident of NZ.

Measurements

Weight in light clothing to the nearest 0.1 kg and standing height, without shoes, to the nearest 0.1 cm, was measured at the 2, 4, 6 and 9 year data collection phases, using standardized procedures. BMI was calculated as weight in kilograms divided by squared height in metres. All procedures and interview protocols had ethical approval from the National Ethics Committee.

Statistics

Of the 1398 children, 1225 (582 girls and 643 boys) were full term (>37 weeks gestation) singleton births to mother's without a history of diabetes. Preterm children, twins and children of mothers with diabetes were excluded as their growth trajectory would differ from that of the reference child.[11] Not all children had responses at every time data collection phase. A total of 3099 (1467 girls 1632 boys) data points were available for weight centile calculation; 3080 (1457 girls, 1623 boys) data points were available for height centile calculation and 2960 (1402 girls, 1558 boys) data points were available for BMI centile

calculation. Age of measurement ranged from 2 to 10 y. Approximately 30% of data points were available for 2 to 4 y, 20% were available for 4 to 6 y, 25% were available for 6 to 9 y and 25% for 9 to 10.5 y. The methods described by Cole and Green[12] were used to derive the skew (L), median (M) and the coefficient of variation (S) parameters parameters from the weight, height and BMI data and to plot the growth trajectory. These LMS parameters are the skew (L), the median (M) and the coefficient of variation (S) for each year of measurement of the growth chart. Parameters were calculated separately for each gender. The 5, 10, 25, 50, 75, 85 and 95th centiles were plotted to coincide with the Centres for Disease Control (CDC) child standard[13]. For symmetry, we added the 90th centile, as well as the 2.5 and 97.5th centiles, to allow the range for 95% of the children to be determined at intermediate ages. While the curves are presented as lines, all data points were plotted on the curves and inspected to ensure that the plotted centiles represented the distribution. The 50th centiles from the WHO growth standard[11] for 2 to 5 year olds and the Centres for Disease Control (CDC) for 5 to 10 year olds were compared. Overweight and obesity were defined by the CDC[13] BMI 85th and 95th centiles. Currently, in the NZ child weight management guidelines, a child with a BMI for age above the 85th and 95th CDC centiles are classified as overweight and obese, respectively[14].

To calculate the LMS parameters lmsqreg package, R v2.12 was used. The data was visualised and compared with two growth standards (i) WHO (2-5 y)[11] and (ii) CDC (5-10 y).[13]

Results

Figures 1 to 3 show standardised curves for weight, height and BMI for age from 2 to 10 years. At age 10 y, almost 95% of Pacific boys and girls were above the CDC 50th centile for weight for age (Figure 1). For height, at age 10y more than 75% of the children were above the 50th centile (Figure 2).The proportion of children whose weight and height were above the

WHO (2 to 5 y) and CDC 50th (5-11 y) centiles (Figures 1 and 2) increased with age. Similarly, for BMI at 10 y, almost 95% of Pacific boys and girls exceeded the CDC 50th centile and more than 50% of boys and slightly less than 50% girls would meet obese criteria (≥CDC95th centile, Figure 3). At age 10 y, more than 75% of boys and approximately 70% girls were above the CDC 85th centile; the action point to raise awareness on obesity for children and young people (Figure 3). The median BMI for a 10 y old Pacific boy was 23 kg/m^2, compared with 17 kg/m^2 for the CDC median boy.

Discussion

This longitudinal study of Pacific Island children tracked from birth has enabled, for the first time, growth trajectory charts to be generated. These are a representation to what the growth of the cohort is; not what optimal growth should be[15]. The growth of the ”ideal” breastfed child in a smoke free environment is provided by WHO growth standard (0-5 y) and the CDC charts are those based primarily on data from cross-sectional data from national health surveys in the United States between 1963 and 1994. The reference curves may not be accurate for Pacific children as they did not include Pacific children in their generation. This snapshot of growth of Pacific children has allowed us, for the first time, to display increased right – skewness as Pacific children age patterns similar to other standardised curves[13, 16]. Heavier children appear to increase in weight and weight relative to height more rapidly than children who track as lighter for their age. Heavier children are also more likely to have a higher prevalence of cardiometabolic risk factors[6, 17]. These findings support the requirement for action points for detection of cardiometabolic abnormalities to be based on historical data which precedes or circumvents the current obesity epidemic. The NZ guidelines for the management of weight in children and young people[14] state that if the BMI for age and sex is ≥the 85th CDC percentile, then awareness should be raised and clinical risks, needs and context evaluated. Further investigations such as fasting lipids and glucose and sleep studies

