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ORIGINAL CONTRIBUTION

G. Turconi
M. Guarcello
L. Maccarini
R. Bazzano
A.Zaccardo
C. Roggi

BMI values and other anthropometric and functional measurements as predictors of obesity in a selected group of adolescents

Summary *Background* Obesity is well known to be a problem all over the world: WHO data report that one billion subjects are overweight and 300 million are obese. Epidemiological data (IOTF) show that prevalence rates are increasing not only in industrialized countries, but also in developing countries, especially as far as the adolescent population is concerned. *Aim of the study* To select adolescents at risk of obesity by BMI calculation and by other anthropometric and functional measurements in the Aosta Valley Mountain Region (Northern Italy). *Methods* 532 adolescents were recruited and participated in the study (254 males and 278 females, aged 15.4 ± 0.7). According to standard methods, the following parameters were measured: weight and height for BMI calculation, four skin folds (mid-triceps, mid-biceps, subscapular and supra-iliac) to compute body fat mass, waist and hip circumferences, systolic (SBP) and diastolic (DBP) blood pressure. Parental weight and height, educational and socio-economic status were requested from the parents using a questionnaire. *Results* Percentages of overweight and obese boys were 20.9 % and 4.7 % respectively, and percentages of overweight and obese girls were 14.7 % and 1.1 % respectively (using Cole's cut off point reference standard). Mean body fat mass percentages (males = 19.3 ± 5.6 %, females 23.3 ± 4.4 %) showed males at risk of obesity, as indicated by a higher prevalence rate of overweight and obesity in this gender. Positive correlations ($p < 0.01$) were found between BMI and the following parameters: mid-triceps skinfolds, body fat mass percentage, waist and hip circumferences, but no correlation emerged with WHR; body fat mass positively correlates ($p < 0.01$) with waist and hip circumferences; students' BMI positively correlates with blood pressure ($p < 0.01$), with parental BMI and shows a positive trend towards parental low education and socioeconomic levels. *Conclusions* Overweight and obesity prevalence rates are higher in males than in females according to literature data; family influences weight condition. The correlations that emerged show that BMI is a good adiposity index also in adolescents, it acts as an indicator of cardiovascular risk condition and is influenced by parental BMI.

Key words BMI – anthropometric measurements – blood pressure – obesity – adolescents

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G. Turconi (✉) · M. Guarcello · R. Bazzano · A. Zaccardo · C. Roggi
Dept. of Health Sciences –
Section of Human Nutrition and Dietetics
Faculty of Medicine – University of Pavia
Via Bassi, 21
27100 Pavia, Italy
Tel.: +39-0382/987-544
Fax: +39-0382/987-570
E-Mail: gturconi@unipv.it

L. Maccarini
Dept. of Preventive, Occupational and Community Medicine – Hygiene Institute
Faculty of Medicine – University of Pavia
Pavia, Italy

Introduction

Obesity is well known to be a problem all over the world: WHO data report that one billion subjects are overweight and 300 million are obese [1]. Epidemiological data show that prevalence rates are increasing not only in industrialized countries, but also in developing countries [1], especially as far as the adolescent population is concerned. From 1980 to the present, obesity prevalence rates have increased threefold in Northern America, the United Kingdom, Central and Eastern Europe, Pacific Is-

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lands, Australia and China [1]. Furthermore, infant obesity is widespread in most geographical areas: according to WHO recent data [1], in USA the number of overweight children has doubled between 1980 and today, while the number of overweight adolescents has increased three times. Young obesity is, therefore, increasing in all European and non-European countries [2]. Adolescent overweight and obesity prevalence rates of 16–22 % are reported in USA [3, 4], 27–34 % in Canada [5, 6], 12–16 % in Northern Europe [7–9], 11–26 % in Southern Europe [10, 11], 9–17 % in Italy [12] and 19–23 % in Bolivia, Columbia, Peru, Honduras and the Dominican Republic [13]. In general, prevalence rates are higher in adolescents than in children [14], and in males than in females.

A cross-sectional study was carried out in Italy by Cacciari et al. [15] on a sample of school children covering 16 of the 20 Italian regions, with data collected between 1994 and 2000, on a total of 54,795 subjects of both sexes, aged 6–20 years. Obesity was classified according to International Obesity Task Force (IOTF)-method BMI cut-offs. The prevalence of overweight was 27 % (boys) and 19 % (girls) in Southern Italy, compared with 17 % (boys) and 10 % (girls) in Central-Northern Italy, while the prevalence of obesity was 5 % (boys) and 4 % (girls) in Southern Italy as against 2 % (boys) and 1 % (girls) in Central-Northern Italy.

