The Association of Paternal and Maternal Body Mass Index on Childhood Overweight

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Purpose: Obesity often aggregates within families, and parental obesity has been identified as a risk factor. To examine the different effects of maternal and paternal body mass index on the prevalence rate and risk of overweight in children. Materials and Methods: A total of 1,418 students, aged 12 or 13 years, were recruited for analysis. Children's body height, weight and waist and hip circumferences were obtained. Self-reported body height and weight of their parents were collected. The 85th percentile of body mass index (BMI) was used as cutoff points to identify the children being overweight. Spearman's correlation and logistic regression analysis were used to examine the parent-offspring BMI relationship. Paternal and maternal BMI were classified into four groups using the quartile categories to examine their different effects on the prevalence rate and risk of children overweight. Results: The association of children's BMI with parents' BMI was the strongest, closely followed by children's waist circumference whereas waist-hip ratio barely had any association. The Spearman's correlation coefficient of the mother-daughter association was the highest among all the parent-offspring association. Among the boys, the prevalence rate for being overweight increased significantly from 9.2% in the lowest quartile to 21.3% in the highest quartile of paternal BMI (p trend<0.005). The effect of maternal BMI on the prevalence rate for being overweight was also noted (p trend<0.0001). Among the girls, an increasing rate of being overweight for the increasing quartile of paternal and maternal BMI was also noted (p trend<0.0001). Multiple logistic regression analysis revealed that maternal BMI was significantly associated with boys' overweight with the odds ratios increased from 1.0 in the lowest quartile to 2.33 in the highest quartile of maternal BMI (p<0.001). However, the association between paternal BMI and boys' overweight was marginally significant (p=0.055). Among the girls, both maternal and paternal BMI were significantly associated with girls' overweight (p<0.001 and p=0.001, respectively). Conclusion: Maternal BMI was an independent risk factor of overweight in both boys and girls. Paternal BMI was also associated with girls' overweight.

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Key words: body mass index, children, overweight

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INTRODUCTION

The prevalence of obesity among children and adolescents has increased gradually and is a major global public health problem because of the health consequences and greater risk of obesity in adulthood[1,2]. Obesity in the adults is difficult to deal with; therefore, obesity prevention should start as early as possible, particularly in the pediatric population. However, the cause of childhood obesity has not been elucidated completely, nor have specific target groups for early intervention measures been identified, even though it is assumed that a complex interaction of genetic, environmental, and behavioral factors is responsible. Obesity often aggregates within families and parental obesity has been identified as a risk factor[3]. Nevertheless, some studies in the infants and preschool children revealed that only a weak relationship between parental body mass index (BMI) and child adiposity[4,5]. It is probable that parental-child adiposity correlation will be more obvious in the teenagers since childhood fatness increasing linearly with an increasing level of parental fatness[6]. The different effects of paternal and maternal BMI on their offspring's overweight are another issue worth to be investigated. Some studies showed that the risk of childhood overweight was significantly associated with both parental and maternal BMI[7,8] while other studies only demonstrated the effect of maternal BMI on the trend of increasing prevalence of children's overweight[4,9]. One plausible reason for this contradictory result is in the definition of cutoff points for overweight and obesity by using BMI. Although the BMI is an easy-to-calculate "surrogate for obesity", especially in large studies, however, the cutoff values vary considerably among investigators and countries and the rationale for the choice of cutoffs is rarely provided. As a result, some conflicts existed, for example, in the Asia-Pacific region; a cutoff point of 25 of BMI for obesity was used in some studies[7,10], while the value of 27 was recommended by the Department of Health in Taiwan[11]. In North America and Europe, most of the surveys used the NHAMES II criteria (BMI $\geq$ 27.8 kg/m^2 in males and $\geq$ 27.3 kg/m^2 for females) or NHANES III criteria (BMI $\geq$ 30 in males and females) as obesity cutoff point[5,8,12]. Thus, it is difficult to compare the studies' results because of the different cutoff values for the definition of obesity. Using the percentile categories in the studied population may be a solution around this issue, and also ensures adequate sample sizes in the obese group as mentioned by Lake et al[13].

There are many studies exploring the impact of parental BMI on their children's overweight or adiposity, and inconsistent results was noted that some studies verified the significant effects of both paternal and maternal BMI on their children's overweight[7,8,12,14] while others failed to demonstrate the effect of fathers' BMI [4,15], and that of mother' BMI[15]. The purpose of this study was to examine the different effects of maternal and paternal BMI on the

prevalence rate and risk of overweight in a population of adolescents. In this study, the paternal and maternal BMI were classified into four groups by using the percentile categories.

