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Childhood Obesity: A Review of Increased Risk for Physical and Psychological Co-morbidities

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Abstract

Background—Worldwide estimates of childhood overweight/obesity are as high as 43 million and rates continue to increase each year. Researchers have taken interest in the childhood obesity epidemic and the impact of this condition across health domains. The consequences of childhood and adolescent obesity are extensive, including both medical and psychosocial comorbidities.

Objective—The purpose of this review was to consolidate and highlight the recent literature on the comorbidities associated with childhood obesity, both nationally and internationally.

Methods—PubMed and PsychINFO searches were conducted on childhood obesity and co-morbidities.

Results—The initial search of the terms "obesity" and "comorbidity" yielded over 5000 published articles. Limits were set to include studies on children and adolescents that were published in peer-reviewed journals from 2002 to 2012. These limits narrowed the search to 938. Review of those articles resulted in 79 that are included in this review. The major medical comorbidities associated with childhood obesity in the current literature are metabolic risk factors, asthma, and dental health issues. Major psychological comorbidities include internalizing and externalizing disorders, ADHD, and sleep problems.

Conclusions—The high prevalence rates of childhood obesity have resulted in extensive research in this area. Limitations to the current childhood obesity literature include differential definitions of weight status and cut off levels for metabolic risk factors across studies. Additionally, some results are based on self-report of diagnoses rather than chart reviews or physician diagnosis. Even so, there is substantial support for metabolic risk factors, internalizing disorders, ADHD, and decreased health related quality of life as comorbidities to obesity in childhood. Additional investigations on other diseases and conditions that may be associated with childhood obesity are warranted and intervention research in this area is critical.

Keywords

Childhood Obesity; Medical Co-morbidities; Psychological Co-morbidities

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Introduction

Obesity is the result of a chronic caloric imbalance, with more calories being consumed than expended each day. History of obesity, hereditary factors, environment, metabolism, behavior, culture, and socioeconomic status all play a role in obesity.[1] Most obese adults were obese as adolescents and most obese adolescents were overweight and/or obese as children.[2] In fact, the origins of obesity are being traced to early childhood development. Children who experience early adiposity rebound (before the age of five years) have increases in mean body mass index (BMI) from age three to adolescence while those that experience late adiposity rebound have decreases in BMI from age three to adolescence; differences between those who experience early and late adiposity rebound are maintained into adulthood. [3,4] Evidence is available to support both genetic [5,6] and environmental components [7,8] to obesity. Availability of healthy snacks and meals [9] and children's choices in food consumption [10] are also important to consider.

In addition to consumption of food, energy expenditure, generally in the form of physical activity, is highly important to maintaining healthy weight. Results from the 2007 Youth Risk Behavioral Survey conducted in the US indicated that among high school students nationwide, 35% had watched television 3 or more hours per day on an average school day during the past month and 65% had not met recommended levels of physical activity during the past week. [11] Recent estimates from the National Health and Nutrition Examination Survey[12] indicate that approximately one third of children in the United States are overweight or obese, with approximately 17% meeting criteria for obesity as measured by a BMI score at or above the 95th percentile. [13] BMI scores can be converted into standardized scores, zBMI, to conduct comparisons between groups.[14] Ethnic minority children are at an increased risk for obesity. [15] Worldwide estimates of childhood overweight/obesity are as high as 43 million. This number reflects an increase from 4.2% in 1990 to 6.7% in 2010.[16]

The rates of obesity in youth are expected to continue to grow. As a result it is imperative to consider the physical health and psychological correlates and consequences of this condition. The consequences of childhood and adolescent obesity are far reaching, not only including health-related physical outcomes, such as high blood pressure, high cholesterol, metabolic syndrome, type 2 diabetes, orthopedic problems, sleep apnea, asthma, and fatty liver disease, but also psychological, social and behavioral consequences, such as risk for problems related to body image, self-esteem, social isolation and discrimination, depression, and reduced quality of life. [1] In 2003 Reilly and colleagues[17] conducted a systematic review of the literature on the health consequences of childhood obesity. They concluded that childhood obesity has significant short term and long-term adverse medical and psychosocial effects extending into adulthood. Strong evidence exists for childhood obesity affecting morbidity and mortality in adulthood.[18] The purpose of this review is to explore and expand upon previously identified associations between childhood obesity with physical and psychological co-morbidities.

Methods

Electronic searches were conducted via PubMed and PsychInfo in October of 2012 using the search terms "obesity" and "comorbidity". The following types of publications were excluded from this review: letters to editors, commentaries, case studies, and review articles. All other publications were considered for inclusion. Articles that did not provide data on medical or psychological co-morbidities of obesity were excluded. Clinical trials and randomized control trials that included baseline information on prevalence of comorbidities in obese children compared to a healthy weight control group were included, otherwise trials were excluded. Most of the studies included in this review were cross sectional, including one time assessments, retrospective chart reviews, and national database analyses. Some studies were prospective or analyzed trends across time. Although the intended sample for this review was pediatric (under the age of 18 years-old), some studies included participants up to the age of 22. Age limits were extended to allow for these studies to be included in the review.

