Childhood Obesity in Canada: A Review of Prevalence Estimates and Risk Factors for Cardiovascular Diseases and Type 2 Diabetes

Geoff D.C. Ball and Linda J. McCargar

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Abstract/Résumé

Childhood obesity in Canada has become increasingly prevalent over the past 2 decades. Despite inconsistencies regarding different anthropometric indicators, cut-offs, and reference populations, both regional and national investigations have revealed high numbers of overweight and obese children and adolescents. A number of risk factors and health consequences have been associated with increased levels of body fatness in youth. Specifically, risk factors for cardiovascular diseases (CVD) and type 2 diabetes are known to develop early in life and tend to emerge in clusters among overweight youngsters. Unhealthy lifestyle behaviours (i.e., physical inactivity), a genetic disposition, and a centralized body fat distribution, all contribute to increased risk. In order to prevent future generations of children from experiencing increased morbidity and mortality as overweight and obese adults, coordinated efforts at all levels (family, school, community, and government) must be established with a long-term commitment to promote healthy nutrition and physical activity behaviours in our youth.

G.D.C. Ball is with the Department of Health Promotion and Disease Prevention Research in the Faculty of Medicine, University of Southern California, Los Angeles, CA; and L.J. McCargar is with the Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB. Studentship support for G.D.C. Ball was provided by the Danone Institute of Canada.

On constate l'augmentation considérable du nombre d'enfants obèses depuis vingt ans. Malgré des divergences concernant les indicateurs anthropométriques, les points de démarcation et les populations de référence, les enquêtes tant régionales que nationales signalent le grand nombre d'enfants et d'adolescents obèses. Quelques facteurs de risque de maladie sont associés à la suradiposité chez les jeunes ; plus spécifiquement, les facteurs de risque de maladie cardiovasculaire et de diabète de type 2 se manifestent en bas âge surtout parmi les jeunes présentant un surpoids. De mauvaises habitudes de vie (i.e. inactivité physique), une prédisposition héréditaire et une accumulation centrale de graisses corporelles contribuent toutes à l'augmentation du risque. Pour éviter l'accroissement de la morbidité et de la mortalité dans les prochaines générations d'enfants, les efforts de tous les milieux (famille, école, communauté, gouvernement) doivent être coordonnés dans un programme à long terme afin de promouvoir de saines habitudes de vie (nutrition, activité physique) chez nos jeunes.

Introduction

In developed nations, obesity is one of the most common metabolic and nutritional disorders in youth (Dietz, 1986). The prevailing perception in the health care, academic, and public arenas is that the high prevalence of obesity in children and adolescents should be cause for concern (Andersen, 2000). Indeed, research suggests that obese boys and girls are at an increased risk of developing a number of physical ailments (i.e., hypertension, dyslipidemia, impaired glucose tolerance, and sleep apnea). Of even greater concern is the teasing, discrimination, and victimization they are known to endure (Must and Strauss, 1999). While immediate health risks can be elevated in some obese children, the refractory nature of obesity also indicates that long-term health can be compromised (Must et al., 1992). Several longitudinal analyses have revealed that obesity (Clarke and Lauer, 1993; Freedman et al., 1997; Srinivasan et al., 1999) and risk factors for cardiovascular diseases (CVD) and type 2 diabetes (Kotani et al., 1997; Srinivasan et al., 1999; Webber et al., 1991) can develop early in life and persist into adolescence and adulthood leading to increased morbidity and mortality.

Obesity is associated with many chronic health problems and presents an enormous challenge to our health care system. In Canada, the total direct cost of obesity in 1997 exceeded $1.8 billion (approximately 2.4% of total health care expenditures) with hypertension, type 2 diabetes, and coronary heart disease being the largest contributors (Birmingham et al., 1999). In the United States, it has been estimated that obesity is responsible for between 280,000–325,000 deaths each year (Allison et al., 1999), second only to smoking (McGinnis and Foege, 1993). Because of the increased personal, social, and economic costs, the treatment and prevention of childhood obesity have been established as research priorities (Hill and Trowbridge, 1998; Must and Strauss, 1999) with the ultimate aim of fostering positive lifestyle behaviours in youth to enhance both short- and long-term health outcomes. Accordingly, the purpose of this paper is to (a) review published prevalence estimates of overweight and obesity in Canadian youth and (b) outline the physiological risk factors that may result from increased levels of body fatness in youth with an emphasis on multiple risk factors linked to CVD and type 2 diabetes.

Prevalence Estimates of Overweight and Obesity in Canadian Youth

REGIONAL STUDIES

Historically, the use of a variety of anthropometric indicators, cut-off points, and reference populations has precluded direct comparisons between studies of overweight Canadian boys and girls. For example, regional studies in Edmonton, AB (Ball et al., 2001; Marshall and Bouffard, 1997), Montreal, QC (Johnson-Down et al., 1997; O'Loughlin et al., 1998), northern Quebec (Bernard et al., 1995) and northern Ontario (Hanley et al., 2000; Katzmarzyk and Malina, 1998) have reported different overweight and obesity prevalence levels within the last decade (Table 1).