Overweight and obesity prevalence data collected in some Italian towns and regions in the last ten years [16–22] are reported in Table 1, which shows how overweight and obesity are more widespread in Southern Italy (Roma, Cassino, L'Aquila, Benevento and Sardegna Region), thus confirming Cacciari's results [15].

Obesity in development years can be attributed to family behavioral factors [23] (unhealthy dietary habits, many hours spent watching television and/or a computer, sedentary lifestyle) and to environmental and cultural influences typical of modern societies (proliferation of fast-food outlets and cafeterias) [1].

The need for identifying and preventing overweight in young people arises from the fact that 40 % of children and 70 % of adolescents become obese adults, and the risk positively correlates both with overweight and early obesity [24]. Moreover it has been shown that mortality and morbidity risk for chronic-degenerative diseases, as a consequence of overweight, is very high in the first years of life [25]. Overweight in children and adolescents was positively correlated both to adverse blood-lipid profile [26] and to early atherosclerotic damage [27], together with the onset of noninsulin dependent diabetes mellitus [28].

Although using BMI for identifying overweight and obesity in children and adolescents is open to discussion, many authors agree on its utility [29–32], and the IOTF points out its usefulness, suggesting the use of Cole's cut-off point reference standard [33] to identify overweight and obesity in young age.

As is the case with adults, BMI in the developmental years also positively correlates with body fat mass measured by skinfolds thickness and body density [34], by TOBEC [35], by DXA [31, 32, 36] and by BIA [37]. Moreover, it correlates with waist circumference [38] and with waist-hip circumferences ratio (WHR) [39]; in adolescents BMI is also influenced both by weight at birth [40] and by parental BMI [11, 40–42].

A positive correlation exists between overweight, BMI and blood pressure [43], and it was reported that body weight is the most important factor involved [42, 44], so that BMI is the best predictor of blood pressure values. Blood pressure correlates with triceps skinfold [42], with abdominal fat [45], with waist circumference [46] and seems to be influenced both by familiar hypertension and high parental BMI [42].

Aim of the study

The aim of this study was to select adolescents at risk of obesity by BMI calculation and by collecting other anthropometric and functional measurements in the Aosta Valley Mountain Region (Northern Italy), in order to plan preventive and corrective strategies aimed at re-

Table 1 Overweight and obesity prevalence rates in some Italian towns and regions

Town/Region	Authors	N° of subjects	Age (years)	Overweight			Obesity		
				M	%	F	M	%	F
Verona	Maffeis C et al. 1993 [16]	1523	4–12	–		–	18[a]		12[a]
Verbania	Ardizzi A et al. 1996 [17]	12174	6–15	–		–		10*	
Roma	Salandri A et al. 1996 [18]	295	–		19*			39*	
L'Aquila	Grispan A et al. 1997 [19]	600	10–14	–		–	30		37
Cassino (Frosinone)	De Vito E et al. 1999 [20]	2053	11–19		21*		10		7
Sardegna	Romiti A et al. 2000 [21]	304	16–18	–		–	24		6
Benevento	D'Argenio P et al. 2001 [22]	1046	10–15	27		27	11		10

[a] 12 year old subjects
* values computed by analyzing males and females together

ducing weight in adolescents and thereby limiting the associated risk factors.

Methods

Sampling

A selected group of adolescents representing all the students of both sexes attending the second year of all the high schools in the Aosta Valley Region (a mainly mountainous zone), Northern Italy, were informed about the protocol research (n° of subjects = 889 individuals, equal to 0.7 % of the entire population living in Aosta Valley Region on December 31, 2001). Five hundred and thirty-two subjects, 254 males (47.7 %) and 278 females (52.3 %), were recruited and participated in the study. The mean age of the sample was 15.4 ± 0.7, with a prevalent distribution between 15 (64.8 % of subjects) and 16 years (26.2 %). We decided to select only the second year high school students, as we intend to follow-up the adolescents during the last school year after a nutrition education intervention.

The study was carried out with the cooperation of both the school teachers and the medical staff of the Regional Public Health Department of Aosta Valley Region. Before starting the study, many meetings were organized together with teachers and students to explain the aim of the research and to request their participation.