Results

The PubMed search initially yielded 4315 results. Limits were applied to narrow the search including being published from 2002 to 2012 (3800 results), age range of participants was between 0 and 18 years old (961), written in English (840 results). A similar search was conducted in Psych Info. This search initially yielded 709 results, using the same limits described above the search was narrowed to 53 articles. Combining the two searches resulted in 893 articles. The author and a research assistant read all abstracts to further narrow the search to 291 articles for in depth review. This list was narrowed down to 79 articles that focused on comorbidities associated with childhood obesity. The 79 articles that compromise this review were organized into four tables based on type of outcome variable (medical or psychological) and country of research (US or international). If medical and psychological outcomes were assessed in one study, then it was listed in both tables. See tables 1 and 2 for details on variable of interest, study population descriptive, and author details.

Medical Co-morbidities

The main medical co-morbidities associated with childhood obesity throughout this review include asthma, metabolic risk factors, and dental health. Some evidence was also available to support a link between childhood obesity and other medical conditions.

Asthma—The majority of the literature available on obesity and asthma in children indicates that there is a relationship between the two conditions [19–21] especially when symptoms of asthma versus an official diagnosis is studied. [22–26] Even in areas where rates of obesity are very low, there are still some associations between obesity and asthma (adjusted OR = 2.36; 95 % CI, 1.02 – 5.44; $P = 0.04$; n = 2926). [27] Studies have found differential effects between genders, with some supporting a relationship between obesity and asthma for boys but not for girls (adjusted OR = 2.36; 95 % CI, 1.02–5.44; $P = 0.04$; n = 2926)[19,27] and others vice versa (OR = 2.73; 95% CI = 1.09 – 6.85, $P = 0.032$ (girls); OR = 1.74; 95% CI, 0.83–3.73, $P = 0.137$ (boys); n = 854).[22,26]

However, there are studies that do not document an association between obesity and asthma, particularly in minority populations[26] or abroad.[28,29] For instance, Vignolo and colleagues[29] did not find differences in rates of asthma between children who were obese and those who were not ($P = .08$, n = 1179) in a sample of Italian youth. Authors propose differences in diet across countries as a potential explanation. Other researchers recognize that there is a relationship between obesity and asthma, but are unable to verify whether increases in obesity help explain the increases in asthma diagnoses. For example, Wickens and colleagues[30] found large increases in the prevalence of asthma diagnoses and medication use in New Zealand across a 10 year span, but statistical tests that adjusted for multiple comparisons indicated that increase in prevalence was not accounted for by increases in BMI ($P = .04$). There is also some evidence for the combination of obesity and asthma to predispose children to higher rates of metabolic risk factors.[33] For asthma related conditions such as other atopic diseases or allergies, results are mixed.[25,34] Some researchers have found evidence to support a link between obesity or percent body fat and these conditions

(OR = 1.03; 95% CI, 1.01 – 1.06; *P* = .017) [35] and others have not (OR = .65, CI, .35 – 1.24, *P* = .19, n = 2926 of having eczema).[25,27]

Metabolic Risk Factors—Although the exact criteria for metabolic syndrome differs across studies[36,37], the primary factors are large waist circumference, hypertension, high triglycerides, hyperglycemia, and low HDL cholesterol. All 35 studies included in this review that examined some aspect of metabolic risk found that overweight/obese children and adolescents are more likely to experience these risk factors than their healthy weight peers [38–40] (see Tables 1 and 2). For instance, in a sample of 186 obese youth from Turkey, nearly 80% had at least one cardiometabolic risk factor, many had more than one risk factor [41]. In a study of overweight or obese Australian youth (n=107), compared to healthy weight matched controls (n=182), youth who were overweight/obese experienced significantly higher levels of hypertension (chi square p value = .012), impaired glucose tolerance (*P* = .037), hyperinsulinism (*P* < .001), and raised alanine transaminase (*P* <. 001).[42] In a study of school aged Hispanic children who were followed for two years it was found that for every one unit increase in zBMI the odds ratio of meeting criteria for metabolic syndrome was 2.4 (CI, 1.21 – 4.63, *P* <.01).[43]

