Objective: To determine whether exercise intolerance and recommended activity restrictions are associated with development of overweight and obesity in children with congenital heart disease.

Design: Retrospective review.

Setting: Pediatric cardiology practice at a teaching hospital.

Participants: A total of 110 pediatric congenital heart disease patients followed up for a mean of 8.4 years.

Main Outcome Measures: Body mass index (BMI), sex-appropriate BMI percentiles, overweight (BMI percentile ≥85), and obesity (BMI percentile ≥95) at follow-up.

Results: As a group, the increase in BMI percentiles was close to 10 points, but the increase was 21.6 points for exercise intolerant children and 27.3 points for activity restricted children. Activity restriction was significantly associated with both overweight (risk ratio [RR], 2.60; 95% confidence interval [CI], 1.34-3.54) and obesity at follow-up (RR, 4.08; 95% CI, 1.42-7.38) after adjusting for weight at baseline. For the subset of 92 children at a healthy weight at baseline, activity restriction was again significantly associated with overweight (RR, 2.51; 95% CI, 1.24-3.52) and obesity (RR, 6.14; 95% CI, 2.54-8.82) at follow-up. Exercise intolerance did not attain statistical significance.

Conclusions: Exercise intolerant and activity restricted children experienced larger increases in absolute BMI and BMI percentile than children with neither exercise intolerance nor activity restriction. Activity restriction was the strongest predictor of risk of overweight and obesity at follow-up. Elevated weight and obesity may cause these children significant additional health burdens. Therefore, when patients must be counseled against physical exertion, they also need to be educated about the importance of appropriate physical activity and good dietary practices.

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According to the US Surgeon General, obesity will soon overtake tobacco smoking as the No. 1 cause of preventable disease and death in the United States. In Canada, obesity rates have also experienced a large increase, doubling between 1985 and 1998 and costing the health care system approximately $1.8 billion in 1997. Children are not exempt from this epidemic. In 1996, 28.8% of boys and 23.6% of girls in Canada were considered overweight (defined as a body mass index [BMI; calculated as weight in kilograms divided by the square of height in meters] ≥85th percentile for age and sex) compared with 15.3% each in 1981, whereas 16.6% of boys and 14.6% of girls in Canada were obese (defined as a BMI ≥95th percentile for age and sex) compared with 5% each in 1981. Rates are similar in the United States, with 15.5% of those aged 6 to 11 years and 15.5% of those aged 12 to 19 years at or above the 95th percentile for BMI. Along with psychological and social consequences, overweight and obese children are at increased risk of a number of medical and surgical conditions. They are far likelier to become obese adults, and cardiovascular disease, ischemic heart disease, and stroke are more common in individuals whose onset of obesity took place in childhood.

Obesity is caused by energy intake chronically exceeding energy expenditure. Some children have physical limitations that may affect their ability to expend calories, thus potentially shifting the energy balance toward a net gain of calories and putting them at risk of becoming overweight or obese. For example, one study of children at an urban community health center suggested that asthma...
was a significant risk factor for obesity due to such limitations in physical activity. Congenital cardiac abnormalities are the most common serious congenital anomaly, occurring in approximately 0.8% of live births. Many children with congenital heart disease are similarly restricted in activity, yet no studies have been performed to see whether they too are at increased risk of developing obesity and potentially acquiring additional burdens to their health. This study reviews a population of children with congenital structural heart disease in a pediatric cardiology practice to determine the prevalence of overweight and obesity and whether recommended activity restrictions are associated with development of obesity.

### METHODS

Medical records in the office of a pediatric cardiologist in Kingston, Ontario (J.F.S.), were identified according to the following inclusion criteria: (1) diagnosed congenital structural heart defect, (2) minimum age of 2 years at baseline, (3) no other disease or syndrome, and (4) still an active patient. Collected data included sex, date of birth, diagnosis, and first and last recorded height and weight and corresponding dates. In addition, clinic letters were reviewed to identify those who were symptomatically exercise intolerant by history (eg, unable to keep up with peers during physical activity, including gym class; diminished capacity to climb stairs, run, and walk on a flat surface) Also identified were those for whom the pediatric cardiologist had recommended activity restriction in accordance with recommended guidelines (eg, excluded from participation in competitive sports demanding at least moderate physical exertion, including tennis, soccer, basketball, baseball, hockey, and football). This recommendation was made at the time of the diagnosis for school-aged children or at the time they would potentially enroll in competitive sports (approximately 4–5 years of age) for younger children. The diagnoses were described and categorized as shunt only, obstruction only, shunt and obstruction (eg, tetralogy of Fallot), and other complex heart disease (eg, single ventricle, transposition, or cardiomyopathy). The Queen’s University Research Ethics Board approved this study.

The BMI was calculated and plotted onto the sex-appropriate BMI growth curve to determine the BMI percentile for that individual at that particular time. At each time point, individuals were categorized as overweight (BMI percentile ≥85) or obese (BMI percentile ≥95). Elapsed time between the first and last measurement and change in BMI percentile were also calculated.

SPSS statistical software, version 11.0, for Windows (SPSS Inc, Chicago, Ill) was used for analysis. We used chi-square testing (Fisher exact tests) to examine associations among categorical variables (sex, diagnosis, exercise intolerance, and activity restriction) and weight status. Independent t tests were used to determine whether there were any statistically significant differences in age, BMI percentile at baseline, BMI percentile at follow-up, and change in BMI on the basis of sex, exercise intolerance, activity restriction, and weight status. Mixed analysis of variance was used to test the magnitude of change in BMI percentile from baseline to follow-up, with activity restriction and exercise intolerance as between factors and the 2 BMI percentiles (baseline and follow-up) as within factors. Logistic regression modeling was performed to identify the association between the primary predictors of exercise intolerance and activity restriction with the outcomes of overweight and obesity, controlling for the effects of potential confounders. These models initially included all patients, followed by models that included just patients who were of healthy weight at baseline. Linear regression for change in BMI percentile was also completed, using all patients. For all regressions, available variables included age, sex, diagnosis, weight status at baseline, activity restriction, and exercise intolerance. Variables that had a moderate association with the outcomes of interest were entered into the models. Finally, prevalence of overweight and obesity among a subset of the sample consisting of patients aged 7 to 13 years at follow-up was compared with the Canadian population rates for the same age group.

