The Relationship of Cardiorespiratory Fitness, Birth Weight, and Parental BMI on Adolescents' Obesity Status

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Background/Objectives: The aims of this study were (1) to analyze differences in CRF, parents' BMI and BW between normal-weight and overweight/obese (OV/OB) adolescents, and (2) to investigate the association of those variables with risk of being OV/OB of their biological offspring.
Subjects/Methods: This study comprised 788 adolescents (477 girls and 311 boys), aged from 12-18 years old. CRF was predicted by maximal multistage 20m shuttle-run test according to procedures described from FITNESSGRAM. Children's BMI was classified according to International Obesity Task Force. Adolescent's BW was assessed from each child's pediatric record at birth. Parent's OV/OB status were defined and classified according to WHO. Socioeconomic status was defined for parental education.
Results: The prevalence OV/OB was 21.4% and 5.3 %, respectively and there were no gender differences. The OV/OB adolescents (girls and boys) had significantly ($p \le 0.05$) lower CRF scores and higher BW ($p \le 0.05$) than the normal-weight. 92.9% of OV/OB girls had one or two parents with OV/OB ($p \le 0.05$). Boys with low CRF (OR: 3.75; $p \le 0.05$) and high BW (OR: 1.65; $p \le 0.05$) were more likely to be classified as OV/OB compared with normal weight. Girls with low CRF (OR: 2.66; $p \le 0.05$), high BW (OR: 2.09; $p \le 0.05$) and at least one parent (OR: 2.28; $p \le 0.05$) or two parents with OV/OB (OR: 4.39; $p \le 0.05$, respectively) were associated with being OV/OB.
Conclusions: Results from this study highlight the centrality of the family adolescents' obesity, especially in girls. Further our data suggested that low CRF and high BW were strong predictors of OV/OB at adolescence.

Keys words: Adolescents; Obesity Status; Cardiorespiratory Fitness, Birth Weight, Parental BMI

The prevalence of childhood obesity has been rising during the past decades in many parts of the world (WHO 2000). Previous studies have shown an high prevalence of overweight and obesity in Portuguese young children (Padez et al 2004) and adolescents (Ribeiro et al 2003). Because the onset of obesity lies in early childhood, it is of great importance to examine the risk trends in order that effective preventive strategies targeting those at risk start as early as possible.
The origin of obesity is complex and is influenced by genetic and environmental factors. For instance, it has been shown that obese parents offspring's have risk of obesity due to shared genes and shared environments (Gordon-Larsen et al 2000). Indeed, fatness tends to aggregate within families (Garn et al 1989) as a result of relations among genetic and environmental factors (Borecki et al 1993, Faith et al 1997) and increases the risk that a child will become an obese adult, (Lake et al 1997, Magarey et al 2003) independent of fatness status in childhood (Whitaker et al 1997).
Birth weight (BW) has also been reported as an important marker of genetic factors and intrauterine environment related with increased obesity prevalence. Some studies have demonstrated associations between fetal experiences and later risk for adult cardiovascular and others chronic diseases (Hales and Barker 2001, Karter et al 1999). It is also known that obesity during the pre-school years was associated with other clinical factors easily assessed at birth (Baird et al 2005). For instance, it was found an association between BW and the risk to be obese in children at the age of 4, 8, 10 and 12 years old (Maffeis et al 1994), while a high BW was associated with higher BMI at age of 7 years (Hui et al 2008, Toschke et al 2004).

On the other hand, the epidemic of overweight likely involves changes in the balance between energy intake and energy expenditure. Indeed, patterns of physical activity; sedentary living and diet, appear to play an important role in long-term weight regulation (Bouchard 2000). Besides, low physical fitness, especially low cardiorespiratory fitness (CRF) showed a significant and inverse relationship with body fatness in a large number of studies (Deforche et al 2003, Kim et al 2005, Mota et al 2006). This highlights the importance of increasing CRF for a protective effect in early ages since there are some evidences that CRF levels tracked from childhood and adolescence into adulthood (Hasselstrom et al 2002) Persons who are physically fit maintain a more favourable caloric balance and lower body weights, both of which protect against the development of cardiovascular disease risk factors (Carnethon et al 2003).

