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Clinical Research

Longitudinal Evaluation of the Prevalence of Overweight/Obesity in Children With Congenital Heart Disease

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See editorial by St-Pierre and Poirier, pages 109-111 of this issue.

ABSTRACT

Background: Regarding long-term cardiovascular health, obesity may have greater implications for children with congenital heart disease (CHD). We sought to determine trends in anthropometry over time and its association with exercise capacity.

Methods: Medical records of pediatric patients with CHD were randomly sampled. Serial measurements of weight and height were abstracted, body mass index (BMI) was calculated, and measurements were converted to percentiles and *z* scores. Analyses of trends were performed using regression models adjusted for repeated measures.

Results: Median follow-up after diagnosis for 725 patients was 7.1 years (interquartile range, 1.9-12.8 years). The median initial weight *z* score was −1.1 (fifth/95th percentile, −3.6/+1.1) and increased over time (+0.103 [0.007] standard deviations [SD]/y; $P < 0.001$). BMI and height *z* scores could only be calculated for patients > 2 years old; at that age, the median BMI *z* score was −0.2 (fifth/95th

RÉSUMÉ

Introduction : Quant à la santé cardiovasculaire à long terme, l'obésité peut avoir des conséquences plus importantes chez les enfants souffrant d'une cardiopathie congénitale (CC). Nous avons cherché à déterminer les tendances temporelles en matière d'anthropométrie et leur association avec l'aptitude à l'effort.

Méthodes : Les dossiers médicaux des patients pédiatriques souffrant de CC ont été sélectionnés de manière aléatoire. Les mesures sérielles du poids et de la taille ont été extraites, l'indice de masse corporelle (IMC) a été calculé, et les mesures ont été converties en percentiles et en écarts réduits. Les analyses sur les tendances ont été réalisées à l'aide des modèles de régression ajustés par mesures répétées.

Résultats : Le suivi médian après le diagnostic de 725 patients était de 7,1 ans (intervalle interquartile, 1,9-12,8 ans). L'écart réduit du poids médian initial était de −1,1 (cinquième/95e percentile, −3,6/+1,1) et augmentait avec le temps (+0,103 [0,007] les écarts types

The prevalence of obesity in children has doubled, for adolescents it has increased 3-fold over the past 20 years,[1] and it continues to increase according to the recent data from the Bogalusa Heart Study.[2]

Historically, patients with congenital heart disease (CHD) were thought to be at risk of poor growth related to feeding difficulties, poor nutritional intake, congestive heart failure, and increased energy expenditure.[3-6] Early surgical interventions may help to normalize their growth pattern, but sometimes parents and health care providers continue to promote high caloric intake and restrict exercise.[4] The high caloric intake and restrictions in their physical activity may increase the risk of becoming obese, which can be associated with an increased risk of cardiovascular disease and early mortality in adulthood.[7-10]

To date, there are no longitudinal data regarding trends over time in obesity and overweight for patients with CHD. Therefore, we performed a retrospective longitudinal study that aimed to characterize the anthropomorphic growth in children with CHD, to estimate the prevalence over time of overweight/obesity, and to determine associated factors.

Methods

Study participants

Patients managed at The Hospital for Sick Children, Toronto, Ontario between 1995 and 2005 were reviewed. Patients were eligible for the study if they had 1 of the following 6 diagnoses: isolated atrial septal defect (ASD), ventricular septal defect (VSD), atrioventricular septal defect (AVSD), tetralogy of Fallot (TOF)/double-outlet right ventricle (DORV), transposition of the great arteries (TGA), or single-ventricle anatomy amenable to a Fontan procedure. Patients were identified from the cardiac surgery and cardiology databases. A random sampling strategy was used to select a representative subset of the eligible patient population

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percentile, −2.6/+1.9) and increased over time (+0.042 [0.007] SD/y; $P < 0.001$), whereas the median height *z* score was −0.3 (fifth/95th percentile, −2.7/+1.4) with no change over time (−0.007 [0.006] SD/y; $P = 0.18$). Using standard BMI percentile cut points to define overweight and obesity, 28% of patients had at least 1 BMI measurement indicating overweight and 17% indicating obesity. Available exercise test results (n = 153) showed that overweight/obese patients had lower percent predicted maximum oxygen consumption (−16 [2]%; $P < 0.001$), higher peak systolic blood pressure (+11 [4] mm Hg; $P = 0.002$), and higher systolic blood pressure response (+7 [3] mm Hg; $P = 0.01$) than normal weight patients.

Conclusions: In conclusion, children with repaired CHD have an important risk of overweight/obesity over time that may increase their cardiovascular risk and impair their exercise capacity.

