Predictors of Metabolically Healthy Obesity in Children

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OBJECTIVE

To determine the prevalence of metabolically healthy obesity (MHO) in children and examine the demographic, adiposity, and lifestyle predictors of MHO status.

RESEARCH DESIGN AND METHODS

This cross-sectional study included 8–17 year olds with a BMI ≥85th percentile who were enrolled in a multidisciplinary pediatric weight management clinic from 2005–2010. Demographic, anthropometric, lifestyle, and cardiometabolic data were retrieved by retrospective medical record review. Participants were dichotomized as either MHO or metabolically unhealthy obese (MUO) according to two separate classification systems based on: *1*) insulin resistance (IR) and *2*) cardiometabolic risk (CR) factors (blood pressure, serum lipids, and glucose). Multivariable logistic regression was used to determine predictors of MHO using odds ratios (ORs) with 95% CIs.

RESULTS

The prevalence of MHO-IR was 31.5% (*n* = 57 of 181) and MHO-CR was 21.5% (*n* = 39 of 181). Waist circumference (OR 0.33 [95% CI 0.18–0.59]; *P* = 0.0002) and dietary fat intake (OR 0.56 [95% CI 0.31–0.95]; *P* = 0.04) were independent predictors of MHO-IR; moderate-to-vigorous physical activity (OR 1.80 [95% CI 1.24–2.62]; *P* = 0.002) was the strongest independent predictor of MHO-CR.

CONCLUSIONS

Up to one in three children with obesity can be classified as MHO. Depending on the definition, adiposity and lifestyle behaviors both play important roles in predicting MHO status. These findings can inform for whom health services for managing pediatric obesity should be prioritized, especially in circumstances when boys and girls present with CR factors.

In Canada, numerous multidisciplinary clinics offer weight management care for children with obesity (1), most of which are affiliated with children's hospitals. The supply of these services is exceeded by the potential demand since there are >2 million young Canadians (2,3) who are either overweight or obese and eligible to receive health services in these clinics. Because of the demand for weight management care, in circumstances when services are limited or difficult to access, there is a need to prioritize service delivery in these specialized centers for those individuals who are at greatest cardiometabolic health risk. By distinguishing individuals with obesity based on their relative health risks, those at *lower* health risk can be guided to less intensive services (e.g., self-management resources or outpatient dietitian counseling), whereas their peers at *higher* health risk can be directed to more intensive services (e.g., multidisciplinary obesity management or bariatric surgery). The heterogeneous

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nature of pediatric obesity suggests that a menu of therapeutic options for children (and their families) is best suited to meet their individual needs, an approach that is consistent with managing obesity as a chronic illness (4).

In adults, some men and women satisfy the criterion for having obesity (BMI $\geq$30 kg/m^2), but do not possess any of the traditional cardiometabolic risk (CR) factors that often accompany a high level of body fat (e.g., insulin resistance [IR], dyslipidemia, and hypertension). A number of reports have demonstrated that these metabolically healthy obese (MHO) adults may comprise 6–40% of all individuals with obesity (5–8). Similarly, children with obesity can vary substantially with respect to their health profile (9), but MHO in the pediatric years has not been well-characterized. With this in mind, the purpose of the current study was to *1*) determine the proportions of children with obesity classified as MHO and *2*) examine demographic, anthropometric, and lifestyle predictors of MHO. Such clinical observations are important from a health services perspective because they can help to inform the allocation of clinical resources for obesity management (10).

RESEARCH DESIGN AND METHODS

This cross-sectional study included 181 boys and girls aged 8–17 years with *1*) an age- and sex-specific BMI $\geq$85th percentile (11) and *2*) complete demographic, anthropometric, cardiometabolic, and lifestyle data. Between January 2005 and December 2010, all participants were referred by physicians to the Pediatric Centre for Weight and Health (PCWH) at the Stollery Children's Hospital (Alberta Health Services, Edmonton, AB, Canada). Data were collected prior to initiating weight management and retrieved retrospectively via medical record review, which included a systematic data management protocol consistent with medical record data extraction methodology (12,13). Ethics approval was provided by the Health Research Ethics Board (University of Alberta) and administrative site approval by Alberta Health Services.

