Early life factors affecting body mass index and waist-hip ratio in adolescence

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A study of the relative contribution of early, parental, contemporary influences on body mass index (BMI) and waist-hip ratio (WHR) in adolescence was carried out in 213 families with adolescents in Geelong, Victoria, Australia. Weight, height and body circumferences were measured in both parents and children and other relevant information was obtained by questionnaire. The parents of the families studied were broadly representative of the Geelong workforce. The data obtained were divided into three categories: early life, parental and contemporary. The early life influences studied were sociodemographic environment, illness during the first year of life, infant feeding practices, weight, height and rate of growth. Parental factors included socioeconomic and anthropometric characteristics. Contemporary influences, studied in the adolescents, included sociodemographic, lifestyle and anthropometric data as for the parents. Multivariate analyses (multiple regression analysis) was used to determine the strongest influence on BMI from each of the following categories: early life, parental and contemporary. Subsequently the factors indentified from each of these three categories were combined in a further multiple regression analysis to determine the strongest overall determinants for BMI and WHR in adolescence. Apart from gender, only BMI at 50 months contributed significantly to BMI in adolescence. Similarly, apart from gender, only BMI at 80 months was a significant determinant of WHR in adolescence.

Introduction

Body mass index or BMI is recognized as one of the most useful indexes for adiposity both in children and adults. BMI is determined by dividing weight in kilogram by height in metres squared[1]. It is independent of height and highly correlated with weight (0.8–0.9). BMI is also highly correlated with body fat (0.7–0.8)[2–4]. In children and adolescents there is currently no accepted normal range for BMI. However, The World Health Organization recommends that BMI is used to report wt–ht relationships on children and adolescents until a better indicator is available for evaluating body fatness. Based on data for children 6–15 years WHO has suggested the following cut-off points for BMI as broad guidelines for defining obesity in both sexes[5]:

Age (year)	BMI (kg/m^2)
≤14 or less	19–20
15	25
≥16	28

Obesity in children and adolescents is associated with increased prevalence of coronary risk factors, decreased growth hormone secretion and carbohydrate intolerance[6–8]. It has also been reported that as many as 80% of obese adolescents remain obese as adults[9,10].

Waist-hip ratio (WHR) is a simple index of fat distribution. It is obtained by dividing waist circumference by hip circumference and provides an indication of the predominance of fat storage in the abdominal region, relative to that in the gluteal region. A high WHR is indicative of a central fat distribution with excess abdominal fat. In adults high values, generally above 0.8 in females and 1.0 in males, are associated with an increased risk of impaired glucose tolerance, hyperinsulinaemia, hypertriglyceridaemia, hypertension and premature death[11,12]. In children and adolescents, body fat distribution has also been found to be related to blood pressure, blood lipids and serum uric acid levels[13–15]. In children WHR appears to be more or less independent of the total degree of body fatness but it is significantly influenced by age[16]. WHR decreases with age from about 1.1 in young children to about 0.8 at puberty and boys have a significantly higher WHR than girls after the age of 4 years[17]. In adults, WHR is positively correlated with body fatness, as measured by BMI[16].

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The association of fatness and a central fat distribution with an increased risk of degenerative disease in adults is well known, but few studies have reported on the correlates of fat distribution in adolescence. In this paper we report on the relative contribution of early, parental and contemporary influences on BMI and WHR in adolescence.

Methods

The data reported here were obtained in the course of a prospective study of 213 families in Geelong, the second largest city in the state of Victoria, Australia with a population of around 150 000. The study was approved by the Deakin University Ethics Committee and the Victorian State Department of Education. The participants in this study were recruited with the cooperation of the principals of 24 out of the 25 secondary schools in the Geelong Statistical District, from all families with a child attending one of these schools in 1987 who was born between July and December 1972. This particular age cohort was chosen because data from early life (infancy and preschool years) were already available for this group from an earlier study[18,19]. The parents of the families studied were broadly representative of the Geelong workforce in terms of country of birth, occupation and postcode of residence.

For the purpose of this paper the data obtained have been divided into three categories: early life, parental and contemporary. Among the early life influences studied were the sociodemographic environment (parents' occupation, number of siblings), illness during the first year of life, infant feeding practices (type of feeding and time of introduction of solids), weight, height and rate of growth. Parental factors included: sociodemographic (country of birth, occupation, education) and anthropometric characteristics (body weight, height, waist and hip circumference). Contemporary influences, studied in the adolescents, included sociodemographic (type of school attended and household size), lifestyle (smoking, alcohol consumption, physical activity and eating habits) and anthropometric data as for the parents.