High blood pressure is consistently related to obesity [44–49] and one of the metabolic risk factors most seen in children. For example, a national study on 1, 021, 211 17-year-old adolescents from Israel, who were receiving a medical evaluation for military service documented increases in both BMI (*P* = <.0001) and high blood pressure (*P* = <.001) across a 14 year period. BMI was associated with high blood pressure (OR = 4.11, CI = 3.89–4.34 and OR = 5.56; CI, 5.09–6.07 for male and female subjects, respectively), type 2 diabetes (OR = 5.56; CI, 5.09–6.07 and OR = 4.42; CI, 3.90 – 5.00, for male and female subjects, respectively) and hyperlipidemia (OR = 16.07, CI, 8.29 – 31.15 and OR = 9.00; CI, 4.36–18.6 for male and female subjects, respectively) even when controlling for origin, level of education and the year of recruitment. Severe hypertension was associated with BMI for males (*P* = <0.001), but not females (*P* = .053). [50] Similar trends regarding high blood pressure and obesity have been reported in American youth, especially in the last 10 years. [51] Obese youth are twice as likely to have hypertension (for SBP > 140, OR = 2.24; CI, 1.46 – 3.45: *P* < 0.001, and for DBP > 90, OR = 2.10: CI, 1.063–4.17, *P* = 0.03)[52] and high blood pressure has been documented as a co-morbidity of obesity in minority and immigrant samples as well. [28,45,53] One study of 1053 patients from an obesity outpatient clinic in Germany found that rates of metabolic syndrome were significantly higher among Turkish patients (40.4%) compared to Germans (27.3%; p = 0.02).[53]

Many studies demonstrated that the degree of obesity impacts level of metabolic risk, with those in the extreme obesity range experiencing the worst outcomes. [37,54] For instance, among adolescents with a BMI above the 97th percentile for their age Lafortuna and colleagues documented rates of metabolic syndrome as high as 40.4% for the German sample and 23.3% for the Italian sample.[37] Evidence for the high rates of metabolic risk factors have been documented in both clinic and population-based settings in extremely obese ethnic minority populations and subgroups. [55]

Dental Health—The role of childhood obesity on dental health has become more prevalent in recent years, with research in this area being conducted with children as young as two. Associations between obesity and dental health have been assessed nationally and internationally. For example, Willerhausen and colleagues[56] documented a significant positive correlation (*P* = .002) between BMI and dental health (caries frequency) in a group of 2071 elementary school aged children in Germany. Similar variables were assessed in a national database study conducted in the US with younger children (ages 2–6).[57] The association between childhood obesity and caries was not significant after controlling for age, race, and poverty/income ratio. However, in the oldest subgroup of the study, the 60–72 month age group, the relationship was significant ($P = .049$). This age group is closer to the lower end of the age range for the Willershausen study[56] indicating that perhaps the relationship between obesity and caries is present for children at certain ages. The relationship between obesity and caries has been documented in other studies as well. [58,59] Marshall and colleagues[60] found a relationship between children who are at risk for overweight ($P < .05$), (but not for overweight) and caries. McGuire and colleagues [61] investigated another aspect of dental health, erosive tooth wear, but found no differences between healthy weight and overweight children.

Other Potential Medical Co-morbidities—In addition to the more established co-morbidities described above, there are a number of additional medical conditions that have been associated with childhood obesity in the literature. For instance, four studies investigated the potential role of obesity on non-alcoholic fatty disease (NAFD). With some supporting the role of obesity in NAFD [69–71] and others not. [72] One example of a study which provided evidence of the link between obesity and NAFD was conducted by Adibi and colleagues. This cross-sectional study was conducted with healthy children between the ages of 6 to 18 years from Isfahan schools, who had been randomly selected for the Isfahan Healthy Heart Program. They found that the prevalence of sonographic fatty liver (SFL) in obese children was 54.4%, which was significantly higher the percent of SFL found in overweight (10.5%) and healthy weight children (1%; $P < 0.001$). Two studies ascertained an association between obesity and gastrointestinal (GI) problems. In a study of 1156 children Stordal and colleagues found that overweight children were nearly twice as likely to report GERD than healthy weight peers (OR = 1.8; 95% CI, 1.2–2.6). [73] In the second study which compared obesity rates of 757 patients from a GI clinic and 255 matched controls results indicated significantly higher rates of obesity for the GI sample, $P < .001$.[73,74]

Some studies have found that children and/or adolescents who are obese are also more likely to have back pains, iron deficiency, disc degeneration, foot problems, elevated serum thyroid-stimulating hormone (TSH), endothelial dysfunction in children, acanthosis nigricans, increased carotid intima media thickness (IMT), differences in timing of sexual maturation, and use antibiotics [20,75–83] but not kidney stone disease.[84]

Psychological Comorbidities

In addition to the traditional medical co-morbidities associated with childhood obesity, researchers are investigating the psychosocial sequelae that accompany obesity at a young age. Research in this area focus on ADHD, internalizing and externalizing disorders, and sleep. See tables 3 and 4 for details.