Anthropometric and functional measurements

After setting up a classroom as a medical room in each school, students were examined by health personnel (medical doctors and dietitians) and the following parameters were measured:

- Weight, measured on subjects wearing only underwear and without shoes by means of a steel yard stick;
- Height, measured on subjects without shoes;
- Four skinfolds thickness (mid-triceps, mid-biceps, subscapular and supra-iliac), measured on subjects according to standard conditions using a Harpenden skinfold thickness calliper; three consecutive measurements were performed and the mean of the three values was considered;
- Waist and hip circumferences, measured on subjects according to standard conditions using a measuring tape;
- Systolic (SBP) and diastolic (DBP) blood pressure according to standard conditions using a sphygmomanometer; three measurements were performed at intervals of 2–5 minutes and the mean of the three values was considered as the blood pressure.

Each student was examined and all measurements were taken during school time; each examination took about 40 minutes.

Parental weight and height, educational and socio-economic status were requested from the parents using a brief questionnaire.

Data analysis

Data were analyzed using the statistical Package for the Social Sciences [47]; Pearson's correlation coefficients were computed to analyze relationships between BMI and the variables investigated. Multiple regression analyses with the stepwise method were used to verify the association between BMI and circumferences, triceps skinfold, fat mass. Binomial logistic regression was used in studying a possible risk assessment algorithm able to correlate BMI with systolic and diastolic pressure and waist circumference.

Research protocol approval by ethics committee

The research protocol was approved by both the Ethics Committee of the Faculty of Medicine of the University of Pavia and the Ethics Committee of the Regional Public Health Department of the Aosta Valley Region.

Informed written consent was obtained from each student and their parents.

Results

BMI

BMI mean values are 21.9 ± 3.4 kg/m^2 and 21.0 ± 2.9 kg/m^2 for males and females, respectively. Percentile distribution data point out that males' BMI values are higher than females', showing 17.4–16.4 kg/m^2 values at the 5th centile for boys and girls respectively, 21.2–20.7 kg/m^2 values for subjects at the 50th centile and 28.9–26.4 kg/m^2 values for subjects at the 95th centile.

Referring to Cole's reference standard centiles [48], Fig. 1 reports students' BMI distribution. Most of the subjects are between the 25th and 98th centile with the following differences between sexes: across the 25th and 75th centile, females' percentage is higher than males', while the opposite occurs across the 75th and 98th centile.

According to the IOTF, Cole's cut-off point reference standard [33] was used to identify overweight and obesity in young age. A total of 20.8 % of males and 14.7 % of females are overweight, and 4.7 % of males and 1.1 % of females are obese (Table 2). As far as underweight is concerned, Cole does not give any suggestion, and we decided to judge underweight subjects those under the

3rd centile, therefore 0.4 % of males and 2.5 % of females are underweight.

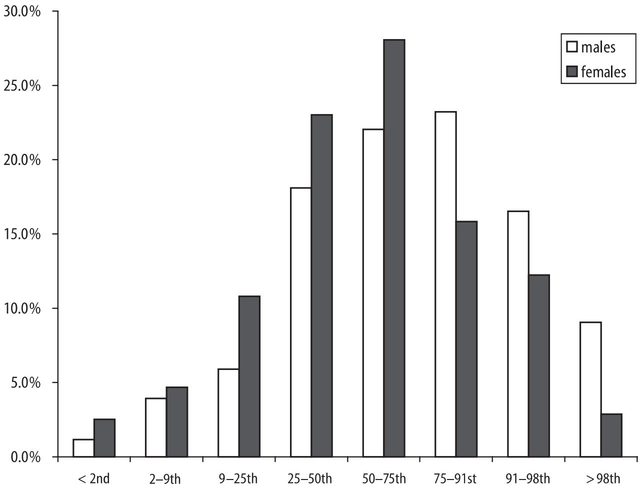

Fig. 1 BMI distribution according to Cole's reference standard centiles (1995) [48]

Table 2 Adolescents' weight classification

Weight classification*	Males		Females	
	n°	%	n°	%
Underweight[a]	1	0.4	7	2.5
Normal weight	188	74.0	227	81.6
Overweight	53	20.9	41	14.7
Obese	12	4.7	3	1.1
Total	254	100	278	100

* according to Cole's cut off points [33]
[a] subjects under 3rd centile

Anthropometric and blood pressure measurements

Four skinfold values, fat mass percentage, waist and hip circumferences, waist/hip ratio (WHR) and blood pressure levels are reported in Table 3 for males and females, respectively. With regard to mid-triceps skinfold, the male mean value is 11.6 mm, which is slightly higher than the 50th centile mean value (9.8 mm); although this value is in agreement with Frisancho's 50th centile value [49]. For females, the mean value is 17.2 mm, which is more similar to the 50th centile mean value (16.8 mm) and in accordance with Frisancho's 50th centile value [49].