Demography, Anthropometry, and Body Composition

Demographic data were collected using a standardized questionnaire that was completed by parents. Participant height was measured to the nearest 0.1 cm using a digital stadiometer (SECA 242; Seca, Hanover, MD), and weight was measured to the nearest 0.1 kg using a medical digital balance scale (SECA 644; Seca). Height and weight were entered into EpiInfo v3.5.1 (Centers for Disease Control and Prevention, Atlanta, GA) to calculate BMI, BMI percentile, and BMI z-score. Waist circumference was measured to the nearest 0.1 cm at the iliac crest using a spring-loaded Gulick anthropometric tape (FitSystems, Calgary, AB, Canada).

Cardiometabolic Measurements

Participants provided a fasting blood sample to determine plasma glucose and insulin, triglycerides (TGs), and HDL cholesterol (HDL-C). Plasma glucose was analyzed with a Beckman LX20 analyzer (Beckman Coulter); all other variables were measured using electrochemiluminescence (Elecsys 2010; Roche, Basel, Switzerland) at the University of Alberta Hospital Laboratory (Edmonton, AB, Canada). IR was calculated according to the homeostatic model assessment of IR (HOMA-IR) using the following formula: fasting insulin (mU/L) $\times$ fasting glucose (mmol/L)/22.5 (14). While subjects were seated and after a 5-min rest, systolic and diastolic blood pressures (SBP and DBP, respectively) were measured manually according to established guidelines (15) with a sphygmomanometer and an appropriately sized arm cuff. A second measure was taken 5 min later; when a difference $\geq$10 mmHg in SBP was observed, the lower of the two values was included.

Dietary and Physical Activity Assessments

Dietary intake was measured prospectively using food records, which varied from 4–7 days in duration and included at least 1 weekend day. The PCWH dietitian instructed all participants and their parents on the correct completion of records using food models, measuring cups and spoons, and sample (completed) food records. Records were completed jointly by participants and parents, which were subsequently returned and reviewed jointly by the dietitian and family to reduce the likelihood of food and beverage omissions and confirm serving sizes and brand names. Data were entered into the Food Processor Diet Analysis Software SQL program (version 10.7.0; ESHA Research, Salem, OR), and average daily intakes were determined. Along with manually tabulating servings per day of sugar-sweetened beverages, the dietitian manually calculated servings per day of vegetables and fruit, milk products, meat and alternatives, and grain products according to *Eating Healthy with Canada's Food Guide* (16).

Pedometers (New Lifestyles Digi Walker SW 200; New Lifestyles, Lee's Summit, MO) were used to quantify total physical activity (PA) (steps/day) over a 4–7-day period with at least 1 weekend day. Participants maintained a log book so that duration of wear and number of steps could be recorded daily. Over the same period, a self-report PA record was kept to document the amount of time participants spent engaged in moderate-to-vigorous PA [MVPA (17)], which represents higher intensity activities and sports (e.g., running, basketball, soccer). As a proxy measure of sedentary activity, time spent viewing screens (e.g., television, video games, and computer games) during leisure time periods was also collected. Upon completion, the PCWH exercise specialist reviewed all records with families to confirm responses and clarify ambiguous information. Families were encouraged to maintain children's usual diet and PA habits at this point to provide a representative view of current lifestyle habits that clinicians could use to inform obesity management recommendations and possible strategies for making improvements.

Definitions of Metabolic Risk

We applied two independent classification systems to examine the presence and predictors of MHO. The first system used a more research relevant definition, wherein children were dichotomized according to the presence/absence of IR, a well-established predictor of type 2 diabetes (18), but an indicator that is seldom calculated and used in clinical practice. IR was determined based on HOMA-IR (14), by which participants with a HOMA-IR score $<$3.16 were deemed MHO and those with a score $\geq$3.16 were categorized in the metabolically unhealthy obese (MUO) group. The second system was a more clinically relevant model, in which participants were dichotomized based on

the presence/absence of the following four traditional CR factors (MHO: 0 risk factors; MUO: ≥1 risk factor): SBP or DBP ≥90th percentile for age, sex, and height (19); TG ≥1.25 mmol/L (20,21); HDL-C ≤1.02 mmol/L (8,20,21); and glucose ≥5.6 mmol/L.