Attention Deficit Hyperactivity Disorder (ADHD)—A number of studies have assessed the relationship between obesity and ADHD and many researchers suggest that the dysregulation these children experience with their behavior extends into their eating habits. Diagnoses of ADHD have been found to be more prevalent in obese children than their healthy weight peers.[85,86] For instance, Erhart and colleagues[87] found that after controlling for age, gender, and socio-economic status, overweight/obese children were found to be twice as likely to have an ADHD diagnosis (OR = 2.0; 95% CI, 1.23 – 3.11). Not all studies have found an association between obesity and ADHD. [28] For example, a large scale community study conducted by Rojo and colleagues of 35,403 13–15 year olds did not support higher rates of ADHD in obese samples. [88] In fact, analyses indicated lower rates of ADHD in the obese group ($X^2 = 19.1$, $P < 0.001$; (OR) = 1.24; 95 (CI), 1.13–1.39) compared to healthy and underweight peers. The main limitation of the Rojo study[88] is that ADHD was assessed with a self-report measure and not through a standardized clinical assessment. The self-reported rates of ADHD in the sample were much higher (24%) than typical prevalence rates (4%). Additionally, Marks and colleagues[89] reported that in a sample of 40 children with ADHD seeking therapy through a telepsychiatry clinic were actually more likely to be underweight or normal weight than overweight or obese ($t(106.379) = 1.991$, $P = 0.049$).

Internalizing/Externalizing Disorders—Higher rates of internalizing and externalizing symptoms and/or disorders have been documented in obese youth compared to healthy weight peers[21,42,90–96]. In comparison to a sample of children with diabetes, children who were obese displayed significantly higher internalizing (50 out of 116 cases vs. 40 out of 155 cases; $p = .004$) and externalizing symptoms (29 out of 116 vs. 19 out of 155; $P = .010$) on parent report questionnaires.[97] However, analyses within the obese group indicated that those in the "super-obese" group (defined by a BMI z-score ≥ 8 had lower symptoms of anxiety Student's *t* test: ($t = 2.795$, $P = .006$) and depression ($t = 2.180$, $P = .031$) compared to other obese children. In some studies the relationship between obesity and depression is not consistent across subgroups. For example, after adjusting for gender, age, race/ethnicity and poverty status a link between obesity and depression was documented in males (adjOR = 2.7; 95% CI, 1.1–7.1) and non-Hispanic Blacks (adjOR = 3.1; 95% CI,1.1–8.3), but not for the overall group of 4,150 adolescents (adjusted odds ratio (adjOR) = 1.6; 95% CI, 0.9 – 2.9) who were included in a study using data from the National Health and Nutrition Examination Survey.[98] In a prospective study Anderson and colleagues[95] found that the presence of internalizing and externalizing disorders in females, but not males, was associated with increases in zBMI, .13 and .09, $P <.05$, respectively. Marks and collegues[89] did not find differences on depression between individuals who were obese and those who were not in a smaller study of 31 patients receiving treatment through a telepsychiatry clinic. Other researchers who may not have documented a relationship between anxiety and depression and weight status, have found significant relationships with similar variables and weight status. For instance in a sample of 8,090 students from Norway poor self-esteem, but not anxiety and depression, was associated with overweight and obesity in male (OR = 0.9; CI, 0.86–0.94) and female (OR = 0.8; CI, 0.74–0.92) adolescents. [99] Data from large school-based cohort (n = 10 403) in China indicated that the perception of weight status, but not BMI, was related to psychopathology (OR = 1.61; CI, 1.17 – 2.20 for males; OR = 1.88; CI, 1.54 – 2.31 for females).[100]

The extent of behavioral problems in overweight children can be quite severe. For instance, in one study using data from a nationally representative sample of kindergartners in the United States (n = 9949) overweight girls had over 81% greater odds of having substantial teacher-reported externalizing behavior problems compared with girls who were not overweight, OR = 1.81; 95% CI, 1.23 – 2.68. [94] As with many of the associated comorbidities of childhood obesity, it is difficult to determine the temporal relationship between obesity and behavioral problems. Many propose behavioral problems are a result of the stigmatization associated with childhood obesity, but there is also evidence to support that behavioral problems may precede overweight status in some children.[101] In a sample of 629 youth clinically significant behavior problems in normal-weight children were independently associated with becoming overweight 2 years later (adjusted OR = 5.23; 95% CI, 1.37–19.93) after adjusting for covariates.

Sleep—Various researchers have examined the role of obesity on sleep. Studies indicate obesity is associated with short sleep duration.[108,109] Specifically, one study showed that compared with healthy weight peers, overweight children slept about 22 minutes less on average ($\beta = -0.174$; $P = .02$), had lower sleep efficiency ($\beta = -0.027$; $P = .01$), lower REM density ($\beta = -0.256$, $P = .02$). [110] In addition to the duration and quality of sleep, the presence of obstructive sleep apnea syndrome (OSAS) in obese children is concerning.