should be considered only if (i) BMI is ≥ 95th CDC percentile (ii) there is a family history of cardiovascular disease and (iii) there is a family history of Type 2 diabetes. Thus, these findings suggest that health practitioners should potentially engage and raise awareness with the family of one out of every two Pacific children before they reach 10 y. In the 2006 national census, the population of Pacific children aged 0-14 years was 75,528 (8.7% of the children in NZ). This means that almost 38,000 Pacific children may be at potential risk of obesity. Previous studies report the prevalence of obesity in Pacific women in NZ at approximately 60%[18]. This is a cause for alarm, since body size of the mother is related to the birth weight of the baby[1] and the cycle of heavier mothers giving birth to heavier babies may continue and amplify through the generations.

For Pacific people resident in the Pacific Islands there is limited information about the prevalence of adult obesity. However, there is some evidence to report that rates of obesity are already high (>50%)[19] and comparable to the prevalence for Pacific Island people living NZ. We also do not know how rapidly Pacific children grew in the past and there is very little information available about the growth of Pacific children and the prevalence of overweight and obesity in the current population of these children living in NZ[20, 21].[22, 23]. Of the research that is available, in 2002 and 2006_7, the prevalence of obesity and overweight using Cole criteria[22] amongst Pacific girls and boys aged 5-14y was relatively stable at 27% and32%, respectively. Recent information about the growth of Pacific adolescents (14 to 18y) comes from the Obesity Prevention in Communities Study in Tonga[23] and South Auckland[24]. They report that over three years, obesity[25] prevalence increased from baseline of 14.8% to 19.3% in Tonga and was maintained at ~30% in the Auckland sample. For children of other ethnic groups, and from earlier times, it is known that growth patterns differ dependent on mode of feeding, smoking practice of the mother and socioeconomic status[26].

These growth curves and their interpretation have limitations. Firstly they do not track individual children but track the cohort from the year 2002 to 2010. We know that many of the girls in this cohort will have already experienced menarche [27] and this is a time of rapid growth which may not be captured by the smaller number of data points above age 10. Furthermore, a number of mothers may have had undiagnosed diabetes during pregnancy, which is associated with accelerated growth and obesity in offspring[28]. While the cohort is representative of the proportions of Pacific ethnic groups in the NZ population, we can only say that their pattern of growth represents a moving snapshot of a cohort of Pacific children born in South Auckland in the year 2000.

This report is a study of the natural progression in physical size of a cohort of Pacific children living in South Auckland. It should be made clear that the PIF study was not an intervention study. Yet national and regional public health interventions or individual medical care were not limited for the participants involved.

Conclusions

This contemporary and graphic depiction of the rapid growth of Pacific children provides evidence of accelerated rates of growth throughout childhood. The prevalence of overweight and obesity increases from 2 to 10 years and is consistent with the increasing body of evidence for the developmental origins of health and disease[29] and the need to prioritise interventions for Pacific families, starting from before pregnancy. Comparison of centiles of the actual growth trajectory of the PIF cohort with reference charts overlaid is a tool that may help assess relative growth of Pacific children in general and inform identification of children for further assessment and treatment.

Conflict of interest

We attest that the work described is original, has not been published previously, is not currently being considered by another journal, and that if accepted for *Pediatric Obesity* will not be published elsewhere. All authors have seen and approved the contents of the submitted manuscript. There is no conflict of interest.

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ER and VO conceived the study design and research question, ER and FS undertook the literature search and VO and ER analysed data. All authors were involved in interpreting the data, writing the paper and had final approval of the submitted and published versions.

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References

1. McCowan L, Stewart AW, Francis A, Gardosi J. A customised birthweight centile calculator developed for a New Zealand population. *Aust N Z J Obstet Gynaecol* 2004; **44**(5)**:** 428-31.

2. Ministry of Health. *A Portrait of Health: Key results of the 2006/07 New Zealand Health Survey*. Ministry of Health: Wellington, 2008.

3. Paterson J, Percival T, Schluter P, Sundborn G, Abbott M, Carter S *et al.* Cohort profile: The Pacific Islands Families (PIF) Study. *Int J Epidemiol* 2008; **37**(2)**:** 273-9.

4. Rush EC, Paterson J, Obolonkin VV, Puniani K. Application of the 2006 WHO growth standard from birth to 4 years to Pacific Island children. *Int J Obes (Lond)* 2008; **32**(3)**:** 567-72.