Ball et al. (2001) reported an *obesity* prevalence of 20.3% and 17.9% in a self-selected sample of mostly Caucasian 6–10-year-old boys and girls, respectively, using the sum of 5 skinfolds (triceps, biceps, subscapular, suprailiac, and medial calf) ≥ 85th percentile as the criterion to determine overweight; data from The Canada Fitness Survey (CFS, 1984) served as the reference population. Because these estimates were based on a relatively small sample (n = 136), the data should be viewed cautiously. Using the same indicator, cut-off point and reference group in an earlier investigation, Marshall and Bouffard (1997) classified 28.8% (boys: 33.0%; girls: 24.2%) of their sample of mostly Caucasian middle-class schoolchildren as obese. However, others have defined *overweight* in boys and girls according to a body mass index (BMI) ≥ 85th percentile from data collected in the U.S. National Health and Nutrition Examination Surveys (NHANES). Johnson-Down et al. (1997) and Bernard et al. (1995) compared children to NHANES II (1976–1980) data while Hanley and colleagues (2000) used NHANES III (1988–1994) as the reference population. Overall, Johnson-Down et al. (1997) found that 39.4% of 9–12 year old children (n = 498) from low-income, urban, multiethnic communities were *overweight*. This sample was subsequently divided into arbitrary sub-categories representing degree of overweight (Table 1). In another assessment with a larger sample (n = 2108) of Montreal-area children, O'Loughlin et al. (1998) found that 35.2% of boys and 33.0% of girls were overweight and 15.1% of boys and 13.3% of girls were obese. This study is unique in that boys and girls had to possess both a BMI and triceps skinfold thickness ≥ 85th percentile to be classified as overweight and a BMI and triceps skinfold thickness ≥ 95th percentile to be classified as obese. If at least one of the measurements fell below the 85th percentile, the individual was considered *not overweight*. However, it is unclear from the discussion whether any individuals had one measurement (i.e., BMI) falling between the 85th and 95th percentiles with the other value (i.e., triceps skinfold) exceeding the 95th percentile cut-off. It is likely that there were few individuals with values in these ranges, but the overall obesity prevalence values may differ slightly depending on how these children were classified.

Several reports have also been published regarding the prevalence of overweight in First Nations communities in Canada. Among students from grades 4, 5, 8, and 9, Bernard et al. (1995) reported an overweight (BMI > 85th percentile) prevalence level of 38% in two First Nation Cree communities in James Bay, QC. When BMI > 95th percentile was used to define overweight status, 17% fell above

Table 1 Regional and National Overweight/Obesity Prevalence Estimates of Canadian Children and Youth

Study	Age	Sample	Indicator & Reference Population	Definition	Prevalence
Ball et al., 2001 (Edmonton, AB)	6–10y	*n* = 136	Sum of 5 skinfolds; CFS	Overweight (≥ 85th percentile)	20.3% boys; 17.9% girls
Bernard et al., 1995 (Northern Quebec)	9–15y	*n* = 144	BMI; NHANES II	Overweight (> 90th & > 95th percentiles)	>90th percentile: 38% boys & girls >95th percentile: 9.0% boys; 24% girls
Hanley et al., 2000 (Northern Ontario)	2–19y	*n* = 445	BMI; NHANES III	Overweight (≥ 85th percentile)	27.7% boys; 33.7% girls
Johnson-Down et al., 1997 (Montreal, QC)	9–12y	*n* = 498	BMI; NHANES II	Somewhat overweight (≥ 85th to ≥95th percentile) Moderately overweight (≥90th to <95th percentile) Very overweight (≥ 95th percentile)	≥ 85th to < 90th percentiles: 13.8% boys; 10.4% girls ≥90th to <95th percentiles: 6.1% boys; 9.6% girls ≥ 95th percentile: 21.9% boys; 16.9% girls
Katzmarzyk & Malina, 1998(Northern Ontario)	5–19y	*n* = 167	BMI; NHANES II	Obese (≥ 85th percentile)	20.8–28.6% boys; 12.3–29.4% girls

Limbert et al, 1994 (National)	7–12y	CFS; *n* = 2601 CSWB; *n* = 337	Triceps skinfold, sum of 5 skinfolds, weight-for-height; CFS & CSWB	Obese (≥ 85th percentile)	1981: 8.7–15.5% boys[1] 1988: 13.6–22.0% boys[1] 1981: 8.8–16.9% girls[1] 1988: 13.0 – 26.9% girls[1]
Marshall & Bouffard, 1997 (Edmonton, AB)	5-6, 9–10y	*n* = 406	Sum of 5 skinfolds; CFS	Obese (≥ 85th percentile)	33.0% boys; 24.2% girls
O'Loughlin et al, 2000 (Montreal, QC)	10–12y	*n* = 2108	BMI and triceps skinfolds, NHANES II	Overweight (≥ 85th percentile) Obese[3] (≥ 95th percentile)	≥ 85th percentile: 35.2% boys;33.0% girls ≥ 95th percentile: 15.1% boys; 13.3% girls
Tremblay & Willms, 2000 (National)	7–13y	CFS; *n* = 4176 NLSCY; n = 7847	BMI; CFS & NLSCY	Overweight (> 85th percentile) Obese (> 95th percentile)	>85th percentile: 1981: 15.0% boys 1996: 35.4% boys 1981: 15.0% girls 1996: 29.2% girls >95th percentile: 1981: 5.0% boys 1996: 16.6% boys 1981: 5.0% girls 1996: 14.6% girls

[1]Estimates vary depending on the indicator and reference population
[2] Individuals classified as "overweight" if both BMI and triceps skinfold ≥ 85th percentile
[3] Individuals classified as "obese" if both BMI and triceps skinfold ≥ 95th percentile
CFS (Canada Fitness Survey), BMI (body mass index), NHANES (National Health and Nutrition Examination Surveys), CSWB (Campbell's Survey on Well-Being in Canada), NLSCY (National Longitudinal Survey of Children and Youth).