MATERIALS AND METHODS

This study surveyed all the first grade students of junior high schools in Hualien city of Taiwan at 2001. Questionnaires were distributed to the students and their parents 2 weeks before the health screening. Data on the following demographic variables were obtained from their biological parents: age, educational levels, current marital status, ethnicity and self-reported height and weight.

The well-trained nurses obtained body height, body weight and waist and hip circumferences of the children. Weight was measured in light clothing while height was measured to the nearest 0.1 cm with the head held in the Frankfort plane. Waist circumference measurement was taken midway between the inferior margin of the last rib and the crest of the iliac bone in a horizontal plane, taken to the nearest 0.1 cm. For hip circumference the measure was taken around the pelvis at the point of maximal protrusion of buttock. Totally, there were 1,724 students aged 12 or 13 years. Among them, 306 students did not attend for physical check or failed to complete the questionnaires. Thus, 1,418 (82.3%) students were recruited for analysis. During analysis, paternal and maternal BMI were classified into four groups using the quartile categories to ensure adequate sample size in each group. The investigation was approved by the Ethics Committee of the Buddhist Tzu Chi General Hospital (Hualien, Taiwan). All students and their parents were carefully instructed about the details of the study and gave their written informed consent to participate in the study.

Definition of childhood overweight

Although the use of BMI to help define overweight in children was recommended, there is no internationally acceptable established cutoff point of BMI to define overweight in children. Therefore, we used the 85th percentile of BMI, as cutoff points to identify the children being overweight which have been recommended by Barlow and others[16,17]. The 85th percentile values of BMI were as follows: for the boys aged year 12 and 13 were 25.36 and 26.03, respectively, and for the girls, 22.52 and 23.96, respectively.

Statistical analysis

SAS for Window software was used for the statistical analysis. The associations between children's BMI, waist circumference and waist-hip ratio (WHR) and parental BMI were assessed by using Spearman's correlation coefficients. The prevalence of overweight in the boys and girls was calculated for each quartile of paternal and maternal BMI, respectively, and was tested by the linear test for trend. Logistic regression analysis was then performed to compare the effects of maternal and paternal BMI on being

overweight in the boys and girls. The odds ratios and their 95% confidence interval (C.I.) were calculated as measures of risk for being overweight. The dependent variable was the status of overweight children, and the independent variable was paternal and maternal BMI, which classified into four groups by using the percentile categories.

RESULTS

Table 1 shows the characteristics of children and their parents. Boys were taller and heavier than girls. In addition, the mean waist circumference and waist hip ratio of boys were bigger than those of girls. The mean age of mothers and fathers were 39.8 and 43.4 years, respectively. Mothers had a lower mean BMI value than fathers.

Table 2 displays the relations between BMI of parents and children's BMI, waist circumference and WHR. In general, the association of children's BMI with parents' BMI was the strongest, closely followed by children's waist circumference whereas

Table 1. The Characteristics of Children and Their Parents

	Boys (n=698)	Girls (n=720)	Fathers (n=1,418)	Mothers (n=1,418)
Age (years)	12.5(0.5)	12.5 (0.5)	43.4(5.2)	39.8(5.0)
Height (cm)	154.8(8.1)	154.1 (5.8)	168.7(5.6)	157.8(5.1)
Weight (kg)	51.1(13.1)	47.2 (10.0)	69.7(10.8)	56.4(8.5)
BMI (kg/m^2)	21.0(4.3)	19.8 (3.6)	24.5(3.4)	22.7(3.3)
Waist (cm)	72.0(11.6)	66.4 (9.0)		
Hip (cm)	87.7(9.5)	87.9 (8.1)		
Waist-hip ratio	0.82(0.06)	0.76 (0.06)		

Data expressed as mean (standard deviation)

Table 2. Spearman's Correlation Coefficients of Children's BMI, Waist Circumference and Waist-Hip Ratio and Their Parents' BMI

	Paternal BMI	Maternal BMI
Boys		
BMI	0.156**	0.176**
Waist circumference	0.153**	0.173**
Waist-hip ratio	0.095*	0.133**
Girls		
BMI	0.255**	0.303**
Waist circumference	0.189**	0.231**
Waist-hip ratio	0.063	0.063

*: $p < 0.05$, **: $p < 0.01$

WHR barely had any association. Among all the parents-offspring associations, the Spearman's correlation coefficient of the mother-daughter association was the highest. In addition, the associations between girls' BMI and their parents' BMI (with fathers: r=0.255, $p<0.01$; with mother: r=0.303, $p<0.01$) were stronger than those for the boys (with fathers: r=0.156, $p<0.01$; with mother: r=0.176, $p<0.01$).