5. Rush E, Gao W, Funaki-Tahifote M, Ngamata R, Matenga-Smith T, Cassidy M *et al.* Birth weight and growth trajectory to six years in Pacific children. *Int J Pediatr Obes* 2010; **5**(2)**:** 192-9.

6. Rush EC, Scragg R, Schaaf D, Juranovich G, Plank LD. Indices of fatness and relationships with age, ethnicity and lipids in New Zealand European, Māori and Pacific children. *Eur J Clin Nutr.* 2009; **63**(5)**:** 627-33.

7. Ong KK, Loos RJ. Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. *Acta Paediatr* 2006; **95**(8)**:** 904-8.

8. Singhal A, Kennedy K, Lanigan J, Fewtrell M, Cole TJ, Stephenson T *et al.* Nutrition in infancy and long-term risk of obesity: evidence from 2 randomized controlled trials. *Am J Clin Nutr* 2010; **92**(5)**:** 1133-44.

9. Paterson J, Tukuitonga C, Abbott M, Feehan M, Silva P, Percival T *et al.* Pacific Islands Families: First Two Years of Life Study--design and methodology. *N Z Med J* 2006; **119**(1228)**:** U1814.

10. Statistics New Zealand. *2001 Census, Cultural diversity tables* Statistics New Zealand: Wellington, 2002.

11. World Health Organisation. *WHO Child Growth Standards: length/height -for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development* World Health Organisation: Geneva, 2006.

12. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. *Statistics in medicine* 1992; **11**(10)**:** 1305-19.

13. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R *et al.* CDC growth charts: United States. *Adv Data* 2000; (314)**:** 1-27.

14. Ministry of Health, Clinical Trials Research Unit. Guidelines for Weight Management in Children and Young People. In. Wellington: Ministry of Health, 2009.

15. Parsons HG, George MA, Innis SM. Growth assessment in clinical practice: whose growth curve? *Curr Gastroenterol Rep* 2011; **13**(3)**:** 286-92.

16. de Onis M, Onyango AW, Borghi E, Garza C, Yang H. Comparison of the World Health Organization (WHO) Child Growth Standards and the National Center for Health Statistics/WHO international growth reference: implications for child health programmes. *Public Health Nutr* 2006; **9**(7)**:** 942-7.

17. Kakinami L, Henderson M, Delvin EE, Levy E, O'Loughlin J, Lambert M *et al.* Association between different growth curve definitions of overweight and obesity and cardiometabolic risk in children. *CMAJ;* 2012; **184**(10)**:** E539-50.

18. Ministry of Health. *A Focus on Pacific Nutrition: Findings from the 2008/09 New Zealand Adult Nutrition Survey*. Ministry of Health: Wellington, 2012.

19. World Health Organisation. (2010). Compare Countries: Using WHO comparable estimates [WWW document]. URL https://apps.who.int/infobase/Comparisons.aspx

20. de Onis M, Blossner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr* 2010; **92**(5)**:** 1257-64.

21. Fukuyama S, Inaoka T, Matsumura Y, Yamauchi T, Natsuhara K, Kimura R *et al.* Anthropometry of 5-19-year-old Tongan children with special interest in the high prevalence of obesity among adolescent girls. *Ann Hum Biol* 2005; **32**(6)**:** 714-23.

22. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007; **335**(7612)**:** 194.

23. Fotu KF, Millar L, Mavoa H, Kremer P, Moodie M, Snowdon W *et al.* Outcome results for the Ma'alahi Youth Project, a Tongan community-based obesity prevention programme for adolescents. *Obes Rev* 2011; **12 Suppl 2:** 41-50.

24. Utter J, Scragg R, Robinson E, Warbrick J, Faeamani G, Foroughian S *et al.* Evaluation of the Living 4 Life project: a youth-led, school-based obesity prevention study. *Obes Rev* 2011; **12 Suppl 2:** 51-60.

25. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007; **85**(9)**:** 660-7.

26. Weaver LT. How did babies grow 100 years ago? *Eur J Clin Nutr* 2011; **65**(1)**:** 3-9.

27. Ministry of Health. *NZ Food NZ Children, key results of the 2002 National Children's Nutrition Survey*. Ministry of Health: Wellington, 2003.

28. Gillman MW, Rifas-Shiman S, Berkey CS, Field AE, Colditz GA. Maternal gestational diabetes, birth weight, and adolescent obesity. *Pediatrics* 2003; **111**(3)**:** e221-6.