the cut-off with significantly more girls (24%) than boys (9%) meeting the criterion. In the Sandy Lake First Nation Community of Northern Ontario, Hanley and coworkers (2000) reported an overall overweight prevalence (based on BMI > 85th percentile) of 27.7% and 33.7% among 2–19-year-old boys and girls, respectively. However, unlike Bernard et al. (1995), they found that levels of overweight varied depending on age and sex, ranging from 18.6% in 15–19-year-old boys to 45.2% in 2–5-year-old girls. Finally, Katzmarzyk and Malina (1998) evaluated the prevalence of overweight among individuals of First Nation (FN) and European ancestry (EA) from the communities of Bear Island and Temagami, respectively, in Northern Ontario; approximately 50% of the area population participated in this survey. Among youth (5–19 years old), overweight (BMI ≥ 85th percentile) prevalence estimates varied from 12.3% among EA females to 29.4% in FN females. While the overall ethnic disparity was substantial, the difference was not as large among males (20.8% EA *versus* 28.6% FN).

It is important to note that the prevalence estimates in the aforementioned studies may yield discordant results because of the application of different reference populations (i.e., CFS, NHANES II, and NHANES III). With this in mind, it is possible that Hanley et al. (2000) may have underestimated the prevalence of overweight in their sample by using NHANES III data for comparison purposes. This point is highlighted by the exclusion of NHANES III (1988–1994) anthropometric data for children ≥ 6 years of age from the updated U.S. growth charts because of the recent upward trend in body fatness among American youth (Kuczmarski et al., 2000). The investigators argued that including these data with height and weight information collected in earlier NHANES rounds would have inflated the 85th and 95th percentiles for BMI thereby decreasing the proportion of children classified above these cut-offs. It has been recommended that American children who possess BMIs above the 85th and 95th percentile cut-offs may be suitable candidates for weight management initiatives (Himes and Dietz, 1994), so under-diagnosing boys and girls as overweight could result in missed opportunities to intervene at a time in life when the promotion of healthy weight-related lifestyle behaviours may be most effective (Epstein et al., 1994).

Another factor that results in varying prevalence estimates is the use of different anthropometric indicators. In light of previous research wherein both skinfolds and the BMI have been applied to estimate obesity prevalence levels, Flegal (1993) illustrated the practical consequences of applying two different measures of obesity status. Using data from the same NHANES series, two groups of researchers arrived at different conclusions regarding the changes in obesity prevalence in male and female African-American and Caucasian youth between 1966 and 1980. Gortmaker et al. (1987) observed that the prevalence of obesity increased dramatically in all groups over a two-decade period when the triceps skinfold thickness (> 85th percentile) was used to define obesity. In contrast, Harlan and coworkers (1988) concluded, over the same time frame, that average BMI levels were constant across the surveys for all ethnic-, age-, and sex-specific comparisons. Given the observed differences in growth and body fat patterning between Caucasian, African-American, and Mexican-American youth (Malina, 1993), obesity prevalence levels within different ethnic groups will undoubtedly be influenced by the chosen indicator.

NATIONAL STUDIES

In agreement with Flegal (1993), other researchers have observed that obesity prevalence estimates vary depending on the anthropometric indicator and the reference population being applied. Using nationally representative data from the CFS (1984), Limbert and colleagues (1994) compared obesity status in 7–12-year-olds using the following indicators (and reference populations): Triceps skinfold thickness (NHANES I and CFS), sum of 5 skinfolds thickness (CFS), and weight-for-height (Hamill et al., 1977). In all cases, values ≥ 85th percentile were used to define obesity. Since the CFS data were used to calculate the percentile cut-offs for both triceps skinfolds and the sum of 5 skinfolds, by definition, 15% of boys and girls were automatically classified as obese using these indicators. However, when triceps skinfolds from children in the CFS survey were compared to the NHANES I reference population, only 8.7% of boys and 8.8% of girls were obese revealing that different reference populations yielded disparate prevalence estimates. Unfortunately, a similar comparison using the sum of 5 skinfolds was not possible as the NHANES I dataset did not include comparable measurements. Group contrasts in weight-for-height were somewhat limited by the restricted age range dictated by the available weight-for-height percentiles, however, the findings revealed that 14.9% of 7–11-year-old boys and 16.9% of 7–9-year-old girls from the CFS dataset were obese, levels not markedly dissimilar from the aforementioned obesity level of 15%.

Limbert et al. (1994) also attempted to estimate the change in obesity prevalence over a 7-year period by comparing CFS data from 1981 to data collected in the Campbell's Survey on Well-being in Canada (CSWB, 1990) in 1988. When skinfold thickness measurements (either triceps or a sum of 5 skinfolds) were used to evaluate the change in obesity prevalence over this interval, the level of obesity was reported to have increased by 33.6–75.8% depending on the sex and choice of indicator. However, these findings should be interpreted carefully since the sample sizes of 7–12-year-old children from these two national surveys differed substantially (CFS: n = 2601; CSWB: n = 337). One of the primary objectives of the CSWB was to update information from the CFS and to further investigate the health of Canadians, so it is possible that determining the time-related change in obesity prevalence among youth was not adequately assessed in this study design.