Statistical Analysis

Means, SDs, and ranges were calculated for all continuous variables. Identical analyses were performed for both IR and CR classification systems. Independent samples *t* tests were used to compare continuous variables between groups. Multivariable logistic regression was used to examine the association between each of the variables and metabolic health status with adjustment for age and sex. Because there were no sex interactions, all analyses were conducted collapsed across sex. Subsequently, each of the strongest independent predictors of MHO within three main categories of variables: *1*) adiposity (weight, BMI, BMI percentile, BMI z-score, and waist circumference); *2*) diet (grain products, meat and alternatives, milk products, and vegetables and fruit, total energy intake, macronutrient intakes, and dietary fiber); and *3*) PA-related (moderate PA, hard PA, very hard PA, total MVPA, steps per day, computer viewing, TV viewing, video game playing, and total leisure time screen time) were entered into a logistic regression model with adjustment for age and sex. To facilitate comparisons between variables, odds ratios (ORs) were expressed per SD units. All analyses were adjusted for sex and age, except when BMI z-score was included in the models since this variable already adjusts for interindividual differences in sex and age. In addition, all analyses were completed with and without including individuals with a BMI between the 85th and 95th percentiles (overweight). Since our analyses yielded similar results, all children with a BMI ≥85th were included in the final analyses. Statistical analyses were performed using SAS software version 9.3 (SAS Institute Inc., Cary, NC) with statistical significance set at $P < 0.05$.

RESULTS

As shown in Table 1, 57 of 181 (31.5%; MHO-IR group) and 39 of 181 (21.5%; MHO-CR group) participants were categorized as MHO. Our group classifications revealed that 21 of 181 (11.6%) participants were classified as being both MHO-CR and MHO-IR, while 106 of 181 (85.5%) were categorized as MUO by both definitions. Across both IR and CR categories, the MHO group tended to be younger, shorter, lighter, and less overweight than their MUO peers (Table 1). Participants in this study were predominantly Caucasian (~80%), were from mid- to upper-middle class households, and had a BMI ≥95th percentile (166 of 181; 92%). Consistent with our study design, metabolic risk factors were in the less healthy direction in the MUO group. We also observed lower total energy and fat intakes, higher PA, and less screen time in MHO compared with MUO groups. The predictors of MHO status, after adjusting for age and sex, are shown in Table 2.

Using the IR classification system, waist circumference (OR 0.92 [95% CI 0.89–0.96]; $P < 0.0001$) was the strongest independent adiposity marker of MHO status. Of the dietary and PA variables, total fat intake (g/day) (OR 0.98 [95% CI 0.97–0.99]; $P = 0.001$) and moderate PA (10 min/day: OR 1.11 [95% CI 1.01–1.23]; $P = 0.04$) were the strongest independent predictors of MHO status after adjusting for sex and age. Using the CR classification system, BMI z-score (OR 0.29 [95% CI 0.11–0.74]; $P = 0.01$), total energy intake (OR [per 100 kcal/day] 0.93 [95% CI 0.88–0.99]; $P = 0.01$), and total MVPA (OR 1.16 [95% CI 1.08–1.26]; $P = 0.0001$) were the most strongly related adiposity, dietary, and PA variables, respectively, after adjusting for sex and age.

As a final step, the strongest adiposity-, diet-, and PA-related variables (adjusting for sex and age) from the aforementioned domain-specific stepwise logistic regression models were entered into final models. Waist circumference and dietary fat intake, but not moderate PA, remained significant independent predictors of MHO-IR status (Table 3). For every SD increase in waist circumference (17.0 cm), there was a 67% reduction in the odds of being in the MHO group, and for every SD increase in dietary fat intake (38.5 g/day), there was a 44% decrease in the odds of being in the MHO group. Total MVPA, but not BMI or total energy intake, was the only significant independent predictor of MHO-CR status. For every SD increase in total MVPA (47 min/day), there was an 80% increase in the odds of being in the MHO group.

CONCLUSIONS

This study was designed to determine the proportions of children with obesity classified as MHO as well as examine demographic, anthropometric, and lifestyle predictors of MHO. Several important findings emerged from our analyses. First, about one in five to one in three children with obesity were at relatively low CR despite possessing a high level of body fat. Second, several different adiposity-, diet-, and PA-related variables independently predicted MHO status. Finally, the predictors of MHO status varied depending on which classification system was used to assign individuals to the MHO and MUO groups.