29. Gluckman PD, Hanson MA, Beedle AS. Early life events and their consequences for later disease: a life history and evolutionary perspective. *Am J Hum Biol* 2007; **19**(1)**:** 1-19.

Legends for figures

Figure 1

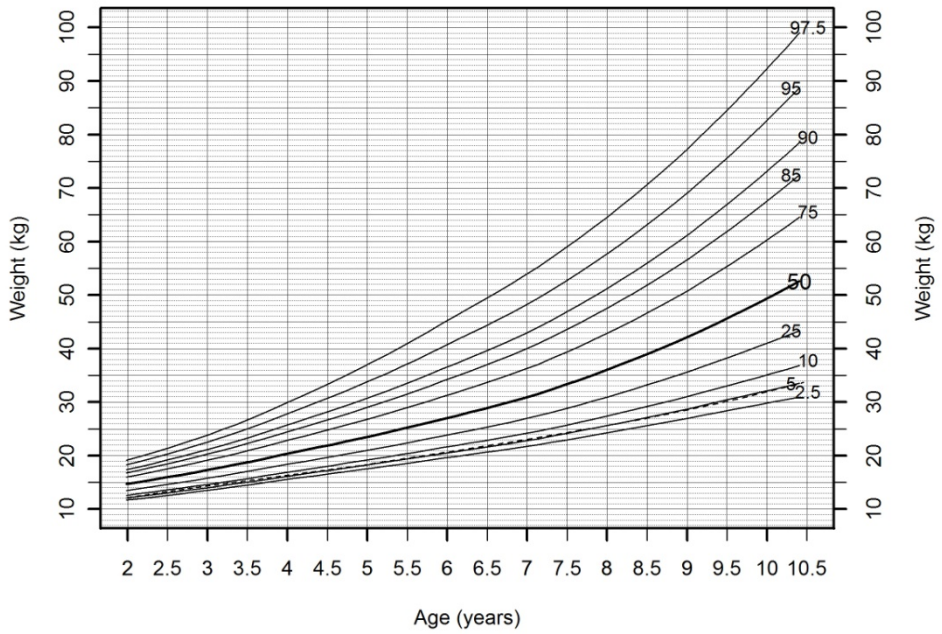
Centile curves for weight of Pacific Island boys (upper) and girls (lower) solid lines, and WHO growth standard 50th percentile 2-5yo and reference CDC 50th percentile 5 – 10 y broken line.

Figure 2

Centile curves for height of Pacific Island (upper) and girls (lower) solid lines, and WHO growth standard 50th percentile 2-5yo and reference CDC 50th percentile 5 – 10 y broken line.

Figure 3

Centile curves for body mass index (BMI) of Pacific Island boys (upper) and girls (lower) solid lines; 50th percentiles from the WHO growth standard 2-5yo and CDC reference 50th percentile 5 – 10 y -- broken line. Dot and dot-dash lines are 85^{th} and 95^{th} CDC centiles.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Weight (kg)
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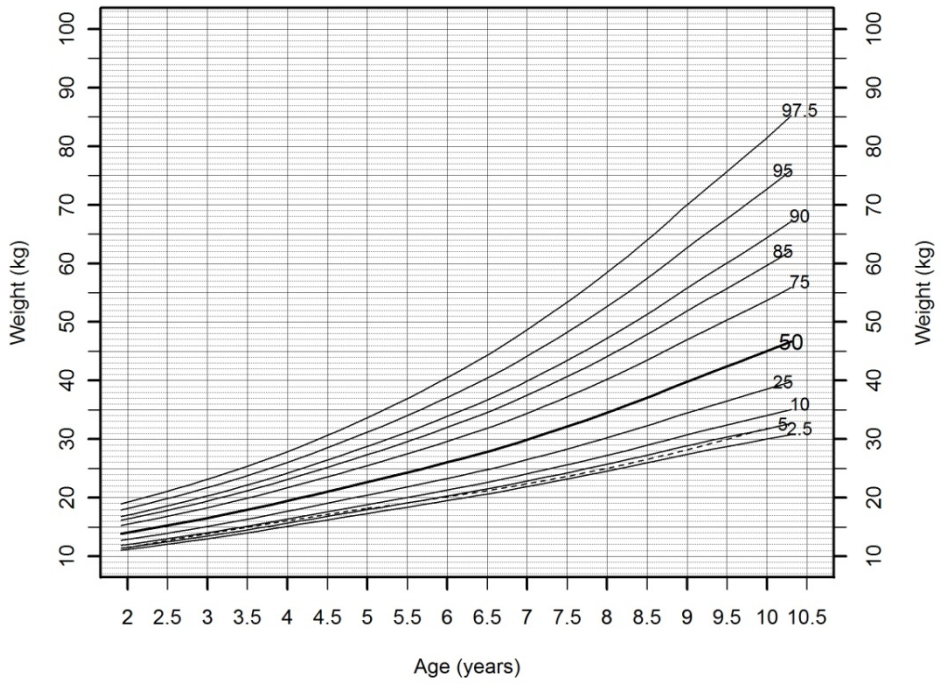
Age (years)