Weight (WT) was measured to the nearest 0.1 kilogram in a swimming costume or hospital gown using a digital platform scale (Soehnle) weighing to 150 kg. Height (HT) was measured to the nearest 0.1 centimetre with a Harpenden anthropometer. Waist circumference was measured at the level of the umbilicus and hip circumference at the most prominent part of the buttocks using a metal measuring tape read to the nearest 0.1 centimetre.

All participants completed a questionnaire about sociodemographic characteristics and lifestyle. Repeat questionnaires completed after an interval of 6 months by 20 families, gave 100 per cent agreement for all sociodemographic questions, and more than 85 % agreement for questions about lifestyle.

Both univariate and multivariate analysis were used to determine the strongest determinants for BMI and WHR. Only associations significant at the 1 % level are reported here.

Results

Anthropometric measurements

Table 1 shows the mean and standard deviation of the relevant anthropometric measurements in the adolescents and parents. In the adolescents there were sex differences at the 1% level for all measurements except BMI. In the parents there were sex differences at the 1% level for all measurements except hip circumference and BMI. Adolescent boys were taller and heavier than girls and had a larger waist circumference but a smaller hip circumference than girls. The girls despite a slightly, but not statistically, higher BMI thus had a lower WHR than the boys. Similar differences between the sexes were found in the fathers and mothers, except that the difference in waist circumference was much greater in the parents than in the adolescents. Over 99% of the fathers and 80% of the adolescent boys had a WHR >0.8 compared with only 46 and 17% respectively of the mothers and adolescent girls. For BMI 71% of the fathers and 44% of the mothers, but only 9% and 7% respectively of the adolescents, had a BMI >25. The correlation between BMI and WHR was of the order of 0.3–0.4 in the adolescents and 0.5 in the parents.

Tables 2 and 3 show, for the adolescents and their parents, correlations of BMI (Table 2) and WHR (Table 3) with weight, height, body circumferences and skinfolds. In the case of BMI all measurements, with the exception of height, were highly correlated, with correlations ranging from 0.5 for triceps skinfold in the fathers to 0.92 for weight in the mothers. Moreover the correlations with BMI were generally of similar magnitude in both sexes and in the adolescents and their parents. In contrast all anthropometric correlations for WHR, with the exception of those for height and waist circumference, were lower than those with BMI and ranged

Table 1. Mean and standard deviation of anthropometric measurements of adolescents and parents.

Variable	Boys (n = 113) Mean	SD	Girls (n = 100) Mean	SD	Fathers (n = 136) Mean	SD	Mothers (n = 193) Mean	SD
Weight (kg)	58.5	10.8	54.9	7.1*	79.6	10.7	65.7	12.9**
Height (cm)	168.5	8.8	160.9	5.5**	172.9	6.8	160.1	6.3**
Waist circ. (cm)	72.6	7.4	69.2	6.5**	92.1	8.4	80.3	11.5**
Hip circ. (cm)	86.4	6.7	91.1	5.6**	98.5	5.5	98.9	8.7
BMI (kg/m^2)	20.5	2.8	21.2	2.6	26.6	2.9	25.6	4.7*
WHR	0.84	0.04	0.75	0.05**	0.9	0.05	0.8	0.07**

Significance level of difference between the sexes: * = P<0.01, ** = P<0.001

from only 0.06 for hip circumference in the adolescent girls to 0.49 for subscapular skinfold in the adolescent boys. Furthermore all correlations with WHR, except those for height, were lower in the adolescents than in their parents. Trunk skinfolds (subscapular and supra-iliac) were also more highly correlated with WHR than limb skinfolds (triceps) in the parents, but this was not so in the adolescents.

Table 2. Correlations between BMI and anthropometric measurements of body size and body fatness in adolescents and their parents.

Measurement	Boys (n=113)	Girls (n=100)	Fathers (n=136)	Mothers (n=193)
Weight	0.828	0.801	0.849	0.918
Height	0.168	–0.161	–0.062	–0.070
Waist circ.	0.827	0.772	0.819	0.886
Hip circ.	0.816	0.836	0.790	0.877
Triceps SF	0.602	0.743	0.502	0.823
Subscapular SF	0.704	0.771	0.703	0.801
Supra-iliac SF	0.701	0.687	0.619	0.783

SF=skinfold

Table 3. Correlations between WHR and anthropometric measurements of body size and body fatness in adolescents and their parents.