Studies indicate that OSAS is more frequent [111] and severe [112] in overweight/obese children compared to healthy weight controls. Kohler and colleagues[113] documented a 3.5 time increase for each standard deviation increase in zBMI among adolescents, OR = 3.55; 95% CI, 1.30 – 9.71; *P* = .01. On the other hand, OSAS was not associated with BMI in a clinic sample of Hispanic youth [28] and sleep problems were not significantly higher in obese youth compared to healthy weight peers in an Australian sample.[49,114]

Discussion

The purpose of this review was to summarize the current literature on the medical and psychological comorbidities associated with childhood obesity across national and international investigations. Overall, there are certain medical and psychological comorbidities associated with childhood obesity that have been fairly well established in the literature.

Medically, the association between childhood obesity and metabolic risk factors is evident. [52,115–117] Other medical comorbidities, such as asthma, have received significant research and fairly consistently a relationship between the two conditions is reported, [19–21] but there are exceptions in certain subsamples.[29,30] Researchers have suggested differences in diet across cultures as a potential explanation for the lack of relationship between obesity and asthma in certain subgroups. [29] As with many potential co-morbidities, the causal link between obesity and asthma remains uncertain since many children with asthma avoid physical activity to reduce likelihood of experiencing symptoms resulting in less energy expenditure and more likelihood of gaining weight. [31] It still needs to be determined whether healthy weight helps regulate asthma symptoms and/or whether good asthma control helps maintain a healthy weight. [32] In general, there is some support for an association between obesity and dental problems, [56,58,59] but more research is needed in the area to decipher the role of potential mediators, such as poor dietary habits and age, that might explain the cause of dental problems in children. Many other medical comorbidities have been associated with childhood obesity in some regard[75–83,118] but insufficient evidence has been presented to conclude that there is a clear relationship between the two. The overlap between medical co-morbidities is another difficulty researchers encounter in this line of research is. Many of the published studies control statistically for the effect of age, gender, SES and other demographic factors that could be related to co-morbidities, however, there are so many potential confounds and so much interdependency among the co-morbidities that it is difficult for researchers to isolate the effects of childhood obesity. One confound that could be better accounted for in the literature is the effect of puberty. Controlling for age does not suffice for individual differences in rates of development. Although some studies account for pubertal status, [82] others do not.[119,120] Pubertal status can be very influential, especially for medical comorbidities.

Within the psychological domain there are many studies which propose that obesity is associated with increased internalizing and externalizing symptoms, ADHD diagnoses, and sleep problems[85,94,95,108], but these relationships are not certain because other studies have not been able to establish these associations or have found inverse relationships.[88,89] One of the greatest challenges within the psychological domain is the definition of the psychological variable of interest. Participants are often asked to self-report diagnoses rather than having chart reviews conducted, or ideally clinician administered structured interviews or assessments. These methods may be a function of cost and feasibility, especially for large-scale longitudinal trials, but they must be considered when interpreting results. Another potential explanation for the lack of consistency in psychological co-morbidities of obesity is the often underestimated value of resiliency. There is significant variation between levels of depression and anxiety documented among studies of obese children. It is likely that other variables, such as level of self-esteem or family support, may explain the relationship (or lack there or) in certain groups. More sophisticated and complex psychosocial modeling will be necessary to help explain the relationship between obesity and internalizing symptoms.

Part of the challenge with this topic area is that there are so many potential comorbidities of obesity that the literature seems oversaturated in some ways, but understudied in others. Across both medical and psychological domains the conclusions that can be drawn from the current literature are limited by the methodology through which data were collected. Although some studies are prospective or at least contain a prospective element within the study design, [49,65] most of the studies are cross sectional and therefore the direction of the relationships cannot be established. In many cases it appears that obesity occurs first and then the subsequent comorbidity arises, but causality cannot be determined until more prospective studies are conducted. Part of the challenge with the call for prospective studies is the length of time between a child being diagnosed as obese and the appearance of co-morbidities, with some co-morbidities not being diagnosed until later adulthood. Another consideration with prospective studies is how young children are becoming obese. It is well established in the literature that obesity rates in preschoolers are increasing rapidly[16], yet only 4 of the articles in this review focused on children under the age of 5. In order to obtain a more comprehensive understanding of the co-morbidities associated with childhood obesity, researchers will need to focus investigations on younger populations.