Weight (kg)
Weight (kg)
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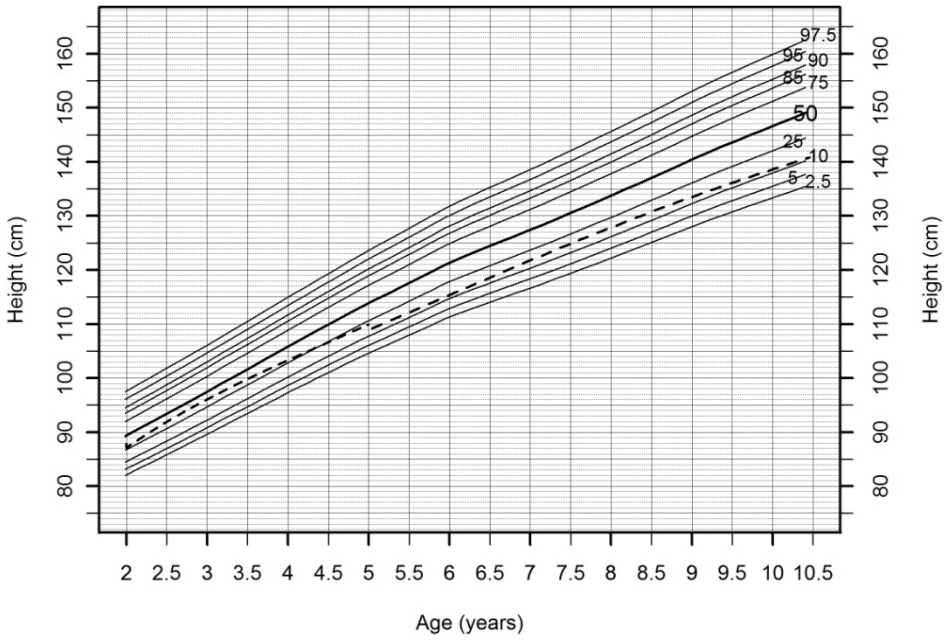
Age (years)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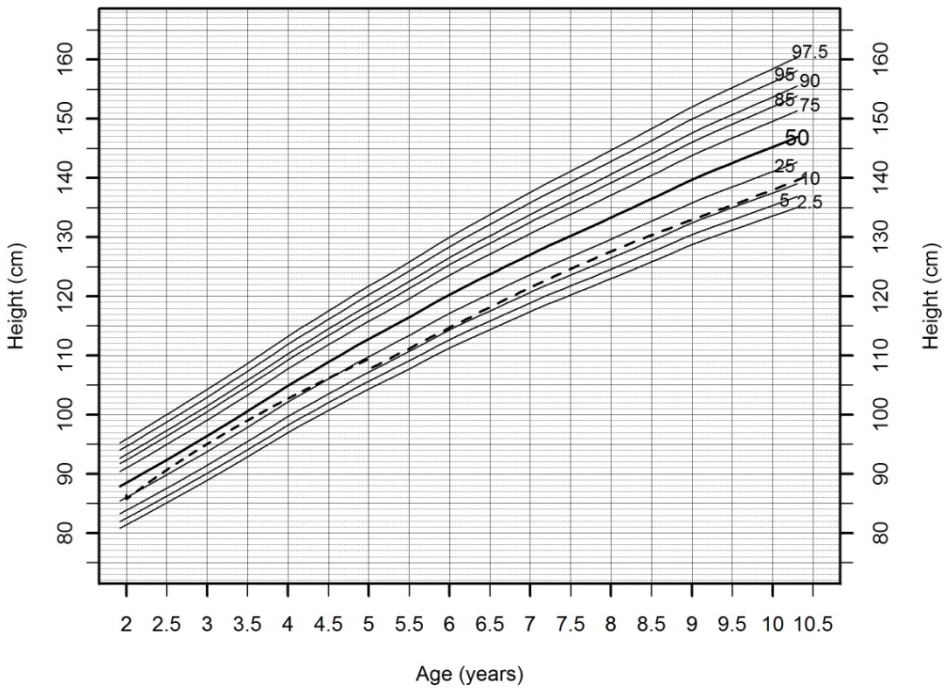
Age (years)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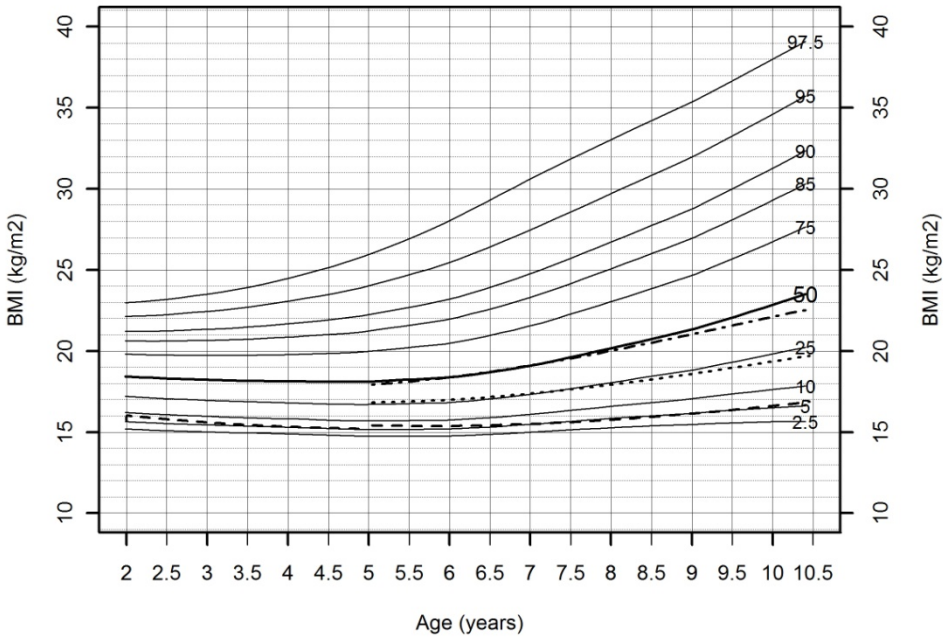
Age (years)