Despite that, the relationship of adolescence obesity with birth-weight and CRF were not found consistently (Gibson et al 2006), especially when parental characteristics were taken into account (Francis et al 2003, McMurray et al 2000)..

Therefore, the aims of this study were (1) to analyze differences in CRF fitness, parents' BMI and BW between normal-weight and overweight/obese adolescents, and (2) to investigate the association between CRF, BW and parents' BMI with the risk of being obese (OV/OB) of their biological offspring using a cohort that includes both maternal and paternal data.

Methods

Participants and data collection

This is a cross-sectional study carried out in middle and high schools from suburban setting comprising all the students registered into 7th until 12th grade during 2006/2007 academic year. A letter informing families that students will be measured was sent home two weeks before measurements took place. This study was conducted according to the guidelines of the Helsinki Declaration of Human Studies. Written given consent was required. The Portuguese Foundation for Science and Technology provided permission to conduct this study.

This study comprised 788 students (477 girls and 311 boys), aged 12-18 years old along with their parents. The questionnaires were distributed and filled out during physical education classes. Data collection was also accomplished by mailing questionnaires to adolescents' parents.

Anthropometric Measures

Body height was measured to the nearest millimetre in bare or stocking feet with the adolescent standing upright against a Holtain stadiometer. Weight was measured to the nearest 0.10 kg, lightly dressed using an electronic weight scale (Seca 708 portable digital beam scale). Body mass index (BMI) was calculated from the ratio of body weight (kg) to body height (m^2). For purposes of this study, participants were classified as either normal weight or overweight/obese based on the IOTF (Cole et al 2000). Parents' BMI was calculated from self-report weight and height and used to evaluate weight status according to WHO recommendations. BMI was divided in three categories: normal weight (18.5 $kg/m^2 \geq$ BMI <25 kg/m^2); overweight (25 $kg/m^2 \geq$ BMI < 30 kg/m^2) and **obese** (BMI≥30 kg/m^2)(WHO 1998). Further, for the analysis of the associations between adolescents obesity with parental characteristics, parents were further divided into three groups: (1) both parents were normal-weight; (2) one overweight/obese parent, and (3) both parents were overweight/obese.

Adolescents' birth weight (BW) was assessed from each child's pediatric record at birth.

Cardiorespiratory Fitness (CRF)

CRF was predicted by maximal multistage 20m shuttle-run test according to procedures described from FITNESSGRAM (FITNESSGRAM 1999). The FITNESSGRAM was selected because of its ease administration to large numbers of subjects, and in addition its choice of reliable and valid health-related physical fitness measures (FITNESSGRAM 1999). The Shuttle Run Test predicted maximal aerobic capacity and showed significant correlation with VO_2max (r=0.80) suggesting that could be used as a measure of aerobic fitness in children (Vincent et al 1999). Students were familiarized with the procedure for each test before recording data. Furthermore**,** the participants received verbal encouragements from the investigators in order to achieve maximum performance. The result was recorded as laps taken to complete the 20m shuttle-run test. Children were then classified according to the age and sex-specific cut-off points of FITNESSGRAM criteria, as belonging to the healthy zone, under or above, respectively.

Socioeconomic status
The highest school education achieved by either mother or father was used to define social class (Parental Education). Single parent families were included, and these children were classified according the school education of the single parent. Parental Education was defined based upon Portuguese Educational system [(1) 9 years' education or less- sub secondary level; (2) 10-12 years' education-secondary level and (3) higher education)] and then assigned into three groups (1=Low (LE); 2= Middle (ME) and 3= High (HE) level of education, respectively). Similar procedures have been applied in the Portuguese context (Mota and Silva 1999).