The definition of childhood obesity, a basic, yet fundamental concept to this area of research is a consistent challenge encountered by researchers in this domain. Many studies conducted in the US in the past 10 years adhere to the same age and gender zBMI percentiles recommended by the Center for Disease Control 85th percentile for overweight and 95th percentile for obese.[121] Others use 90th percentile for overweight and 97th percentile for obese.[87] The World Health Organization uses 2 standard deviations above the WHO growth standard median as guidelines for overweight and does not use the term obese. [122] Other researchers use the International Obesity Task Force guidelines[123] or guidelines specific to the country the research is being conducted.[53] Some investigators use adult overweight (BMI>25) and obesity (BMI>30) guidelines. [73] Although the merits of each of these classification systems can be debated, the lack of consistency among BMI thresholds used by researchers makes consolidating evidence across studies problematic and a limitation of the literature as a whole. BMI also needs to be assessed more rigorously. Although the majority of studies used trained staff to administer anthropometric assessments, there are studies that use self-reported weight and height, a limitation of some of the large national database studies.[124] In addition to variations in the definition and measurement of obesity, there are also inconsistencies regarding the cut off points for the metabolic risk factors, which makes it very difficult to compare findings across studies and identify trends. [37] It is important to set consistent criteria for MS in children and adolescents in order for researchers' efforts to be maximized and not duplicated. It is possible that some of the inconsistencies in findings across studies are due to variations in definitions of key terms such as obesity and MS.

Seventy-nine studies were identified in a 10 year time span on the topic of childhood obesity and co-morbidities and the number being published continues to grow. Despite the recognition of the importance of this condition in children, the rates of childhood obesity continue to increase and unfortunately the reality of the long-term ramifications is becoming solidified in the literature. There is evidence to support significant medical and psychological sequelae of the condition into adulthood. The current literature supports the importance of continued work in this area to further understand the complexities of the intertwined comorbidities associated with childhood obesity. Future research is needed to determine a more precise course for children who are obese and the need to continue intervention efforts in this population cannot be understated.

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Table 1

Psychological/Behavioral Co-morbidity	Age range	Ethnicity	Author, Year
Internalizing Disorders			
Anxiety and depression	9–18 years	92% white; 8% other	Anderson, 2006
Anxiety and depression	11–17 years	62% white; 38% non-white	Hillman, 2010
Depression	12–19 years	16% non-Hispanic white, 21% non-Hispanic black, 18.8% Mexican-Americans	Merikangas, 2012
General internalizing symptoms	5–12 years	55% White; 29% African American; 3% Hispanic; 1% Native American; 12% mixed race	Fiese, 2009
Externalizing Disorders			
ADHD	6–17 years	****62(62)% white; 15(14)% AA; 16(17)% Hispanic; 7(7)% other	Kim, 2011
ADHD	6–18 years	85% Hispanic	Mirza, 2004
Behavioral problems	*4–5 years	** Girls 56 (65)% white ** Boys 66 (59) % white	Datar, 2004
Behavioral problems	8–11 years	53% white; 27% black; 20% Hispanic	Lumeng, 2003
Externalizing symptoms	5–12 years	55% White; 29% African American; 3% Hispanic; 1% Native American; 12% mixed race	Fiese, 2009
Sleep Problems			
Obstructive sleep apnea syndrome	2–17 years	---	Carno, 2009
Obstructive sleep apnea (OSA)	3–5 years; 13–16 years	***33(38)% White non-Hispanic; 37(46)% black non-Hispanic, 27(5)% Hispanic; 3(3)% other; 3(9)% American Indian	Lazorick, 2011
Obstructive sleep apnea, daytime somnolence	6–18 years	85% Hispanic	Mirza, 2004
Sleep disruptions	5–12 years	55% White; 29% African American; 3% Hispanic; 1% Native American; 12% mixed race	Fiese, 2009
Sleep problems	7–17 years	85% White; 12% Black; 3% other	Liu, 2008
Snoring	6–18 years	85% Hispanic	Mirza, 2004
Other			
Disordered eating	14–18 years	83% African-American; 7% white; 2% Hispanic; 2% other; 6% unknown	Trent, 2009
Psychological Conditions	<21 years	---	Marks, 2009
Medical Co-morbidity	**Age range**	**Ethnicity**	**Author, Year**
Metabolic Risk Factors			
Abnormal cholesterol, HDL, and triglyceride levels	8–20 years	100% Mexican-Americans	Fortmeier-Saucier, 2008
Hypertension	3–5 years; 13–16 years	***33(38)% White non-Hispanic; 37(46)% black non-Hispanic, 27(5)% Hispanic; 3(3)% other; 3(9)% American Indian	Lazorick, 2011