More recently, Tremblay and Willms (2000) evaluated secular trends in weight status (using the BMI) comparing data from the CFS, CSWB, and the National Longitudinal Survey of Children and Youth (NLSCY, 1996) (Table 1). They concluded that overweight (BMI > 85th percentile) increased from 15% in 1981 to 35.4% in 1996 (a 136.0% increase) among boys and from 15% to 29.2% (a 94.7% increase) in girls. Obesity (BMI > 95th percentile) also increased—from 5.0% to 16.6% and from 5.0% to 14.6% in boys and girls, respectively. From a methodological standpoint, it is important to note that the data collected in the CFS and CSWB surveys were based on actual measurements whereas anthropometric information collected in the NLSCY was collected using parental reports. The authors acknowledged that the NLSCY data likely underestimated the true prevalence of overweight in their sample, a point supported by previous research suggesting that there are systematic errors involved when proxies report anthropometric data (Marshall and Ball, 1998).

The prevalence estimates by Limbert et al. (1994) and Tremblay and Willms (2000) were calculated using age- and gender-specific percentile cut-offs derived from populations of Canadian children. Recently, in order to establish a more international reference population and to remove the arbitrariness associated with percentile cut-offs, Cole et al. (2000) proposed an overweight and obesity classification system based on the accepted health-related cut-offs used in adults (25 kg/m^2 and 30 kg/m^2, respectively) (World Health Organization, 1998). Since height and weight changes occur throughout the child and adolescent years, using absolute BMI levels to classify overweight and obesity are inappropriate for growing boys and girls. Thus, Cole and colleagues employed LMS regression techniques in their international dataset by passing a line through the adult cut-off values at age 18 to calculate age- and gender-specific cut-offs. Using these new definitions, Katzmarzyk (2001) reanalyzed data from the CFS (1981) and NLSCY (1996) surveys and found slightly lower overweight and obesity prevalence rates for both genders at both intervals compared to the values reported by Tremblay and Willms (2000). However, the most salient finding of this subsequent comparison, regardless of the "true" prevalence levels, is that the overall trend of increasing overweight and obesity was consistent in both sets of analyses.

There has been long-standing debate regarding the best indicator to use for assessing obesity in youth. Kraemer et al. (1990) described several criteria that should be considered when selecting a measure of adiposity. Ideally, an indicator should be accessible, individual, reliable, and valid. Several convenient indicators (i.e., skinfold thicknesses, weight-for-height, BMI, Ponderal index [$weight^{0.33}$ / height], Rohrer's index [weight / $height^3$], circumferences, and visual estimation) have all been used to assess overweight and obesity status. While no single indicator satisfies all of the above criteria, if one measure must be used to define overweight and obesity in children and adolescents, the BMI is recommended (Bellizzi and Dietz, 1999; Cole et al., 2000; Himes, 1999; Pietrobelli et al., 1998; Power et al., 1997; Troiano and Flegal, 1998). The BMI is an accurate and valid indicator of weight status in children and adolescents (Malina and Katzmarzyk, 1999), is significantly correlated with total body fatness (Daniels et al., 1997; Deurenberg et al., 1991; Goran et al., 1996), and measurements of height and weight are easy and convenient to perform in most settings. While the aforementioned Canadian studies applied different criteria to establish prevalence estimates of overweight and obesity, the emergence of the BMI as the preferred indicator should provide a universal frame of reference for future surveys, especially since standardized international definitions of overweight and obesity using the BMI are now available (Cole et al., 2000).

It is possible that the discrepancies between Canadian estimates from regional and national studies represent a true difference in overweight and obesity prevalence. However, these differences may also reflect variations in sampling techniques, geography, ethnicity, season, maturation, socioeconomic status, reference populations, and the anthropometric indicators used to define relative weight status. While there are few published reports of the etiology of obesity among Canadian children, studies from other countries suggest that obesity may be the result of increased height and weight (leading to an increased BMI) at a given age which may relate to earlier maturation (at least in girls) (Adair and Gordon-Larsen, 2001; Kaplowitz et al., 2001), decreased levels of physical activity (Jebb and Moore,

1999), and increased levels of physical inactivity (Gortmaker et al., 1996; Robinson, 1999). Nationally-representative data on the dietary intakes of Canadian children do not presently exist, but the role of diet in the etiology of obesity has been confounded by some of the methods (i.e., self-report) used to assess nutrition habits and because under-reporting of energy intakes is common (Bandini et al., 1997; Champagne et al., 1998). Clearly, energy balance is involved in the development of obesity in youth, but further research is still necessary to clarify the role of lifestyle factors in this relationship (Goran and Sun, 1998).

Notwithstanding the disparities regarding the methodological issues associated with defining weight status in children and adolescents, the terms used to characterize high levels of body fatness, and the myriad etiological factors involved, it is clear that obesity is widespread and has increased dramatically over the last two decades among Canadian youth. The present situation in Canada is similar to that of the United States (Ogden et al., 1997; Troiano et al., 1995) and the United Kingdom (Chinn and Rona, 1994) and highlights the growing global trend of increased body fatness among children and adolescents (WHO, 1998).

Risk Factors Associated With Obesity in Youth

Obesity in youth represents one of the most frustrating conditions to treat (Barlow and Dietz, 1998). Whether obesity is a risk factor for disease or a disease in its own right is a current topic of debate (Heshka et al., 2001). Interestingly, while childhood obesity has been classified as a disease by U.S. researchers (Bandini and Dietz, 1992), it has not been categorized as such in Canada (Canadian Task Force, 1994). This controversy may be due, in part, to the fact that many obese youngsters do not present with an overt illness and because a larger body size may be more desirable within some populations. As well, childhood obesity has traditionally been perceived as an esthetic issue as opposed to a real health concern (Steen et al., 1996; Young-Hyman et al., 2000). However, extensive evidence suggests that a high level of body fat is associated with numerous psychosocial and physiological risk factors and health consequences (Table 2).