Statistics
Means and standard deviations were calculated to describe participants' characteristics by sex and obesity status. The comparisons between sex and obesity status was done by independent t-test for anthropometric variables and chi-square test for cut of points of BMI, CRF, parental BMI and parental education. For both gender, the independent association of predictors with BMI as dependent variable (Normal Weight and Overweight/Obese) was examined using stepwise logistic regression analysis with age, birth weight, parental obesity status and parental education as independent variables. Statistical analysis was performed using SPSS 15 software (SPSS Inc., Chicago, IL, USA) and Microsoft Excel 2000. The level of significance was set at $p \leq 0.05$.

Results

Table I shows descriptive statistics (mean and SD) of adolescents and parents by sex. Boys were taller, heavier, had higher BW and higher CRF than girls ($p \leq 0.05$), while girls were older. No statistical significant differences were found with regard the BMI. The overall prevalence of overweight and obesity was 21.4% and 5.3 %, respectively. No statistical significant differences between genders were found. In addition we found that a higher ($p \leq 0.05$) proportion of girls (49.9%) were classified as unfit than boys (35.7%) were. Fifteen percent of fathers were classified as obese while 53% were classified as overweight. For mothers the numbers were 36,6% for overweight and 13,4% for obese, respectively.

Table 1 – Sample Characteristics

Characteristics		Total (n=788)	Girls (n=477)	Boys (n=311)	p
Age (years)		15.08±1.87	15.24±1.74	14.82±2.02	***0.003***
Weight (kg)		59.60±11.79	57.96±9.91	62.10±13.84	***0.000***
Height (m^2)		1.65±0.09	1.62±0.07	1.69±0.10	***0.000***
BMI (kg/m^2)		21.93±3.47	22.10±3.36	21.66±3.63	***ns***
Birthweight (BW) (kg)		3.31±0.55	3.25±0.52	3.39±0.59	***0.001***
Cardiorepiratory Fitness (CRF) (laps)		41.28±20.22	31.34±12.12	56.52±20.66	***0.000***
Father BMI		26.64±3.33	26.59±3.32	26.71±3.36	***ns***
Mother BMI		25.59±3.95	25.81±4.00	25.26±3.85	***ns***
BMI (%)	Normal Weight	73.2	73.4	73	
	Overweight	21.4	21.2	21.9	***ns***
	Obese	5.3	5.5	5.1	
CRF (%)	Under Health Zone	44.3	49.9	35.7	***p≤0.05***
	Health Zone and Above	55.7	50.1	64.3	
P-BMI (%)	Two parents with Normal Weight	31.5	32.4	30	
	At least one parent with OV/OB	53.7	53.6	53.9	***ns***
	Two parents with OV/OB	14.8	14	16	
P-Edu (%)	Low Education	57.0	58.9	54.0	
	Middle Education	23.7	23.3	24.4	***ns***
	High Education	19.3	17.8	21.5	

BMI – Body Mass Index; CRF – Cardiorepiratory Fitness; P-BMI – Parental BMI; P-Edu – Parental Education;
OV/OB – Overweighy/Obesens - *p>0.05*

Table 2 shows differences within gender according to obesity status for the variables under study. Regardless gender the OV/OB group was significantly heavier, had higher BMI, had higher BW and had both parents with high BMI values than their normal-weight peers. However, as expected, the CRF values (laps) were significantly lower in OV/OB than in normal weight groups. Besides, a statistically higher ($p \leq 0.05$) proportion of OV/OB girls (61.4%) and boys (54.8%) were assigned to the under health zone (unfit) compared to their lean counterparts. Parental BMI differed between NW and OV/OB only in girls ($p \leq 0.05$).No statistical significant differences were found regarding parental education.

Insert Table 2

Stepwise logistic regression analysis (Figure 1) showed that boys with low CRF (OR: 3.75; CI: 2.14-6.59; $p \leq 0.05$) and high BW (OR: 1.65; CI: 1.02-2.67; $p \leq 0.05$) were more likely to be classified as OV/OB compared with normal weight peers. Girls with low CRF (OR: 2.66; CI: 1.64-4.32; $p \leq 0.05$), high BW (OR: 2.09; CI: 1.36-3.24; $p \leq 0.05$) and that at least have one parent with OV/OB (OR: 2.28; CI: 1.05-4.95; $p \leq 0.05$) or two parents with OV/OB (OR: 4.39; CI: 1.99-9.64; $p \leq 0.05$) were more likely to be classified as OV/OB compared with normal weight peers.