Obesity is a heterogeneous condition, an observation that has been highlighted by characterizing MHO in adults. Two large clinical studies (7,8) were among the first to describe a subset of adults with obesity that was at relatively low metabolic health risk despite possessing a high amount of body fat. Subsequent reports have shown that up to 40% of adults with obesity may be classified as MHO. Using nationally representative data collected in the U.S. National Health and Nutrition Examination Survey (1998–2004) (22), approximately one-half of overweight and one-third of obese adults were classified as metabolically healthy, prevalence levels that represent ~36 million and 19.5 million U.S. adults, respectively. In pediatrics, the documented prevalence of MHO has also varied considerably with proportions ranging from 6–36% (23–26), a range that encompasses the proportions found in the current study. The diversity of risk factors and thresholds applied to dichotomize cardiometabolic health risk may contribute to the interstudy variability in the prevalence of MHO. Independent of the issues associated with defining MHO, young people with obesity present clinically with varying severity of cardiometabolic health consequences. It is important to acknowledge that at the time of this study, the MHO individuals were healthier than their MUO peers according to traditional measures of cardiometabolic health risk, but it is unknown whether this distinction would remain stable over time or can be

Table 1—Comparison of demography, anthropometry, CR, and lifestyle factors between participants classified as MHO or MUO according to high/low levels of IR and CR