Measurement	Boys (n=113)	Girls (n=100)	Fathers (n=136)	Mothers (n=193)
Weight	0.263	0.194	0.470	0.473
Height	–0.015	–0.176	0.067	–0.078
Waist circ.	0.637	0.755	0.802	0.790
Hip circ.	0.133	0.057	0.263	0.278
Triceps SF	0.439	0.295	0.253	0.434
Subscapular SF	0.493	0.370	0.455	0.613
Supra-iliac SF	0.475	0.362	0.460	0.618

Factors affecting BMI and WHR

Table 4 summarizes the results of the univariate analyses. Student's *t*-test was used to assess the significance of differences between BMI and WHR for dichotomous variables, for example, between adolescents who consumed or did not consume fish oil in early life. Correlation was used to assess the strength of associations between anthropometric variables in parents and adolescents and over time. Of the variables studied, those which had a statistically significant influence on BMI and WHR in adolescence were mainly anthropometric measures in early life. These included growth rate during infancy and weight and height at 50 and 80 months. Overall BMI in adolescent boys appeared to be more strongly influenced by anthropometric status in early life than did BMI in adolescent girls. Only fathers' BMI correlated with adolescents' BMI. In boys the only

Table 4. Significant univariate associations ($P<0.01$) with BMI and WHR in adolescence.

Factor	BMI	WHR
Early life:		
WV birth–age 6	+M	
WV birth–age 9	+M	
WT at age 50	+	
BMI at age 50	+	
WT at age 80	+M	
BMI at age 80	+M	+M
Fish oil	–	–
Parental:		
Father's BMI	+	
Contemporary:		
Frequency of exercise		–F
Egg	+M	

+ = positive association; – = negative association; + or – alone = both sexes; M = male; F = female; WV = weight velocity. Age is in months

Table 5. Summary of factors influencing BMI (multivariate analysis).

Factor	No.	Variable	R^2 (%)	R^2 adj (%)	F	P
Early life:	2	SEX, BMI50	35.0	32.9	17.21	0.001
Parental:	2	SEX, FBMI	7.5	5.6	3.93	0.023
Contemporary:	2	SEX, EGG	2.9	1.6	2.24	0.110
Combined:	2	SEX, BMI50	35.0	32.9	17.21	0.001

BMI = 1.28 + 1.21 BMI50 – 1.22 SEX (kg/m^2)

Table 6. Summary of factors influencing WHR (multivariate analysis).

Factor	No.	Variable	R^2 (%)	R^2 adj (%)	F	P
Early life:	2	SEX, BMI80	37.2	36.1	34.37	0.001
Parental:	–	–	–	–	–	–
Contemporary:	2	SEX, SES	38.8	37.9	45.91	0.001
Combined:	2	SEX, BMI80	37.2	36.1	34.37	0.001

WHR = 0.655 + 0.00689 (BMI80) + 0.0722 (SEX) significant influence on WHR in adolescence was BMI at 80 months, while in adolescent girls WHR was negatively associated with the frequency of exercise. Parental WHR did not correlate with adolescents' WHR. The only contemporary factors which showed a significant association with BMI or WHR were egg consumption in boys with BMI and the frequency of exercise in girls with WHR.

Tables 5 and 6 show the results from multivariate analyses. Multiple regression analysis was used to determine the strongest influence on BMI (Table 5) from each of the following categories: early life, parental and contemporary. Subsequently the factors identified from each of these three categories were combined in a further multiple regression analysis to determine the strongest overall determinant for BMI in adolescence. Apart from gender, only BMI at 50 months contributed significantly to BMI in adolescence. Inclusion of parental and contemporary influences did not increase the percentage of explained variation in BMI (value of R^2). Similarly , apart from gender, only BMI at 80 months was a significant determinant of WHR in adolescence (Table 6). For both BMI and WHR about one-third of the variation in adolescence was explained by gender and BMI in early life.

Discussion

In the present study adolescent boys aged 14–15 years had a higher WHR than adolescent girls of the same age. This reflected both a higher waist circumference in the boys and a higher hip circumference in girls, although the difference in waist circumference was by no means as pronounced as in the parents. Over 80% of the adolescent boys already had a WHR>0.8 compared with less than 20% of the adolescent girls. In contrast the prevalence of obesity (BMI>25) was much lower and similar in both sexes (9% and 7% respectively). Almost all of the obese boys, but only about half of the obese girls, also had a WHR>0.8. The correlation between BMI and WHR, however, was similar between the sexes both in the adolescents and in their parents, although it was apparently stronger in the latter (0.5 vs 0.3) probably because of the greater range of fatness in the adults. The similar level of correlation between BMI and WHR in both sexes suggests that an increase in BMI is associated with a similar increase in the level of abdominal fat in males and females, but because of the underlying gender-related differences in fat distribution this increase is less evident in females when assessed in terms of WHR.

The finding that in adolescents WHR is less strongly correlated with other anthropometric measures of body fat distribution than in the parents, suggests that WHR, unlike BMI which correlates strongly with other anthropometric measures of body fatness in both adolescents and parents, needs to be interpreted differently in this age group. It is likely that in adolescence WHR is both a measure of maturity and of a tendency for a more central fat distribution.