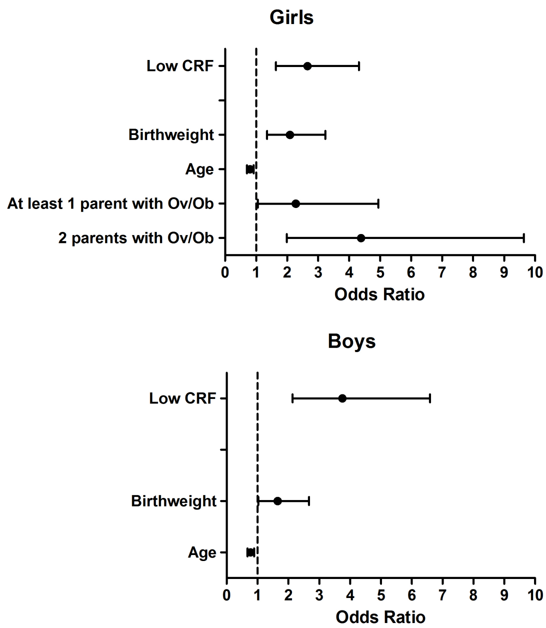

Figure 1 - Prevalence of Overweight and Obesity by stepwise multiple logistic regression analysis in each gender.

Discussion

This paper examined the association between CRF and obesity status in adolescents taking into account BW, parental BMI and education. Prevalence of overweight and obesity in the present study was 21.4% and 5.3% in all samples. Although participants were not country representative, the prevalence of overweight and obesity was similar to values reported in other samples of Portuguese youth (Padez et al 2004, Ribeiro et al 2003). This prevalence values found in our study must be highlighted because our data also showed that the percentage of OV/OB adolescents at risk of CRF (under health zone) was significantly higher ($p \leq 0.05$) compared to normal-weight peers**.** Although the overall percentage of adolescents at risk for CRF are at the same magnitude of that described Irish adolescents (Boreham et al 1993) and our data agree with other study showing that boys more often reach the CRF health zones criterion than girls (Riddoch et al 2004), our results might have some importance from a preventive point of view because they potentially pointed out some future health negative implications. Indeed, there are evidences showing that low levels of CRF associated with excess body fat and sedentary daily life are significant predictors of developing heart disease (Janssen et al 2005) as well as they suggested the health impact of small increases in youth with lower fitness levels (Klasson-Heggebo et al 2006). Thus, since tracking in obesity (Dietz 2004, Guo et al 2002) and CRF (Janz and Mahoney 1997); (Twisk et al 2000) from childhood to adulthood has been described and a secular decreasing trend of CRF was found (Martins et al 2008) our findings raised concerns with regard those whom are classified as OV/OB and unfit, which was already pointed out previously (Pate et al 2006).

Furthermore**,** the major finding of this study was that parent obesity was a strong predictor of adolescents OV/OB girls and not in boys. Although some studies showed an association between parents' obesity level and their offspring obesity status (Maffeis et al 1998, Treuth et al 2003, Whitaker et al 1997), our data highlighted the association of parents' BMI and their daughter. This was already suggested in other survey showing that the number of overweight parents predicted fat gain among normal weight girls (Treuth et al 2003). Furthermore our data clearly showed that association was even stronger when obesity was found in both, rather than in only one parent, which agrees with other studies (Davison and Birch 2001, Herbert et al 2006). For instance, having an obese mother was associated with earlier age at obesity onset (Gordon-Larsen et al 2007). This is particularly worthy because some data suggested that an overweight child living in a family where one or more parent is overweight is likely to remain overweight throughout his or her childhood and into adolescence and adulthood (Magarey et al 2003). Therefore our data suggested that adolescents' BMI status in girls, but not in boys, is likely to reflect the fact that childhood overweight/obesity occurs within a familial context, in which environmental factors besides genetic factors played an important role. Thus, our data suggests, especially in girls, the necessity of taking the familial environment into consideration when designing intervention programs.