Chronic illnesses such as type 2 diabetes have traditionally been considered adult phenomena, but this perception may be changing. For example, recent reports suggest that type 2 diabetes has become more common among sub-groups of overweight boys and girls (Dean, 1998; Fagot-Campagna et al., 2000; Libman and Arslanian, 1999; Rosenbloom et al., 1999). Although such findings merit concern, most studies linking obesity with adverse health consequences are based on clinical samples of children receiving medical treatment and may not reflect the true prevalence within the population. An especially alarming trend is that risk factors for diseases such as CVD and type 2 diabetes can manifest themselves early in life and tend to emerge in *clusters* among obese children. This clustering of risk factors (i.e., dyslipidemia, hypertension, hyperinsulinemia, and obesity) has been given several names, including Syndrome $\times$ (Reaven, 1988), the Insulin Resistance Syndrome (IRS) (Haffner et al., 1992) and, more recently, the Metabolic Syndrome (Alberti and Zimmet, 1998) and the Metabolic Cardiovascular Syndrome (Tremblay, 1998). It is fairly clear that obesity and a genetic susceptibility combined with a lifestyle characterized by low levels of physical activity and high fat /high energy

Table 2 Risk Factors and Health Consequences Related to Obesity in Youth[1]

Cardiovascular	Dyslipidemia (increased total cholesterol, low-density lipoprotein-cholesterol, and triglycerides), and elevated systolic and diastolic blood pressure
Endocrine	Insulin resistance, abnormal glucose metabolism, and polycystic ovary syndrome
Gastroenterological	Gallstone formation and hepatic steatosis
Lifestyle	Low fitness, low physical activity, low movement competence, high fruit juice/pop intake, high television viewing, and low socioeconomic status
Orthopedic	Accelerated growth, capital epiphysis, and Blount's disease
Psychosocial	Low self-esteem, poor body image, barophobia (fear of fatness), and low socioeconomic status
Pulmonary	Asthma, sleep apnea, and pickwickian syndrome
Persistence into adulthood	The longer obesity is maintained in youth, the greater the likelihood of obesity tracking into later life.

[1]Adapted from Must and Strauss (1999).

diets places susceptible individuals at increased health risk (Beck-Nielsen, 1999; DeFronzo and Ferrannini, 1991).

Multiple Risk Factors for CVD and Type 2 Diabetes in Youth

Numerous researchers have used cross-sectional investigations to determine the presence of risk factor clusters related to chronic diseases in children and adolescents. Among 10–15-year-old black (n = 251) and white (n = 285) boys, Morrison et al. (1999a) found that overweight boys in both racial groups were more likely to possess risk factors for CVD than non-overweight boys. More specifically, boys with a BMI ≥ 85th percentile possessed higher low-density lipoprotein-cholesterol (LDL-C), triglycerides (TG), systolic blood pressure (SBP), diastolic blood pressure (DBP), central adiposity, and lower high-density lipoprotein-cholesterol (HDL-C) values than boys with a BMI < 85th percentile. Overweight boys were also much more likely to have ≥ 2 risk factors than non-overweight boys (whites: 55.3% versus 12.7%; blacks: 41% versus 13.7%). The same research group (Morrison et al., 1999b) made similar observations in a sample of 9–10-year-old black (n = 918) and white (n = 953) girls. Overweight girls (BMI ≥ 85th percentile) scored less favorably than non-overweight girls (BMI < 85th percentile) with regards to serum lipids and blood pressure values. As in boys, overweight girls from both races were more likely to possess at least 2 risk factors for CVD than their non-overweight peers.

In a report from the Bogalusa Heart Study, Freedman et al. (1999) found that the proportion of children who were overweight increased as the number of risk

factors increased. Among 5–17-year-olds, overweight children represented 9% (n = 335) of the 3884 boys and girls with no risk factors, 23% (258/1141) of the children with 1 risk factor, and 74% (82/111) of the children with ≥ 3 risk factors for CVD. In this large sample (n = 9167), overweight subjects were more likely to have high TG and low HDL-C levels, and 90% of children with high levels of insulin and TG were overweight. Overweight 5–10-year-old boys and girls were 9.7 times as likely to have 2 risk factors and 43.5 times as likely to have 3 risk factors than normal weight children. Similar observations were found in a group of Taiwanese schoolchildren (n = 1366) in that multiple risk factors for CVD and type 2 diabetes were much more prevalent in obese boys and girls than in non-obese children (Chu et al., 1998). Approximately 70% of obese boys had at least 1 risk factor, twice the prevalence of non-obese boys. The prevalence of ≥ 2 risk factors was 4–5 times greater in obese compared to non-obese boys and girls.

In a sample of Swedish adolescents (n = 1032) categorized according to BMI quartiles, boys and girls in the highest quartile were more likely than their peers in the lowest quartile to possess a cluster of risk factors (Bergstrom et al., 1996). Specifically, adolescents in the high quartile were more likely to have ≥ 2 risk factors than those in the low quartile (boys: 54% versus 32%; girls: 56% versus 22%). Risk factors also tended to cluster in a sample of obese Hungarian adolescents (Csabi et al., 2000). Obese boys (n = 103) and girls (n = 77) were much more likely to possess hypertension, hyperinsulinemia, hypercholesterolemia, hypertriglyceridemia, and low levels of HDL-C than controls and only 14.4% of obese children were free from any risk factors. Obese children were at ~19 times greater risk of developing 1 risk factor and ~6 times more likely to possess > 1 risk factor. Overall, the metabolic syndrome was present in 8.9% of the obese children while clustering of risk factors was almost non-existent in controls.