[E]/a; $P < 0,001$). Les écarts réduits de l'IMC et de la taille pouvaient seulement être calculés chez les patients > 2 ans. À cet âge, l'écart réduit de l'IMC médian était de −0,2 (cinquième/95^{e} percentile, −2,6/+1,9) et augmentait avec le temps (+0,042 [0,007] E/a; $P < 0,001$), alors que l'écart réduit de la taille médiane était de −0,3 (cinquième/95^{e} percentile, −2,7/+1,4) et ne montrait aucune tendance (−0,007 [0,006] E/a; $P = 0,18$). Selon les seuils en percentiles de l'IMC définissant la surcharge pondérale et l'obésité, 28 % des patients avaient au moins 1 mesure de l'IMC qui indiquait la surcharge pondérale et 17 % des patients, l'obésité. Les résultats de l'épreuve d'effort (n = 153) montraient que les patients en surcharge pondérale et obèses obtenaient un pourcentage plus faible qui prédisait une consommation maximale d'oxygène (−16 [2]%; $P < 0,001$), une pression artérielle systolique maximale plus élevée (+11 [4] mm Hg; $P = 0,002$) et une réponse de la pression artérielle systolique plus élevée (+7 [3] mm Hg; $P = 0,01$) que les patients ayant un poids normal.

Conclusions : En conclusion, les enfants ayant une CC réparée ont avec le temps un important risque de surcharge pondérale et d'obésité qui peut augmenter leur risque cardiovasculaire et diminuer leur aptitude à l'effort.

(20%-22% in larger patient populations with ASD, DORV/TOF, and VSD and 30%-35% in smaller patient populations with AVSD, TGA, and single-ventricle anatomy amenable to a Fontan procedure). Sampling of the population rather than complete coverage was used to increase study feasibility. The yielded sample size was sufficient to obtain robust statistical estimates that could only have been marginally improved with a greater sample size. All patients had to have survived > 3 months after complete repair and be regularly followed at The Hospital for Sick Children. Patients with overlapping cardiac diagnoses, those with postsurgical follow-up primarily at another institution, and those who eventually underwent heart transplantation were excluded.

Measurements

At each hospital visit, the patient's height, weight, current medications, and cardiac status were reviewed. Weight, height, and body mass index (BMI) were converted to age- and sex-based *z* scores using the algorithm provided by the Division of Nutrition and Physical Activity of the Center for Disease Control, Atlanta, GA.[11] Height and BMI *z* scores are only available after age 2 years, whereas weight *z* scores are available from birth onward. Specific algorithms for patients with Down syndrome were not used because equations are not available, and there are no charts for BMI. However, Down syndrome was included as an adjustment factor in all regression models. Patients with BMI ≥ the 85th percentile but < the 95th percentile were classified as overweight, whereas those with BMI percentiles ≥ the 95th percentile were classified as obese. Systolic and diastolic blood pressures were converted into age, sex, and height percentile-based *z* scores according to published equations for all measurements performed after age 2 years.[12]

A subgroup of patients underwent cardiopulmonary exercise testing as part of their routine follow-up. Cardiopulmonary exercise testing was completed by a certified exercise physiologist while measuring the following parameters: breath-by-breath gas exchange to determine maximal oxygen consumption and carbon dioxide production (V_{O_2} and V_{CO_2}, respectively), respiratory exchange ratio (V_{CO_2}/V_{O_2}), electrocardiographic findings, oxygen saturation, blood pressure, and heart rate. Exercise testing was completed on an upright cycle ergometer using a graded exercise protocol. The test was terminated on volitional exhaustion. For those patients, we compared exercise test results between overweight or obese patients and patients with a BMI < the 85th percentile.

Data analysis

Patient and surgical characteristics (those not changing over time), as well as results from the exercise tests, are described as means with standard deviations and medians with fifth and 95th percentiles and frequencies as appropriate. Primary analyses were done using generalized estimating equation (GEE) regression models (linear for continuous outcomes, logistic for binary outcomes) adjusted for repeated measures over time through an autoregressive covariance structure. Multiple mathematical transformations of age were tested to properly model growth over time. The Akaike information criterion was used to compare the fit of multiple models for a given outcome. Based on this analysis, a natural logarithm transformation of age was found to only marginally improve model fit over linear models. Linear models are therefore reported to facilitate interpretation. Risk factor analysis was performed in multivariable GEE regression models to determine factors associated with higher weight and BMI *z* scores and increased odds of overweight/obesity. These models automatically included age at measurement, sex, before or after repair status, Down syndrome, other genetic abnormalities, and patient diagnosis. Forward entry of other variables was used to obtain final regression models. Differences between overweight/obese and non−overweight/obese patients in exercise testing results were assessed in linear regression models adjusted for repeated measures through a compound symmetry covariance structure, cardiac diagnosis,