### RESULTS

Table 1 gives the characteristics of the 110 patients who met the study criteria. The average ± SD interval between baseline and follow-up assessment was 8.4 ± 3.2 years. Mean ± SD change in BMI percentile was 9.7 ± 32.2 points. Of the 92 with a healthy weight at baseline, 12 became overweight and 10 became obese (Table 2). Four of 10 considered overweight at baseline achieved a healthy weight at follow-up and 1 became obese. None of the 8 who were obese at baseline achieved a healthy weight, although 2 did drop from the obese into the overweight category. Mean percentile changes increased overall for the healthy group; the obese group remained stable and the overweight group dropped slightly (Figure 1).
The patients were subsequently classified as activity restricted, exercise intolerant, or both and compared with the group with neither problem. All groups showed an increase in BMI percentiles from baseline to follow-up, but the increase was the most marked for the group that had both activity restriction and exercise intolerance, followed by the activity restrictions alone and then exercise intolerance alone (Figure 2).

Four final logistic regression models were developed. The first 2 included all patients, controlling for baseline weight status (whether they were overweight or obese) by forcing these variables into the models. The next 2 models examined the subset of 92 patients who were of healthy weight at baseline (Table 5). Odds ratios were converted to risk ratios (RRs) to facilitate accurate interpretation of the results.14

When controlling for weight status at baseline, those who were activity restricted were more likely to become either overweight (RR, 2.60) or obese (RR, 4.08). Exercise intolerance did not attain statistical significance in either model, although it approached significance in the model for obesity. When examining just those patients of healthy weight at baseline, activity restriction again had a significant association with both overweight (RR, 2.51) and obesity (RR, 6.14), whereas exercise intolerance was not statistically significantly associated with either outcome.

Stepwise linear regression supported the results of the logistic regression. Four variables were included in the final model. A problem other than shunt or obstruction was associated with a 24-point decrease in BMI percentile (95% confidence interval [CI], −45.01 to −3.12), whereas being overweight at baseline was associated with a 19-point decrease (95% CI, −34.88 to −3.99). Exercise intolerance was associated with a 15-point increase (95% CI, 0.48-29.30), and activity restriction was associated with a 25-point increase (95% CI, 6.55-42.99).
The results showed that, as a group, children with congenital structural heart disease have overweight and obesity rates similar to those of the overall pediatric population. However, those reported to be exercise intolerant had substantially higher rates of obesity compared with the other children in the sample, whereas those who were advised to restrict their activity had statistically significantly higher rates of both overweight and obesity. The impact of exercise intolerance was not as strong as that of activity restriction. The effect of exercise intolerance was nonsignificant in the subset of patients who were of a healthy weight at baseline, whereas those who were advised to restrict their activity were neither exercise intolerant nor activity restricted. Finally, we were unable to control for parental obesity, a known risk factor, because these data were unavailable in the patient medical record.

Several limitations of this study need to be identified. First, the list of factors considered in the analysis was not exhaustive. Factors not considered included the following: the specifics of the lesion, severity of the lesion, treatment, caloric intake, home environment, and family history. Second, categorization as exercise intolerant was a subjective categorization based on patient or parent report. Stress tests to objectively determine tolerance thresholds were not included in this study. No distinction was made between patients who were exercise intolerant owing to their heart condition and those whose heart lesion was such that it should not have been the cause of their exercise intolerance (of note, obesity did not predict exercise intolerance in this population). Similarly, the categorization of activity restriction related only to the advice of the supervising pediatric cardiologist. No information was available with regard to how much activity a restricted patient engaged in or to what degree his or her activity was restricted. Despite the limitations, the study raises some interesting questions. The strong association between obesity and activity restriction raises concern that some harm may result from advising children with congenital heart disease or with other serious conditions to restrict their activity. The increasing BMIs, higher BMI percentiles, and elevated overweight and obesity rates may cause these children significant additional health burdens. This does not imply that patients at risk of sudden death or serious arrhythmia should not be counseled.
about the dangers of overexertion. However, knowing that prescribed exercise curtailments may themselves pose a risk may necessitate further preventive measures.

Perhaps we need to be more aggressive in our efforts to educate this subset of patients about the importance of ongoing appropriate physical activity and good dietary practices. This could include counseling with a skilled dietitian and a well-defined exercise program. With mild forms of congenital heart disease, most sports will be permitted. With moderate disease, individual assessment, including exercise stress testing, may identify patients able to participate in intermediate-level sports. For severe forms of congenital cardiac abnormalities, activities such as walking, recreational swimming and cycling, golf, and bowling should be encouraged to reinforce the importance of lifelong healthy exercise.\(^\text{12}\) The cooperation and support of family and frequent follow up with reinforcement of exercise and dietary recommendations by the child’s primary health care physician are also important facets of successful weight control that could be routinely incorporated into the care of these children.

This study was designed to provide some preliminary insights into the association among activity restriction, exercise intolerance, and the development of overweight and obesity. We recommend that further research reviewing the weight profiles of pediatric patients with prescribed activity restrictions be undertaken to confirm these findings.

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