The sum of four skinfolds was computed and body fat percentage was calculated according to the Westrate and Deurenberg equation [50], giving results of 19.3 ± 5.6 % for males and 23.3 ± 4.4 % for females. Males' waist circumference mean value is 75.6 ± 10.7 cm, while hip circumference mean value is 90.7 ± 10.5 cm; in females waist circumference mean value is 69.6 ± 7.7 cm and hip circumference mean value is 90.5 ± 9.1 cm.

Males' mean values are 76 ± 7 mm Hg (DBP) and 124 ± 11 mm Hg (SBP), while females' mean values are 75 ± 7 mm Hg (DBP) and 118 ± 11 mm Hg (SBP).

Relationship between BMI and other anthropometric and functional measurements

Both in males and females BMI positively correlates ($p < 0.01$) with triceps skinfold, with fat mass percentage ($p < 0.01$), with waist and hip circumferences ($p < 0.01$), with a R value ranging between 0.54 and 0.78, but no correlation exists with WHR. Body fat mass percentage also positively correlates with both waist and hip circumferences ($p < 0.01$), with a R value ranging between 0.42 and 0.68, but does not correlate with WHR in either sex.

Table 3 Anthropometric and blood pressure measurements

Variable	Males				Females			
	Mean ± SD	5th*	50th*	95th*	Mean ± SD	5th*	50th*	95th*
Triceps s.[a] (mm)	11.6 ± 5.9	5.2	9.8	23.2	17.2 ± 5.4	9.4	16.8	26.2
Biceps s.[a] (mm)	6.2 ± 3.8	2.9	4.9	13.4	9.3 ± 4.5	4.2	8.5	17.8
Subsc. s.[a] (mm)	10.0 ± 4.3	5.8	8.8	17.7	11.6 ± 4.0	7.0	10.9	19.8
Suprail. s.[a] (mm)	14.4 ± 9.8	5.1	11.5	36.4	17.1 ± 7.8	7.7	16.0	34.4
Fat mass (%)	19.3 ± 5.6	11.6	18.7	30.5	23.3 ± 4.4	16.1	23.6	30.0
Waist circumf. (cm)	75.6 ± 10.7	66.0	74.0	94.2	69.6 ± 7.7	60.5	69.0	84.0
Hip circumf. (cm)	90.7 ± 10.5	79.0	90.0	105.2	90.5 ± 9.1	79.0	90.0	104.0
Waist/Hip ratio (WHR)	0.85 ± 0.36	0.76	0.83	0.92	0.79 ± 0.48	0.70	0.77	0.85
Diastolic pressure DBP (mmHg)	76 ± 7	60	80	90	75 ± 7	60	78	85
Systolic pressure SBP (mmHg)	124 ± 11	110	120	140	118 ± 11	100	120	140

* centiles values
[a] skinfolds

Moreover, a positive correlation exists between BMI and blood pressure ($p < 0.01$) (diastolic and systolic) in males and females, with a R value ranging between 0.21 and 0.36.

Multiple regression analysis carried out by the stepwise method to verify the impact of the two circumferences and triceps skinfolds on BMI in the total sample shows that waist circumference is the most closely correlated ($R = 0.70$). When the model analyses waist circumference and fat mass together, the R value is equal to 0.78. However, when the model analyzes waist and hip circumferences and fat mass, R value is equal to 0.79. Adding triceps skinfolds, the R value does not show any increase. For girls, the results of multiple regression are confirmed, while for boys, fat mass emerges as the most closely correlated variable.

BMI compared to waist circumference and blood pressure does not allow the creation of a risk assessment algorithm, as the logistic binomial regression (with BMI subdivided in normal weight and overweight plus obese subjects) does not show an important risk increase (risk increase values ranging between 0.5 % and 6 %).

Relationship between parental and adolescents' BMI

Adolescents' BMI positively correlates to the same extent with both the father's ($p < 0.01$) and mother's ($p < 0.01$) BMI in males and females with R values equal to 0.23 and 0.24 respectively.

Relationship between parental socio-economic and education levels and adolescents' BMI

Adolescents' BMI does not show a significant correlation with parental socio-economic and education levels; nevertheless, it shows a positive trend both towards parental low education and low socio-economic levels.

Discussion

BMI data point out the prevalence of a high percentage of overweight subjects in both sexes, but it is higher in males, while the prevalence rate of obese adolescents is lower. The high percentage of overweight subjects is worrying, and preventive and corrective strategies need to be undertaken in school programs aimed at reducing this risk condition. A few subjects are underweight under the 3rd centile, including just one male and seven females, highlighting that overweight is undoubtedly the most important problem in the area studied.