Several studies have addressed the association between BW and late development of cardiovascular diseases (Karter et al 1999) and obesity (Stettler et al 2002). Our data demonstrated that high BW girls had two times higher odds of being OW/OB, while boys had. 1.65 times higher odds of being classified as OW/Ob, which are consistent with other studies showing a positive association between BW and further prevalence of obesity in both children an adolescents (Curhan et al 1996); (Dubois and Girard 2006); (Wei et al 2007). Therefore, our data showed that regardless gender high BW was a strong predictor of being OV/OB at adolescence and, thus, strategy options taking into consideration the intrauterine life should be taken.

Strengths of this study included the large sample size and response rate of parents as well as measures of SES. This study has also some limitations that should be acknowledged. First, our parental BMI are based on self-report data, which could indicate an underestimation of the true prevalence of overweight and obesity (Yun et al 2006). Nevertheless, BMI from self-report data was found to be sufficiently accurate and widely used in epidemiological studies, once objectively measurements of weight and height in large samples can be difficult and unaffordable. Second, no dietary factors were assessed and it is well know the influence of diet on the energy regulation. Further studies should also consider the nutritional factors that might be related to obesity

Conclusion

Results from this study highlight the centrality of the family adolescents' obesity, especially in girls. Further our data suggested that low CRF and high BW were strong predictors of OV/OB at adolescence.

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Table 2 – Mean and SD of adolescents and parents characteristics by BMI category within each sex

		Girls			Boys		
Characteristics		**Normal Weight (n=350)**	**Overweight/Obese (n=127)**	p	**Normal Weight (n=227)**	**Overweight/Obese (n=84)**	p
Age (years)		15.32±1.71	15.04±1.81	ns	15.04±1.96	14.25±2.10	***0.002***
Weight (kg)		54.05±7.05	68.74±8.59	***0.000***	58.18±10.56	72.71±15.98	***0.000***
Height (m^2)		1.62±0.07	1.61±0.07	ns	1.69±0.11	1.67±0.09	ns
BMI (kg/m^2)		20.53±1.89	26.43±2.62	***0.000***	20.15±2.00	25.75±3.89	***0.000***
Birthweight (BW) (kg)		3.20±0.51	3.40±0.52	***0.000***	3,35±0.56	3.50±0.63	***0.046***
Cardiorepiratory Fitness (CRF) (laps)		32.80±12.00	27.31±11.59	***0.000***	60.88±20.05	44.76±17.54	***0.000***
Father BMI (kg/m^2)		26.25±3.12	27.54±3.65	***0.000***	26.25±3.25	28.02±3.36	***0.000***
Mother BMI (kg/m^2)		25.18±3.64	27.57±4.41	***0.000***	24.99±3.64	25.96±4.31	***0.050***
CRF (%)	Under Health Zone	45.7	61.4		28.6	54.8	***p≤0.05***
	Health Zone and Above	54.3	38.6	***p≤0.05***	71.4	45.2	
P-BMI (%)	Two parents with Normal Weight	18.9	7.1		21.4	12.7	
	At least one parent with OV/OB	52.9	46.5		45.0	49.4	ns
	Two parents with OV/OB	28.3	46.5	***p≤0.05***	33.6	38.0	
P-Edu (%)	Low Education	58.9	59.1		54.6	52.4	
	Middle Education	22.3	26.0		22.5	29.8	ns
	High Education	18.9	15.0	ns	22.9	17.9	

BMI – Body Mass Index; LBW – Low Birth Weight; NBW – Normal Birth Weight; HBW - High Birth Weight; PBMI – Parental BMI

ns - *p>0.05*