The cross-sectional studies linking overweight and obesity with adverse risk factors highlight important relationships between health-related variables. However, longitudinal investigations are necessary for evaluating changes over time. Bao and colleagues (1994) observed that risk factors persisted (tracked) from childhood into young adulthood in a sample (n = 1176) of 5–17-year-olds. Over an 8-year period, a multiple risk index score (derived from the relative rankings of individual SBP, total cholesterol [TC]-to-HDL-C, and insulin levels) was found to track better than individual risk factors alone. Overall, the Spearman correlation coefficient between year 1 and year 8 multiple risk index scores was 0.64 (P = 0.0001) while the individual risk factor correlations were slightly lower (TC-HDL-C, r = 0.57; SBP, r = 0.54; and insulin level, r = 0.34). Webber and colleagues (1991) followed 1,586 children and found approximately 50% of children with TC and LDL-C levels >75th percentile at baseline had elevated levels 12 years later. Following lipid or lipoprotein levels, obesity status was the next best predictor of follow-up lipid levels. These findings are in agreement with earlier research (Gillum et al., 1982). As well, in a group of 2,433 Finnish youth (9–24 years of age), 30%–44% who were in the highest fasting insulin quartile at baseline remained there 6 years later (Ronnemaa et al., 1991). Not unexpectedly, high TG, SBP, and low HDL-C levels clustered among subjects within the highest insulin quartile. Taken together, these data support the concept that children and adolescents who possess risk factors for CVD and type 2 diabetes early in life tend to maintain their health risks over time.

Along with risk factors for CVD and type 2 diabetes, obesity is also known to track from childhood into adulthood (Clarke and Lauer, 1993). Whitaker et al. (1997) calculated that the odds ratio of becoming an obese adult increased with greater degrees of obesity and older age. After adjusting for parental obesity, the odds ratios of developing obesity in adulthood associated with childhood obesity varied from 1.3 (95% confidence interval [CI]: 0.6–3.0) at 1–2 years of age to 17.5 (95% CI: 7.7–39.5) at 15–17 years of age. As well, Guo and Chumlea (1999) showed that children who were above the 95th percentile for BMI were between 1.3–6.1 more likely to be overweight as adults (at 35 years of age) than those who were at the 75th percentile in their youth, suggesting that tracking is more likely at higher degrees of body fatness. Research also suggests that the persistence of obesity from youth to adulthood may be more deleterious from a health perspective than if obesity develops later in life (Vanhala et al., 1998). Prolonged insulin resistance associated with the multiple risk factors of the metabolic syndrome may be mediated through high levels of body fatness that track from youth to adulthood. Because the tracking of both body fatness and risk factors for CVD and type 2 diabetes is evident among overweight boys and girls, the likelihood that youngsters will experience premature weight-related morbidity and mortality later in life is increased (Must et al., 1992).

Upon review, the prevalence of multiple risk factors in overweight children in the aforementioned studies may appear high. However, to put the metabolic syndrome in youth into perspective, definitions of risk factors in children and adolescents and the prevalence of the syndrome in adult populations must be considered. Determining the true prevalence of risk factors for CVD and type 2 diabetes in youth is complicated since abnormal levels have not been clearly defined for all variables. Specific guidelines have been proposed to characterize the metabolic syndrome in adults (Alberti and Zimmet, 1998), but no such recommendations exist for younger populations. Consequently, most researchers have compared boys and girls to population-specific standards. For example, Batey et al. (1997) defined an adverse risk factor when a value for a specific variable was greater than the median value for the study population. Chu et al. (1998) classified children with hypertension, hyperlipidemia, and hyperglycemia if individual values were ≥ 90th age- and sex-specific percentile, while Freedman et al. (1999) used a combination of absolute (for blood lipids) and percentile (for insulin) cut-off levels. Still others have used > 75th percentile as a cut-off point (Bao et al., 1994; Bergstrom et al., 1996; Chen et al., 1999). In adults, the metabolic syndrome has been defined numerous ways, but it appears that the prevalence of the syndrome is low in population-based studies. Prevalence estimates have ranged from 0.7% (Haffner et al., 1992) to 2.9% (Wannamethee et al., 1998) to 3.7% (Eriksson et al., 1992), but is likely greater in "high risk" groups (i.e., overweight/obese, pre-existing CVD or type 2 diabetes).

While it has been hypothesized that hyperinsulinemia plays the dominant pathophysiologic role in Syndrome × (Reaven, 1988), to our knowledge, only one study in young people (5–38 years of age) has supported this concept (Chen et al., 1999). In contrast, several studies of adult populations have failed to support the idea that a single independent process is involved (Donahue et al., 1997; Gray et al., 1998; Meigs et al., 1997). The mechanisms linking obesity to risk factors for CVD and type 2 diabetes in youth have yet to be clearly defined, but despite this

uncertainty, a key putative factor involved in the metabolic syndrome is body fatness and, more specifically, abdominal body fat distribution (Bao et al., 1993; Ferguson et al., 1998; Goran and Gower, 1999; Gower et al., 1999; Jarrett, 1992; Slyper, 1998; Wannamethee et al., 1998).