	IR categorization			CR categorization		
	MHO (n = 57)	MUO (n = 124)	P value	MHO (n = 39)	MUO (n = 142)	P value
Demography/anthropometry						
Age (years)	12.1 ± 3.0	13.2 ± 2.6	0.01	12.1 ± 2.7	13.1 ± 2.7	0.06
Height (cm)	152.1 ± 14.3	160.4 ± 12.5	0.0001	153.4 ± 14.8	159.0 ± 13.0	0.02
Weight (kg)	68.2 ± 22.3	88.9 ± 26.8	<0.0001	71.5 ± 25.3	85.4 ± 26.9	0.004
BMI (kg/m^2)	28.8 ± 4.7	33.9 ± 6.8	0.003	29.5 ± 5.4	33.0 ± 6.8	0.004
BMI percentile	97.3 ± 2.8	98.4 ± 2.1	0.005	97.5 ± 2.7	98.2 ± 2.3	0.1
BMI z-score	2.0 ± 0.4	2.3 ± 0.4	<0.0001	2.1 ± 0.4	2.3 ± 0.4	0.02
Waist circumference (cm)	95.3 ± 13.3	109.7 ± 16.6	<0.0001	98.4 ± 15.6	107.0 ± 16.9	0.005
Cardiometabolic risk						
SBP (mmHg)	104 ± 9	112 ± 11	<0.0001	105 ± 8	111 ± 11	0.0003
DBP (mmHg)	66 ± 8	71 ± 9	0.001	68 ± 7	70 ± 9	0.2
Total cholesterol (mmol/L)	4.5 ± 1.1	4.4 ± 0.8	0.8	4.4 ± 0.9	4.5 ± 0.9	0.6
Total cholesterol/HDL-C ratio	4.3 ± 1.3	4.6 ± 1.1	0.1	3.5 ± 0.7	4.8 ± 1.1	<0.0001
HDL-C (mmol/L)	1.1 ± 0.2	1.0 ± 0.2	0.09	1.3 ± 0.2	1.0 ± 0.2	<0.0001
LDL cholesterol (mmol/L)	2.9 ± 1.0	2.7 ± 0.7	0.3	2.7 ± 0.8	2.8 ± 0.8	0.7
TG (mmol/L)	1.2 ± 0.6	1.6 ± 0.7	0.001	0.9 ± 0.2	1.7 ± 0.7	<0.0001
Insulin (mU/L)	10.0 ± 3.4	29.9 ± 15.7	<0.0001	15.5 ± 9.0	25.8 ± 16.9	<0.0001
Glucose (mmol/L)	4.7 ± 0.4	5.0 ± 0.4	0.0001	4.9 ± 0.3	4.9 ± 0.4	0.5
HOMA-IR	2.1 ± 0.7	6.6 ± 3.8	<0.0001	3.4 ± 2.0	5.7 ± 4.0	<0.0001
Diet						
Grain products (servings/day)	7.5 ± 2.4	8.8 ± 3.7	0.007	7.6 ± 2.3	8.6 ± 3.6	0.03
Meat and alternatives (servings/day)	1.9 ± 0.8	2.4 ± 1.3	0.002	2.1 ± 0.8	2.3 ± 1.3	0.1
Milk products (servings/day)	2.0 ± 1.0	2.2 ± 1.3	0.3	1.9 ± 1.1	2.1 ± 1.2	0.2
Vegetables and fruit (servings/day)	3.8 ± 1.8	3.6 ± 2.1	0.6	3.7 ± 1.8	3.6 ± 2.0	0.9
Energy intake (kcal/day)	1,851 ± 502	2,272 ± 797	<0.0001	1,854 ± 485	2,218 ± 781	0.0005
Fat intake (g/day)	64.5 ± 28.2	85.5 ± 40.7	<0.0001	65.2 ± 22.9	82.0 ± 41.0	0.001
Fat intake (%)	30.0 ± 7.4	33.1 ± 6.1	0.002	31.1 ± 5.3	32.5 ± 7.0	0.3
Carbohydrate intake (g/day)	247.0 ± 65.9	292.9 ± 102.1	0.0004	250.3 ± 65.1	286.1 ± 99.8	0.009
Carbohydrate intake (%)	54.0 ± 8.3	52.2 ± 7.7	0.1	54.4 ± 6.1	52.3 ± 8.3	0.08
Protein intake (g/day)	75.3 ± 28.7	91.2 ± 43.8	0.004	73.9 ± 20.4	89.5 ± 43.7	0.002
Protein intake (%)	16.5 ± 5.7	16.1 ± 5.0	0.6	16.2 ± 2.9	16.3 ± 5.7	0.9
Fiber intake (g/day)	16.9 ± 5.7	17.1 ± 6.8	0.8	16.6 ± 5.6	17.2 ± 6.7	0.7
PA						
PA (steps/day)	8,651 ± 3,092	7,358 ± 2,918	0.007	8,218 ± 3,356	7,641 ± 2,929	0.3
Moderate PA (min/day)	45.1 ± 38.0	29.3 ± 30.0	0.007	52.0 ± 45.6	29.4 ± 27.5	0.005
Hard PA (min/day)	21.7 ± 20.2	16.6 ± 22.6	0.2	27.3 ± 24.3	15.7 ± 20.6	0.003
Very hard PA (min/day)	5.1 ± 12.9	5.0 ± 12.0	0.9	7.7 ± 15.1	4.3 ± 11.3	0.2
MVPA (min/day)	71.8 ± 51.9	51.0 ± 43.3	0.006	87.0 ± 58.7	49.5 ± 39.8	0.0005
Computer time (min/day)	36.5 ± 64.6	43.1 ± 58.8	0.5	25.9 ± 47.2	45.1 ± 63.3	0.04
Television time (min/day)	95.8 ± 69.8	121.0 ± 99.2	0.05	98.3 ± 78.0	117.1 ± 94.7	0.3
Video game time (min/day)	22.9 ± 43.6	30.5 ± 65.6	0.4	35.6 ± 67.9	26.1 ± 57.2	0.4
Total screen time (min/day)	155.2 ± 114.3	194.6 ± 130.5	0.05	159.8 ± 114.5	188.3 ± 129.5	0.2

extended to other domains of health (e.g., musculoskeletal, psychosocial) or if the inclusion of other markers of cardiometabolic health (e.g., apolipoprotein B48) would change the proportions reported in this study.

Currently, there is no universal definition of MHO. High total body fat and HDL-C levels plus low visceral fat, ectopic fat, IR, inflammation, and TG levels are common features of MHO in adults (27), but there has been less study of MHO in pediatrics. In adults, MHO is most often defined using IR; we chose to include a more clinically relevant definition as well. Using both definitions of MHO makes our results meaningful to clinicians and researchers alike. Further, including two definitions of MHO was instructive in several ways, as it does not appear that MHO-IR is analogous to MHO-CR. In fact, only 54% of our MHO-CR sample was also MHO-IR. As such, it may be expected that there were also differences in how MHO-CR and MHO-IR related to obesity and lifestyle predictors. First, even in our relatively homogeneous sample, waist circumference was a predictor of IR. This reinforces the importance of weight management, or at a minimum, prevention of further weight gain. Dietary fat intake (albeit to a lesser degree) was also a predictor of MHO when it was defined according to the degree of IR. Weigensberg et al. (28) found that children who consumed a high level of dietary fat had higher levels of IR and acute insulin response to glucose compared with their peers who consumed less fat, but this was exclusive to African Americans (not Caucasians). Our findings, which included mostly Caucasian children, do not allow us to speculate on the amount of dietary fat that may lead to increased IR; however, at least in our sample, the impact of dietary fat on MHO was modest in comparison with