In the present study although univariate analyses identified early-life, parental and contemporary factors with a significant influence on BMI and WHR in adolescence only BMI in early life was found to have a statistically significant influence on BMI and WHR in adolescence when these were combined in a multivariate analysis. Somewhat surprisingly BMI at 50 months was more strongly associated with BMI in adolescence than BMI at 80 months. This finding is contrary to earlier observations[20], that in general the BMI in the immediate preceding period is the best predictor of the BMI percentile in any subsequent age period. Body fat appears to be minimal at this stage of life[21] and therefore the level of fatness at this time may be of particular importance in determining later fatness. BMI reflects lean body mass as well as body fat[22] and individuals who have a higher BMI are also likely to have more lean body mass and to be taller than thinner individuals, a pattern often observed during childhood and adolescence[23]. The reason why BMI at 80 months was more strongly predictive of WHR in adolescence than BMI at 50 months is not clear from this study.

In summary the present study provides direct evidence for the important contribution of early environment to fatness and fat distribution in adolescence. The observed associations between BMI and WHR in adolescents and their parents, suggest that a higher BMI is associated in adolescents, as well as in adults of both sexes, with a higher WHR and a more central fat distribution. However, since the correlations between WHR and other anthropometric measures of body fat distribution were not as strong in adolescence as in later life it may be inappropriate to interpret WHR in adolescence by the same criteria as in adults. BMI in contrast was equally strongly correlated with measures of body fatness in both adolescents and adults.

Acknowledgements — This work was in part supported by a grant from Mead Johnson, Thailand. Also gratefully acknowledged are the help and co-operation of the participating secondary schools and subjects in this study.

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Asia Pacific Journal of Clinical Nutrition 1992; 1: 21–26

แฟคเตอร์ที่มีผลต่อดัชนีความอ้วนและการกระจายของไขมันในเด็กวัยรุ่น

ได้ทำการศึกษาถึงแฟคเตอร์ต่างๆ (ในวัยเด็ก ในพ่อแม่ของเด็กวัยรุ่น และตัวเด็กวัยรุ่น) ที่มีผลต่อดัชนีความอ้วนและการกระจายของไขมันในเด็กวัยรุ่นอายุ 14 - 15 ปี จำนวน 213 ครอบครัว ชาวออสเตรเลีย แฟคเตอร์ที่ศึกษาในวัยเด็กได้แก่ ประวัติการเจ็บป่วยในวัยทารก การเลี้ยงดูเด็ก น้ำหนัก ส่วนสูง และอัตราการเจริญเติบโต แฟคเตอร์ที่ศึกษาในพ่อแม่ได้แก่ ฐานะทางเศรษฐกิจ น้ำหนัก ส่วนสูง เส้นรอบเอว และตะโพก แฟคเตอร์ที่ศึกษาในตัวเด็กวัยรุ่นได้แก่ น้ำหนัก ส่วนสูง เส้นรอบเอวและตะโพก และวิถีการดำรงชีวิต จากการวิเคราะห์ทางสถิติพบว่า ดัชนีความอ้วนของเด็กวัยรุ่นเมื่อตอนอายุ 50 เดือน เป็นตัวบ่งชี้ถึงความอ้วนในเด็กวัยรุ่น และ ดัชนีความอ้วนของเด็กวัยรุ่นเมื่อตอนอายุ 80 เดือน เป็นตัวบ่งชี้ถึงการกระจายของไขมันในเด็กวัยรุ่น

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Asia Pacific Journal of Clinical Nutrition 1992; **1**: 21–26

作者在澳洲，維省Geelong地區，選取了213個有青少年的家庭為試驗對象。研究了他們早期的、父母的和現在的三方面因素對体重指數和腰臀圍比值的影響。測量了青少年本人和他們父母的身高，体重和体圍，並用問卷詢問有關資料。研究對象是Geelong 地區的工人家庭，有廣泛的代表性。研究數据分成早期的、父母的和現在的三點，早期因素研究了社會人口統計，出生後一年的疾病、嬰兒餵養、体重、身高與生長率。父母因素研究了社會經濟和人体測量的資料。現在因素研究了青少年的社會人口統計，生活方式和人体測量的數据。用多變量分別分析了早期的、父母的和現在的因素，並找出影嚮体重指數最大的因素。最後，把早期的父母的和現在的因素合併起來，用多變量分析並找出對青少年体重指數和腰臀圍比值影嚮最大的總因素。結果顯示，只有50個月大的体重指數對青少年体重指數影嚮最大。同樣，只有80個月大的体重指數對青少年的腰臀圍比值影嚮最大。