The Measurement of Body Fat Distribution

Traditionally, anthropometric indicators such as the waist circumference, waist-to-hip ratio and trunk-to-extremity skinfold thickness ratio (i.e., subscapular-to-triceps) have been used to estimate abdominal body fatness in youth (Mueller et al., 1989; Sangi and Mueller, 1991; Weststrate et al., 1989). Convenience and low cost make these choices desirable, however, the correlations between these indirect estimates and more precise, direct measures have been weak and inconsistent (Brambilla et al., 1994; de Ridder et al., 1992; Fox et al., 1993; Goran et al., 1995b). Also, anthropometry cannot be used to determine the relative influence of visceral adipose tissue (VAT) and subcutaneous abdominal adipose tissue (SAAT) on health outcomes. The emergence of imaging techniques such as computed axial tomography (CAT) and magnetic resonance imaging (MRI) in body composition research have allowed for the accurate quantification of and distinction between VAT and SAAT (Baumgartner et al., 1993; Ross et al., 1993). Both CAT and MRI are useful, but their high cost and limited availability prevent widespread application beyond the clinical setting. Because individuals who undergo CAT measurements are exposed to ionizing radiation, MRI is the more popular choice within pediatric populations, especially when repeated measurements are performed over time. Dual-energy X-ray absorptiometry (DXA) has also been useful in assessing regional body fat depots (Daniels et al., 1999). While DXA is unable to distinguish VAT from SAAT, preliminary research suggests that regional scans may be beneficial for estimating total abdominal and visceral fat in obese children and adolescents (Tershkovec et al., 2001). Imaging procedures provide reliable and valid body composition data, and recently, regression equations based on combinations of anthropometric and demographic data have been developed to estimate VAT in children (Goran et al., 1998; Owens et al., 1999). These formulae should be useful for health professionals and researchers working in non-clinical settings or when imaging techniques are unavailable or impractical.

Body Fat Distribution and Risk Factors for CVD and Type 2 Diabetes

Using anthropometric indicators, researchers have observed positive correlations between risk factors for CVD (Zonderland et al., 1990; Zwiauer et al., 1990) and type 2 diabetes (Legido et al., 1989) and central body fat distribution in youngsters. However, newer imaging techniques have led to more precise determinations of body fat depots and their relationship to corresponding health outcomes. Using MRI to assess body fat patterning, Caprio et al. (1996) revealed that VAT was positively correlated with fasting insulin ($r = 0.55$, $p < 0.03$) and TG ($r = 0.53$, $p < .04$) and negatively associated with HDL-C ($r = –.54$, $p < .04$) levels among obese adolescent girls. As well, femoral adipose tissue was negatively related to LDL-C ($r = –.56$, $p < .05$) and TG ($r = –.51$, $p < .05$) suggesting that, as in adults

(Emery et al., 1993), this body fat depot may exert either a neutral or protective effect with respect to health outcomes. Interestingly, VAT was not related to any risk factors for CVD in non-obese girls and the only significant relationship in the non-obese group was between SAAT and fasting insulin levels ($r = 0.69$, $p < .02$). In a biracial group of obese 7–11-year-old boys and girls ($n = 64$), Owens et al. (1998) found VAT to be positively associated with TG, TC/HDL-C ratio, and fasting insulin levels and negatively correlated with HDL-C and LDL-C particle size. SAAT, % total body fatness and total fat mass (TFM) were also related to lipid and lipoprotein risk factors, but only VAT (determined using MRI) explained a significant proportion of the variance in lipid levels. While VAT was most strongly associated with lipid-related risk factors, TFM proved to be the strongest predictor of non-lipid risk factors (i.e., fasting insulin and SBP values). In prepubertal children, Gower et al. (1999) concluded that VAT was positively related to TG and fasting insulin, independent of subcutaneous and total body fat. However, contrary to earlier research in a group of adolescent girls (Caprio et al., 1995), insulin sensitivity was significantly related to TFM and not VAT.

Further investigation into the role of VAT and different body fat depots is warranted, yet the findings to date suggest that different fat depots correspond to different risk factors depending on TFM. The presence of risk factors is likely dependent upon age and physical maturation. Although the interrelationships are complex, data suggest that risk factors in youth vary depending on a number of other factors as well.

ETHNICITY

Comparisons between Caucasian, African-American, and Mexican-American children have revealed some important racial differences. Evidence suggests that African-American children possess lower insulin sensitivity (Ku et al., 2000; Svec et al., 1992) and higher insulin secretion (Arslanian and Suprasongsin, 1996; Ku et al., 2000) than whites, which may partly explain the greater prevalence of type 2 diabetes among African-American adults (Brancati et al., 2000; Robbins et al., 2000) and particularly, adult women (Okosun, 2000). Daniels et al. (1996) observed higher blood pressure values in African-American versus Caucasian girls, a finding likely related to differences in maturation and body size. In a report from the Bogalusa Heart Study (Freedman et al., 1999), overall risk factor clustering was less prevalent among African-Americans than Caucasians, but the odds ratios between overweight and multiple risk factors were similar between groups. In a comparison of 403 Mexican-American (MA) and non-Hispanic white (NHW) third grade children, Batey et al. (1997) observed that clusters of risk factors were exhibited to a greater degree in MA children than in NHW. Overall, more MA children had ≥ 3 risk factors than NHW (55% versus 37%, respectively) and three times as many MA children (15.8%) as NHW children (5.2%) had 5 risk factors. Differences were more pronounced in boys than in girls. MA boys had higher fasting insulin, glucose, SBP, BMI, and lower HDL-C levels than NHW boys, whereas MA girls differed from the NHW peers in fasting insulin and glucose values only.