Table 2—Associations between individual adiposity-, diet-, and PA-related variables and MHO status according to high/low levels of IR and CR

	IR categorization			CR categorization		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Adiposity						
Weight (kg)	0.95	0.93–0.97	<0.0001	0.97	0.95–1.00	0.02
BMI (kg/m^2)	0.84	0.78–0.92	<0.0001	0.91	0.84–0.99	0.02
BMI percentile	0.82	0.70–0.95	0.009	0.89	0.77–1.02	0.09
BMI z-score	0.16	0.06–0.41	0.0001	0.29	0.11–0.74	0.01
Waist circumference (cm)	0.92	0.89–0.96	<0.0001	0.97	0.94–1.00	0.02
Diet						
Grain products (servings/day)	0.90	0.80–1.01	0.06	0.89	0.78–1.02	0.09
Meat and alternatives (servings/day)	0.70	0.50–0.98	0.04	0.81	0.57–1.16	0.3
Milk products (servings/day)	0.88	0.67–1.16	0.4	0.82	0.59–1.15	0.3
Vegetables and fruit (servings/day)	1.05	0.89–1.23	0.6	1.02	0.85–1.22	0.9
Energy intake (kcal/day)	0.91	0.86–0.97	0.002	0.91	0.85–0.98	0.007
Fat intake (g/day)	0.98	0.97–0.99	0.001	0.98	0.97–1.00	0.02
Fat intake (%)	0.92	0.87–0.98	0.008	0.97	0.92–1.03	0.3
Carbohydrate intake (g/day)	0.99	0.99–1.00	0.008	1.00	0.99–1.00	0.05
Carbohydrate intake (%)	1.03	0.99–1.08	0.2	1.05	0.99–1.10	0.1
Protein intake (g/day)	0.99	0.98–1.00	0.05	0.98	0.97–1.00	0.03
Protein intake (%)	1.02	0.96–1.08	0.6	0.99	0.92–1.06	0.7
Fiber intake (g/day)	1.00	0.95–1.06	0.9	0.99	0.94–1.06	0.9
PA						
Total PA (100 steps/day)	1.01	1.00–1.03	0.01	1.01	0.99–1.02	0.4
Moderate PA (10 min/day)	1.14	1.03–1.25	0.01	1.22	1.10–1.36	0.0003
Hard PA (10 min/day)	1.09	0.94–1.26	0.3	1.20	1.03–1.40	0.02
Very hard PA (10 min/day)	0.98	0.75–1.28	0.9	1.13	0.87–1.47	0.4
MVPA (10 min/day)	1.08	1.01–1.16	0.02	1.16	1.08–1.26	0.0001
Computer time (10 min/day)	1.00	0.94–1.06	0.9	0.93	0.86–1.02	0.1
Television time (10 min/day)	0.97	0.93–1.01	0.1	0.98	0.93–1.02	0.3
Video game time (10 min/day)	0.99	0.93–1.05	0.7	1.02	0.96–1.08	0.5
Total screen time (10 min/day)	0.98	0.95–1.01	0.2	0.98	0.95–1.01	0.2

All ORs are expressed in SD units and were adjusted for both age and sex.

the role of central body fatness. Second, when we defined MHO according to CR categories using blood pressure, lipids, and glucose data, MVPA emerged as an important predictor, and anthropometric and dietary variables were no longer significantly related to MHO-CR independent of MVPA. Our data demonstrate that being moderately-to-vigorously active may have a clinically meaningful impact on the cardiometabolic health status of children with obesity. This finding is particularly important given how difficult it is for children with obesity to lose and maintain weight loss over time (29) and that regular PA (30,31), and more intense PA in particular (32), may have a positive effect on the cardiometabolic health of boys and girls. From a practical standpoint, those individuals classified as having higher cardiometabolic health risk could be prioritized for care sooner or identified to receive more aggressive therapies than their lower-risk peers; for instance, MHO children may benefit from interventions that help them to maintain their current weight, whereas their MUO peers may benefit from more intensive health services to promote weight loss.