The prevalence rates for being overweight in the boys with their parents' BMI were displayed in Table 3. As the paternal BMI increased, the prevalence rate of overweight increased from 9.2% in the lowest as reference group to 21.3% in the highest quartile of the paternal BMI (p trend<0.005). The effect of maternal BMI on the prevalence rate for being overweight was also noted (p trend<0.0001). Similarly, the prevalence rate of overweight in the daughters was positively associated with both paternal BMI and maternal BMI as shown in Table 4. Compared with the reference group, the prevalence rate increased from 10.0% to 22.2% for the highest quartile of the paternal BMI (p trend<0.0001), while the rate increased from 6.7% to 26.1% for the maternal BMI (p trend<0.0001).

Multi-variate logistic regression analysis was then performed to compare the effects of maternal and paternal BMI on being overweight in the boys and girls as shown in Table 5. Maternal BMI was significantly associated with boys' overweight with the odds ratios increased from 1.0 in the lowest quartile to 2.33 in the highest quartile of maternal BMI ($p<0.001$). However, the association between paternal BMI and boys' overweight was marginally significant ($p=0.055$). Among the girls, both maternal and paternal BMI

Table 3. Prevalence of Overweight in the Boys According to the Quartiles of Their Parents' BMI

Boys	Parents' BMI (kg/m^2)			
	1st quartile	2nd quartile	3rd quartile	4th quartile
	BMI (Father)			
	<22.04	22.04-24.21	24.22-26.73	>26.73
Overweight number / Total number	16/173	24/172	27 /179	37/174
Overweight* (%)	9.2	14.0	15.1	21.3
	BMI (Mother)			
	<20.31	20.31-22.21	22.22-24.12	>24.12
Overweight number / Total number	18/170	12/179	32/175	42/174
Overweight# (%)	10.6	6.7	18.3	24.1

*: p trend < 0.005, #: p trend < 0.0001

Table 4. Prevalence of Overweight in the Girls According to the Quartiles of Their Parents' BMI

Girls	Parents' BMI (kg/m^2)			
	1st quartile	2nd quartile	3rd quartile	4th quartile
	BMI (Father)			
	<22.28	22.28-24.09	24.09-26.44	>26.37
Overweight number / Total number	18/180	15/182	34/178	40/180
Overweight* (%)	10.0	8.2	19.1	22.2
	BMI (Mother)			
	<20.40	20.40-22.07	22.11-24.54	>24.54
Overweight number / Total number	12/179	20/180	28/181	47/180
Overweight* (%)	6.7	11.1	15.5	26.1

*: p trend < 0.0001

Table 5. Logistic Regression Analysis to Assess the Effects of Maternal and Paternal BMI on Being Overweight in the Boys and Girls

	Boys		Girls	
	Odds ratio (95% C.I.)	*P* value	Odds ratio (95% C.I.)	*P* value
BMI (Father)		0.055		0.001
2nd vs 1st quartile	1.23 (0.62-2.45)	0.556	1.13 (0.55-2.31)	0.747
3rd vs 1st quartile	1.49 (0.76-2.91)	0.242	2.11 (1.10-4.06)	0.025
4th vs 1st quartile	2.24 (1.19-4.20)	0.012	2.94 (1.57-5.52)	0.001
BMI (Mother)		<0.001		<0.001
2nd vs 1st quartile	0.53 (0.24-1.17)	0.116	1.40 (0.68-2.89)	0.363
3rd vs 1st quartile	1.77 (0.95-3.32)	0.074	1.86 (0.93-3.71)	0.081
4th vs 1st quartile	2.33 (1.26-4.30)	0.007	3.97 (2.08-7.58)	<0.001

C.I.: confidence interval

were significantly associated with girls' overweight ($p<0.001$ and $p=0.001$, respectively).