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Psychological/Behavioral Co-morbidity	**Age range**	**Ethnicity**	**Author, Year**
Cardiovascular risk profile High Blood pressure	6–18 years	85% Hispanic	Mirza, 2004
High blood pressure	8–17 years	Mexican-America; Puerto-Rican; Cuban-American	Din-Dzietham, 2007
High blood pressure	14–18 years	83% African-American; 7% white; 2% Hispanic; 2% other; 6% unknown	Trent, 2009
Gastrointestinal complaints	2–20 years	---	Teitelbaum, 2009
Hypertension (HTN); left ventricular hypertrophy (LVH).	13–19 years	70% Caucasian; 9% African-American; 14% Hispanic; 6% other	Movahed, 2011
Metabolic syndrome	12–18 years	74% Latin; 26% Caribbean-black	Messiah, 2010
Metabolic syndrome	5–8 years	93% Hispanic; 7% other	Patino-Fernandez, 2008
Microalbuminuria and cardiovascular risk factors	12–19 years	27% non-Hispanic white; 31% non- Hispanic black; 39% Hispanic; 3% other	Nguyen, 2008
Thyroid function	6–17 years	---	Bhowmick, 2007
Pre-diabetes	3–5 years; 13–16 years	*** 33(38)% White non-Hispanic; 37(46)% black non-Hispanic, 27(5)% Hispanic; 3(3)% other; 3(9)% American Indian	Lazorick, 2011
Asthma			
Asthma	12–19 years	60% Caucasian; 19% African-American; 12% Hispanic; 9% biracial/other	Abramson, 2008
Asthma	5–12 years	55% White; 29% African American; 3% Hispanic; 1% Native American; 12% mixed race	Fiese, 2009
Asthma	7–18 years	****57(60)% White; 6(4)% Black; 29(28)% Hispanic; 8(9)% other	Gilliland, 2003
Asthma	3–5 years; 13–16 years	*** 33(38)% White non-Hispanic; 37(46)% black non-Hispanic, 27(5)% Hispanic; 3(3)% other; 3(9)% American Indian	Lazorick, 2011
Asthma	6–18 years	85% Hispanic; 15% other	Mirza, 2004
Asthma	9–22 years	96% Native American; 4% other	Noonan, 2010
Asthma	14–18 years	83% African-American; 7% white; 2% Hispanic; 2% other; 6% unknown	Trent, 2009
Dental Health			
Dental cavities	2–6 years	61% non-Hispanic White; 14% non-Hispanic Black; 20% Hispanic; 6% other	Hong, 2008
Erosive tooth wear	13–19 years	65% white; 15% African-American; 16% Hispanic; 4% other	McGuire, 2008
Medical Expenditures			
Health care expenditures	6–19 years	15% non-Hispanic Black; 18% Hispanic; 4% Asian; 63% other/unspecified	Trasande, 2009
Other			
Back pain, gastroesophageal reflux disease, acanthosis nigricans	3–5 years; 13–16 years	*** 33(38)% White non-Hispanic; 37(46)% black non-Hispanic, 27(5)% Hispanic; 3(3)% other; 3(9)% American Indian	Lazorick, 2011
Iron deficiency	12–17 years	**27 (32)% non-Hispanic white; 40 (30)% non-Hispanic African-American; 33(39)% Hispanic	Tussing-Humphreys, 2009

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Psychological/Behavioral Co-morbidity	Age range	Ethnicity	Author, Year
Complications after reduction mammaplasty surgery	13–20 years	---	Webb, 2012
Deep venous thrombosis	1–17 years	---	Vu, 2008
Endothelial dysfunction	4–12 years	59% white; 31% black; 5% Hispanic; 5% other	Bhattacharjee, 2012
Sexual maturation	8–14 years	26(25)% non-Hispanic white; 35(36)% non-Hispanic black; 35(35)% Mexican-American; 4(4)% other	Wang, 2002
Surgery	3–17 year	35% Caucasian; 17% African-American; 42% Hispanic; 11% other	Olutoye, 2011