Table 3—Independent associations between adiposity-, diet-, and PA-related variables and MHO status according to high/low levels of IR and CR

	ORs	95% CI	*P* value
IR categorization			
Age (years)	1.29	0.83–2.02	0.26
Sex (boy = 0; girl = 1)	0.97	0.67–1.40	0.85
Waist circumference (cm)	0.33	0.18–0.59	0.0002
Fat intake (g/day)	0.56	0.31–0.95	0.04
Moderate PA (min/day)	1.27	0.90–1.82	0.17
CR categorization			
Age (years)	0.83	0.84–1.26	0.4
Sex (boy = 0; girl = 1)	0.68	0.45–1.02	0.06
BMI z-score	0.75	0.50–1.12	0.2
Energy intake (kcal/day)	0.66	0.39–1.14	0.1
MVPA (min/day)	1.80	1.24–2.62	0.002

ORs are expressed per SD units to facilitate the comparison of ORs between variables.

The heterogeneity of obesity has led to the development of health risk classification systems to prioritize health services for individuals at greatest obesity-related health risk. For instance, the Edmonton Obesity Staging System (EOSS) was proposed as a five-level clinical and functional staging system to describe the morbidity and functional limitations associated with obesity (33). EOSS stage 0 or 1 (similar to MHO

status) indicates no or minor obesity-related conditions, while stages 2 and 3 indicate some degree of obesity-related illness. Using data ($n \sim$30,000) from the Aerobics Center Longitudinal Study, adults categorized as EOSS 0 or 1 were not at increased risk of all-cause and at lower risk for cardiovascular mortality compared with healthy weight individuals (34). In a related study that included National Health and Nutrition Examination Survey data from 1988–1994 and 1999–2004, EOSS scores of 2 and 3 were associated with increased mortality versus scores of 0 or 1, and these relationships remained significant even after controlling for adiposity and CR (35). According to EOSS, patients in stages 0 and 1 should be monitored and encouraged to prevent further weight gain, and only EOSS stages 2 and 3 should be prescribed weight loss. Thus, not all individuals with obesity should be treated similarly based on their body weight alone. Preliminary research has been completed to develop and validate a pediatric version of EOSS that can help to prioritize pediatric weight-management care (36)

Despite its strengths, there are limitations to this study. First, in the absence of a universal definition of MHO, the CR factors we selected were based on convenience since they were routinely assessed in our clinic. Likewise, the lifestyle predictors we included were derived from the assessments completed by our dietitians and fitness professionals. Other studies may report different proportions with and predictors of MHO depending on definitions and predictor variables. Our intention was not to argue for or against specific MHO definitions, although our findings revealed that variability existed in the proportions of and predictors of MHO when different definitions were applied. Second, the ethnic homogeneity of our sample prevented us from examining whether MHO varied across ethnicities. This is an important question to address since CR is known to vary by ethnicity (37,38). Third, our analyses included only those individuals who were referred by physicians and completed a comprehensive health evaluation prior to initiating weight management, so our results should not be generalized to children who declined treatment following a referral or who did not provide the full complement of anthropometric, cardiometabolic, and lifestyle data. Fourth, data regarding sexual maturation were unavailable to us because this information was not collected routinely in our clinic. This prevented us from exploring the potential role of puberty within this study. However, puberty and age are highly correlated with one another, and, as others have reported (39,40), age can represent a reasonable proxy measure of maturity. Finally, given the cross-sectional study design, we are unable to report on the time- and/or intervention-dependent changes that may influence MHO and MUO groups, although follow-up longitudinal analyses are planned to examine this issue.

The high prevalence of pediatric obesity highlights the importance of delivering health services for obesity management in a manner that is both efficient and effective. Our study offers important insights into MHO in children that can inform how such services are delivered. At a minimum, these data can be used to inform clinicians about the heterogeneity of pediatric obesity. Clinicians can play a valuable role in completing a comprehensive medical and cardiometabolic health assessment to determine the presence/absence of MHO, which may be used to guide clinical decision-making regarding treatment urgency and intensity when cardiometabolic health risks are present.

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