BMI (kg/m2)
BMI (kg/m2)
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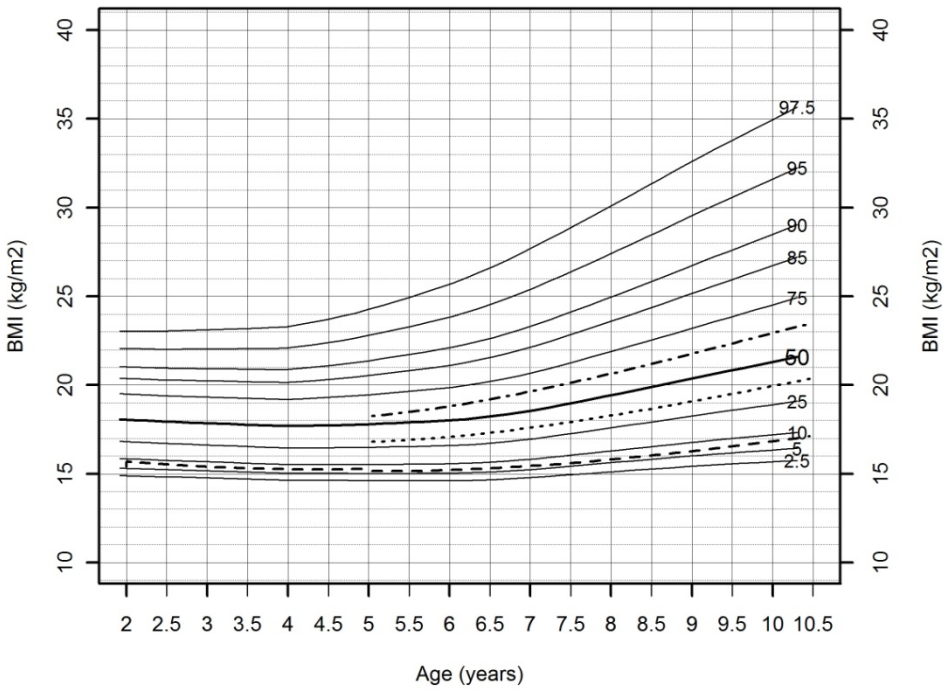
Age (years)


BMI (kg/m2)
BMI (kg/m2)
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Age (years)