Trends in body fat distribution and the changes that occur during growth and development have also been reported for some ethnic groups. For example, during

childhood and adolescence, African-American males tend to possess greater trunk-to-extremity (T/E) (e.g., subscapular / triceps skinfold thickness) subcutaneous fat than Caucasian and Mexican-American males while in females, the T/E ratio is similar in African-American and Mexican-American groups, but larger than that for Caucasians (Malina, 1996). Several researchers have observed lower levels of VAT in African-American boys and girls than Caucasians (Gower et al., 1999; Owens et al., 2000; Yanovski et al., 1996). Using anthropometric indicators, Caucasian children have been shown to have less central body fat than Native American (Goran et al., 1995a) and Mexican (Greaves et al., 1989) children, but similar amounts compared to Asian youngsters (Wardle et al., 1996). These data suggest that, along with differences in body fatness, there appears to be an underlying genetic susceptibility in some populations to developing a central body fat distribution and risk factors for CVD, type 2 diabetes, and the accompanying complications (Fagot-Campagna et al., 2000; Hanis et al., 1991; Sievers et al., 1999). For a more detailed description of ethnic variation in body composition throughout the lifecycle, see Malina (1996).

MATURATION AND SEX

As children physically mature during puberty, the hormonal milieu has a profound impact on body fat deposition and distribution. Levels of estrogen, testosterone, and growth hormone rise during this period; concomitantly, body fat tends to shift from peripheral (i.e., arms and legs) to central regions (i.e., truncal) and from subcutaneous to internal sites (i.e., intra-abdominal). As well, sex differences become more marked; boys deposit more muscle tissue during this time while girls accumulate more fat tissue. However, while boys increase their lean body mass (LBM) by 33–35 kg between 10–20 years of age, the increase seen in girls is about half as much (16–18 kg) (Groff et al., 1995). The rapid increase in LBM that occurs during the growth spurt is accompanied by a decrease in body fatness among boys. Although adolescent girls also gain LBM during the adolescent growth spurt, a greater percentage of weight gain is the result of fat accretion. Data from Canada's Fitness Survey (1984) revealed a sexual dismorphism in body fatness with greater skinfold thicknesses (biceps, triceps, subscapular, suprailiac, and medial calf) becoming more marked in girls after 12 years of age.

Collectively, these data suggest that VAT is linked to some risk factors for CVD and type 2 diabetes, but other fat depots (i.e., SAAT and TFM) also play important roles. As well, ethnicity, physical maturation, and sex all have independent roles in the etiology of multiple risk factors for CVD and type 2 diabetes.

Summary and Recommendations for Future Research

Obesity in youth has emerged as an epidemic that will have profound public health consequences as boys and girls with high levels of body fat become overweight and obese adults. Corresponding health risks such as dyslipidemia, hypertension, impaired glucose tolerance, and decreased insulin sensitivity, not to mention the potential adverse psychosocial costs, have been well documented. Some risk factors for CVD and type 2 diabetes appear to be influenced by total body fat, while

others are related to specific fat depots, but our knowledge of this is somewhat limited by availability of precise measurement techniques. Factors such as ethnicity, maturation, and sex also play roles in the development of obesity-related health risks. In view of the increasing prevalence of childhood obesity and its impact on health and well-being, it is of paramount importance to take action to address this growing problem. Obesity has developed into a key health priority and the following broad themes of research should be expanded upon to further our knowledge of this health issue among Canadian youth.

SURVEILLANCE

A national surveillance system is required to monitor trends in growth, maturation, and risk factors for type 2 diabetes and CVD, given that much of the data on anthropometric growth patterns and risk factors are derived from other countries that possess different ethnic, cultural, seasonal, geographic, and behavioural characteristics. A system that tracks actual measurements of height, weight, and other key anthropometric parameters over time would be ideal. As previously discussed, regional surveys, small sample sizes, and the exclusion of many ethnic groups precludes a truly comprehensive and accurate assessment of obesity in Canadian youth.

TREATMENT

Available data suggest that the behavioural treatment of obesity in youth can be successful (Epstein et al., 1990), however, the majority of this evidence is derived from one US-based research group (Epstein et al., 2001). Further, the sample populations in these studies have predominantly been comprised of middle- to upper-middle class Caucasian families. An important and timely research priority in Canada, considering the multi-cultural population should include exploring, designing, and providing appropriate interventions for obese children and families from diverse ethnic and socioeconomic backgrounds. In particular, comprehensive trials that include a multi-disciplinary team of health professionals and incorporate a variety of treatment modalities that target lifestyle behaviours such as diet, physical activity, and physical inactivity are required. In particular, an emphasis should be placed on critically evaluating interventions (in both community and clinical settings) for those children who may be at greatest risk (and, in turn, possess the greatest theoretical opportunity to benefit) due to the degree of obesity, presence of risk factors, and a positive family history of CVD or type 2 diabetes.

PREVENTION

Specific, targeted approaches may be useful for overweight youth from families who seek out treatment, however, to have a substantial impact on the increasing problem of obesity in Canada, a more comprehensive perspective is necessary. The coordinated efforts of policy makers, health professionals, researchers, community leaders, school administrators, teachers, and parents are necessary. Emerging evidence from adults suggests that diseases such as type 2 diabetes can be prevented through lifestyle strategies that influence weight-related behaviours such as diet and physical activity (Knowler et al., 2002). It is vital that preventive

strategies for all children are developed and implemented through schools, community-based initiatives (Andersen, 2000; Cole, 1997; Hill and Trowbridge, 1998), and in families, as a means of reducing the prevalence of adult obesity in Canada and its related diseases in the future (Limbert et al., 1994). Ultimately, obesity prevention will require a multi-level approach to produce an environment that supports healthy eating and physical activity habits through a broad and integrated range of strategies.

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