DISCUSSION

Studies exploring the impact of parental BMI on their children's overweight revealed inconsistent results[7,8,12,16,17]. Some attributed this conflict data to the age difference in the study subjects. It was reported that the age of 5-7 is regarded as

a critical period that parental obesity first becomes strongly associated with childhood overweight, therefore, the impact of parental BMI on the manifestation of overweight in the children becomes more important in children who are at least 7 years old[18]. Our study revealed that both paternal and maternal BMI were positively correlated with their children's BMI, regardless of their gender. Besides, compared with other studies, the magnitude of the correlations between the parental BMI and their children's BMI were similar[8,16], but slightly higher than that reported in Danielzik's study[5]. Nevertheless, the associations between children' BMI and their parents is weak as all the r values in the correlation analysis is below 0.4 in the present study and others[5,8,16]. Further studies are needed to explore this.

In this study, both paternal and maternal BMI were classified into four groups using the quartile categories. Through this way, our study showed that as the paternal or maternal BMI increased from the lowest to the highest quartile, both the prevalence rate and risk for being overweight in the children also significantly elevated. This further confirmed the theory that both paternal and maternal BMI are risk factors of being overweight in their offspring.

The different effects of paternal and maternal BMI on their children's BMI had been examined in many studies, but few of them verified the predominant maternal role on the risk of being overweight in their children[7-9]. Our study showed a stronger effect of maternal BMI than paternal BMI, as the correlation coefficient of the mother-daughter association was the highest among all the parent-offspring associations. In addition, the results of the logistic regression analysis revealed that the effect of maternal BMI on the risk of being overweight in both boys and girls was stronger than that of the paternal BMI. This greater influence of maternal adiposity is in agreement with those from previous studies[7-9,16]. Maternal factors that may contribute to this stronger relationship between mothers' BMI and their children' s overweight include mitochondria inheritance, maternal genetic influence, intrauterine conditions during pregnancy and sociodemographic factors [4,19]. Our previous study suggested that maternal diabetic history played a role in type 2 diabetes mellitus[20] and it is interesting to know to what extent and how the maternal role plays in the pathogenesis of both obesity and diabetes, since these two are closely related.

There were several limitations to this study. The body mass index cut-off accepted as definitions of overweight in adults is based on increased risks of morbidity and mortality. However, there is no internationally acceptable index cutoff point to assess childhood overweight. Therefore, the 85th percentile of BMI recommended by Barlow and others was accepted in this study[14,15]. Second, the self-reported height and weight of parents might not be exactly accurate and could produce some recall bias. However, the limitations of the self-reported data do not appear to have a major

effect on the relations that are of interest because, as mentioned in other report, the parent-child correlations are consistent with other studies based on measured heights and weights[21].

In conclusion, our study showed that the association of children's BMI with parents' BMI was the strongest, closely followed by children's waist circumference whereas waist-hip ratio barely had any association. In addition, maternal BMI was an independent risk factor of overweight in both boys and girls, while paternal BMI was associated with girls' overweight.

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父親與母親的身體質量指數對小孩體重過重的影響

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目的：肥胖常常出現在同一個家族，而父母親是否肥胖已被證實爲小孩體重過重的危險因子，本研究目的是探討父親與母親的身體質量指數對於小孩體重過重是否有不同的影響。材料與方法：我們在91年針對花蓮市國中學生進行肥胖調查，總共有1,418名年齡在12到13歲的學生參加，我們測量學生的身高、體重、腰圍與臀圍，然後以身體質量指數在85百分位作爲體重過重的標準，至於父母親的身高、體重的相關資料則是經由問卷向父母親收集。統計方法是用史匹曼相關係數（Spearman's correlation analysis），與邏輯斯迴歸分析（logistic regression analysis）。結果：孩童的身體質量指數與雙親的身體質量指數關聯性最強，其次爲孩童的腰圍，至於孩童的腰臀圍和雙親的身體質量指數關聯性最差。在雙親－子女的相關係數分析中，以母親－女兒的相關性最強。若將男學童依照父親的身體質量指數分爲四組，則最低組與最高組男學童體重過重的盛行率分別爲9.2%與21.3%，若依照母親的身體質量指數分爲四組，則最低組與最高組男學童體重過重的盛行率分別爲10.6%與24.1%；在女學童方面，依父親及母親的身體質量指數分成四組，則女學童體重過重的盛行率在最高組也明顯高於其他三組。多變項迴歸分析結果顯示，男學童是否肥胖與母親的身體質量指數有關（$p<0.001$），但是和父親的身體質量指數關聯性較差（$p=0.055$）；至於女學童是否肥胖與母親及父親的身體質量指數都有關（分別爲$p<0.001$與$p=0.001$）。結論：母親的身體質量指數爲男學童或女學童是否肥胖的獨立危險因子，而父親的身體質量指數和女學童是否肥胖有關。

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