---No ethnicity data available

*Estimated range based on mean and standard deviation

**Overweight/obese(healthy weight)%

***Age at time 1(Age at time 2)%

****Girls (boys)%

Table 2

Co-morbidities of Childhood Obesity from International Studies

Psychological/Behavioral comorbidity	**Age range**		**Author, Year**
Internalizing Disorders			
Anxiety and depression	6–13 years	Australia	Bell, 2007
Anxiety and depression	6–13 years	Australia	Bell, 2011
Anxiety Depression Self-esteem	13–19 years	Norway	Bjornelv, 2011
Depression, self-esteem	8–13 years	Western Australian	Gibson, 2008
Internalizing disorders	6–14 years	German	Eschenbeck, 2009
Internalizing disorders	5–17 years	France	Vila, 2004
Externalizing Disorders			
ADHD	8–17 years	Israel	Agranat-Meged, 2005
ADHD	11–17 years	Germany	Erhart, 2012
ADHD	13–15 years	Spain	Rojo, 2006
Externalizing disorders	6–14 years	German	Eschenbeck, 2009
Externalizing disorders	5–17 years	France	Vila, 2004
Sleep Problems			
Obstructive sleep apnea (OSA)	6–13 years	Australia	Bell, 2007
Obstructive sleep apnea syndrome (OSAS)	2–18 years	Australia	Kohler, 2009
Sleep disorders	6–14 years	German	Eschenbeck, 2009
Sleep duration	3–10 years	Germany	Bayer, 2009
Sleep duration	7 years	New Zealand	Nixon, 2008
Sleep problems	*5–11 years	Australia	Wake, 2010
Other			
Body dissatisfaction, eating disorder symptoms, bullying	8–13 years	Western Australian	Gibson, 2008
Bullying	6–13 years	Australia	Bell, 2011
Dieting behaviors	*5–11 years	Australia	Wake, 2010
Psychopathological symptoms health not associated	12–24 years	China	Huang, 2011
Social skills	5–17 years	France	Vila, 2004
Medical comorbidities			
Metabolic Risk Factors			
Blood pressure	6–13 years	Taiwan	Chu, 2007
Blood pressure, HDL-cholesterol, triglycerides and carbohydrate metabolism	1–20 years	Europe	I'Allemand, 2008
Blood pressure	6–18 years	Greece	Karatzi, 2009
Blood pressure	10–18 years	Poland	Krzyzaniak, 2011
Cardiovascular risk factors	3–18 years	The Netherlands	Langens, 2008
Cardiovascular risk factors	8–15 years	Portugal	Ribeiro, 2004
Cardiovascular risk factors and metabolic syndrome	6–16 years	Turkey	Serap, 2007
Carotid intima-media thickness increased	*7–12 years	Turkey	Hacıhamdioglu, 2011
Gastro-oesophageal reflux	7–16 years	Norwegian	Stordal, 2006

Psychological/Behavioral comorbidity	**Age range**		**Author, Year**
Hypertension, hyperlipidemia	17 years	Israel	Levin, 2010
Hypertension	11–17 years	Ludhiana	Mohan, 2004
Hypertension, LDL, hypertriglyceridemia	7–8 years	Taiwan	Ng, 2004
Hypertension	5–11 years	Australia	Wake, 2010
Metabolic risk	1–18 years	Germany	Flechtner-Mors, 2012
Metabolic risk	6–18 years	China	Lee, 2011
Metabolic risk	6–18 years	Germany	Reinehr, 2010
Metabolic syndrome	1–17 years	Berlin	Dannemann, 2011
Metabolic syndrome	12–14 years	Mexico	Del-Rio-Navarro, 2010
Metabolic syndrome	12–18 years	Italy Germany	Lafortuna, 2010
Non-alcoholic fatty liver disease	15–19 years	Brazil	Dámaso, 2008
Non-alcoholic fatty liver disease (NAFLD)	7–13 years	Turkey	Eminoğlu, 2008
Non-alcoholic fatty liver disease	6–10 years	Brazil	Suano de Souza, 2008
Sonographic Fatty Liver	6–18 years	Iran	Adibi, 2009
Type 2 diabetes	17 years	Israel	Levin, 2010
Asthma			
Asthma	6–11 years	Greece	Spathopoulos, 2009
Asthma	13–14 years	Macedonia	Vlaski, 2006
Asthma symptoms	6–15 years	France	Mahut, 2012
Asthma	4–5 years	Australia	Tai, 2009
Asthma Atopic disease	5–16 years	Portugal	Silva, 2007
Asthma	2–16 years	Italy	Vignolo, 2005
Asthma	5–11 years	Australia	Wake, 2010
Asthma	11–12 years	New Zealand	Wickens, 2005
Dental health			
Cavities	6–10 years	Germany	Willershausen, 2007
Surgery			
Perioperative implications	2–16 years	Egypt	El-Metainy, 2011
Other			
Airway hyper-responsiveness and exercise-induced bronchospasm frequencies	9–15 years	Turkey	Ulger, 2006
Airway hyper-responsiveness	10–12 years	Korea	Jang, 2006
Allergy	12–17 years	Vietnam	Irie, 2005
Atopy	6–11 years	Greece	Spathopoulos, 2009
Disc degeneration	13–20 years	China	Samartzis, 2011
Flat foot	3–6 years	Austria	Pfeiffer, 2006
Impaired glucose tolerance (IGT) hyperinsulinism dyslipidaemia raised alanine transaminase	6–13 years	Australia	Bell, 2011
Intima media thickness (IMT)	*6–10 years	Italy	Giannini, 2008
Muscle and joint problems	5–11 years	Australia	Wake, 2010

Psychological/Behavioral comorbidity	Age range		Author, Year
Musculoskeletal pain, headaches, acanthosis nigricans	6–13 years	Australia	Bell, 2007
Musculoskeletal pain	6–13 years	Australia	Bell, 2011
Musculoskeletal problems	2–17 years	The Netherlands	Krul, 2009
Poor health status School absenteeism	8 years	The Netherlands	Wijga, 2010
Risk factors for atherosclerosis	6–20 years	Poland	Glowinska, 2003
Upper Airway Obstruction	4–12 years	Australia	Kohler, 2008