Our results are higher than those reported by Cacciari et al. [15] in a sample subjects aged 6–20 years, which show a prevalence of overweight in Central-Northern Italy equal to 17 % in boys and 10 % in girls and a prevalence of obesity equal to 2 % in boys and 1 % in girls respectively. Nevertheless, they are lower than those found in Southern Italy [18–22] (Table 1), in agreement with a higher prevalence of overweight and obesity in this area. No comparison can be made with results obtained in Verona [16] and in Verbania [17] because different age groups than ours were investigated.

Moreover, body fat mass percentage is evidence for risk of obesity especially for males as our data are higher both than those reported by Shafer [30] in a German adolescent population (males = 12 % of body fat mass; females 21 %) and than those reported by Ellis [51] in a Caucasian male adolescent population (14.8 %), thus showing that boys are at risk of obesity as already pointed out by higher prevalence rates of overweight and obesity in this gender.

No correlation exists between WHR and BMI, while the latter positively correlates ($p < 0.01$) with each circumference measurement. Waist circumference value was also shown [52, 53] to be a better predictor than WHR in adolescents, as it positively correlates with abdominal fat measured by DXA. Our results are higher than those reported by other authors in the same age groups. McCarty et al. [54] reported in British adolescents waist circumference mean values equal to 70.8 ± 7.1 cm in males and 64.9 ± 4.9 cm in females; another study carried out in Cuba [55] shows the 50th centile waist circumference values equal to 68 cm for males and 64 cm for females, while similar to our data are those obtained in other studies carried out in USA [54] and in Spain [56] (50th centile waist circumference values equal to 74 cm for males and 69 cm for females).

Diastolic and systolic pressure mean values are equal to 76 ± 7 mm Hg and 124 ± 11 for males and equal to 75 ± 7 mm Hg and 118 ± 11 mm Hg for females, resulting in higher values than those reported by other authors as Italian normal standard values [57] (116/70 mm Hg for males and 111/66 mm Hg for females aged 15 years). 50th centile values are also higher than those measured in 15 year old Brazilian adolescents [58] equal to 117/61 mm Hg for males and 110/62 for females. In subjects aged 11–15 years, Maida et al. [59] reported mean values equal to 104/42 mm Hg in males and 109/44 mm Hg in females.

All correlations carried out between BMI and the other anthropometric and functional measurements are positively correlated, except WHR, which, as previously reported, is not related to BMI. These results are confirmed by multiple regression analysis that shows waist circumference is the most closely associated variable to BMI for females, while for males it is fat mass. This finding confirms that in adolescent girls, as in the adult population, when compared with WHR, waist circumference measurement seems to be the simplest way to estimate overweight and obesity and the risk of developing cardiovascular diseases. In conclusion, BMI is a good adiposity index also in adolescents; moreover, it acts as an indicator of cardiovascular risk condition being correlated to blood pressure values.

The correlation that emerged between parental and adolescents' BMI values confirms literature data [11, 40–42] that show an influence of both parents' BMI on their children, probably due both to genetic conditions and unhealthy dietary habits leading to over consumption, together with a sedentary lifestyle. In particular, they confirm the data obtained in a previous study carried out in Southern Italy [60] in which children's BMI correlated with the fathers' and mothers' BMI to the same extent. Therefore, adolescents' risk of becoming overweight increases with parental overweight and obesity, thus showing that familial disposition has to be taken into account to identify risk groups for preventive measures. Although no significant correlation between adolescents' BMI and parental socio-economic and education levels emerged, a positive trend was shown with these variables showing that also these factors may influence weight condition, as reported by other authors [11, 61].

Conclusions

The results of this study may identify a high percentage of subjects at risk of obesity and correlated diseases in the area studied. Overweight and obesity prevalence rates are higher in males than in females and are lower in Northern Italy than in Central-Southern Italy according to literature data; family influences adolescents' weight condition. Correlations that emerged between BMI and the other anthropometric and functional measurements show that BMI is a good adiposity index also in adolescents, it acts as an indicator of developing cardiovascular diseases and is influenced by parental BMI.

These results underline the need to plan preventive and corrective strategies aimed at reducing weight in adolescents and thus limiting the associated risk factors. Nutritional intervention programs should be carried out in the school, also involving students' parents and their medical doctors, and should be taught by trained teachers using the most appropriate communication techniques. Some indexes of intervention efficacy will be selected and analyzed, such as dietary habits and consumption, physical activity level, body weight loss and positive changes of other risk factors associated with high BMI values.

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