Socioeconomic Position and Heart Rate Recovery After Maximal Exercise in Children

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Objective: To determine whether socioeconomic (SE) position is associated with first-minute (1-minute) heart rate (HR) recovery in healthy children and adolescents (hereafter referred to as children).

Design: In a cross-sectional study, we compared 1-minute HR recovery in 3 groups of children (low, medium, and high SE) using multivariable analysis. The groups were based on neighborhood SE data extracted from the US 2000 census database.

Setting: Children’s Hospital Boston.

Participants: Four hundred eighty children referred for exercise testing to exclude cardiac disease and discharged as showing normal results.

Main Exposures: Socioeconomic position and body mass index (BMI).

Main Outcome Measure: Heart rate recovery after a maximal treadmill exercise test (Bruce protocol) following a consistent 1-minute cool-down period.

Results: The low SE group had a higher proportion of children with a high BMI (≥85th percentile) \( (P=0.07) \) and exercised for a shorter duration, controlling for age, sex, and BMI \( (P<0.001) \). After adjusting for age \( (P<0.001) \) and sex \( (P<0.001) \), a significant interaction of SE group with BMI was found \( (P=0.04) \). There was no difference in HR recovery in the 3 SE groups in children with a normal BMI (<85th percentile). Among children with a high BMI, only those from low and middle SE neighborhoods had impaired 1-minute HR recovery.

Conclusion: Children with a high BMI in low and middle SE positions appear to have worse cardiovascular health compared with children with a high BMI in a high SE position.


Attenuated first-minute (1-minute) heart rate (HR) recovery on cessation of exercise is a recently described cardiovascular risk factor and has been associated with increased risk of all-cause mortality and sudden cardiac death in adults independent of traditional risk factors. Physiologically, 1-minute HR recovery (defined as HR at peak exercise–HR at 1 minute during recovery) is a function of vagal reactivation. Association of 1-minute HR recovery with health states, both healthy and poor, suggests that it is a marker of cardiovascular health. One-minute HR recovery improves after cardiac rehabilitation in adults with coronary artery disease or heart failure and in children with severe congenital heart disease.

Low socioeconomic (SE) position is associated with adverse health outcomes such as higher all-cause mortality, higher cancer incidence, and increased incidence and prevalence of coronary heart disease in adults. Clinical, social, and demographic factors that mediate these associations have been extensively studied. A recent study described impaired 1-minute HR recovery as a physiological pathway variable between a low SE position and all-cause mortality in a large cohort of clinic-based adults with suspected or known coronary artery disease. Patients from low SE neighborhoods had impaired functional capacity and attenuated 1-minute HR recovery compared with those from higher SE neighborhoods. The strength of association between a low SE position and all-cause mortality decreased after controlling for functional capacity and HR recovery in a multivariable model. Thus, functional capacity and 1-minute HR recovery, markers of cardiovascular health, provided a physiological link in the association between low SE position and all-cause mortality in adults.

Limited data describe the impact of low SE position on cardiovascular health in children. Previous studies have suggested an association of low SE position with poor cardiovascular health behavior in individuals 12 to 21 years of age. Low SE position has also been associated with

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childhood and adolescent obesity. We therefore hypothesized that the association between low SE position and attenuated 1-minute HR recovery observed in adults has its origins in childhood. Thus, the objective of this study was to determine whether SE position is associated with 1-minute HR recovery after a standard exercise test in healthy children. We also assessed the association of SE position with exercise performance in these children.

METHODS

STUDY COHORT

We screened the Exercise Physiology Laboratory database at Children's Hospital Boston to identify all patients younger than 19 years who were referred for exercise testing during 6 consecutive years (2001-2006) for evaluation of chest pain, fatigue, shortness of breath, palpitations, or a family history of heart disease; who were not known to have any cardiac disease; and who underwent a treadmill exercise test using the Bruce protocol. Clinical notes were reviewed to select patients who, after their complete clinical evaluation (history, physical examination, electrocardiography, exercise testing, and, if indicated, cardiac ultrasonography and preexercise and postexercise pulmonary function assessment) were discharged from the cardiology clinic as showing normal results. We excluded subjects with a history of syncope, those with a known systemic illness, or those receiving any cardiovascular medications. We identified 485 such children and adolescents (hereinafter referred to as children for the purposes of this study). We excluded 5 because their home address was not available in the medical records and their neighborhood SE data could not be obtained. The remaining 480 children formed the analytic cohort for this study. The study was approved by the institutional review board with a waiver of informed consent.

ASSESSMENT OF SE POSITION

The SE position for each child was calculated from the SE characteristics of the block group of residence. A block group contains on average 1000 residents, is the smallest geographic unit for which census SE data are tabulated, and is designed to be relatively homogeneous with respect to economic status and living conditions of its residents. A block group is essentially the neighborhood of a person’s residence. Each child’s home address at the time of exercise testing was used to extract the block group of residence from the US Census Web site. Based on a previously described measure to determine the SE position of a neighborhood from block group data, a composite SE score was determined for each child, and this score was used as the main indicator of the SE position of the child.11,16 The 6 SE variables selected for the composite score were originally described by Diez Roux et al11 using factor analysis, a statistical technique to determine which variables from a large set (eg, a large set of census SE variables) can be meaningfully combined into a composite score.

To determine this score, data on 6 SE variables for each child’s block group were collected from the US 2000 census database. These variables represent 3 dimensions of wealth and income (the logarithm of the median household income, the logarithm of the median value of housing units, and the percentage of households receiving interest, dividend, or net rental income), 2 dimensions of education (the percentage of adults ≥25 years who had completed high school and the percentage of adults ≥25 years who had completed college), and 1 dimension of occupation (the percentage of employed persons ≥16 years in executive, managerial, or professional specialty occupations) for the residents of the block group. For each variable, a z score for each block group was calculated by subtracting the overall mean of that variable (across all block groups in the sample) from the value of the variable for that block group and dividing by the standard deviation. The summary SE score for each child was obtained by summing the 6 z scores (1 for each of the 6 variables) for that child.

EXERCISE TEST AND RECOVERY

All children underwent an incremental, symptom-limited treadmill exercise test according to the standard Bruce protocol. Baseline HR and blood pressure were recorded. Heart rate and rhythm were continuously monitored during the test with electrocardiography. Exercise duration (as a measure of exercise performance) and HR at maximum exercise (peak HR) were noted. Recovery from exercise followed a consistent protocol of a 1-minute cool-down period (1.5 mph, 0% inclination). Thereafter, the subjects descended from the treadmill and sat down in a chair and were monitored for another 5 to 10 minutes of recovery. Heart rate was recorded at 1 minute during recovery. The primary outcome variable was 1-minute HR recovery (defined as peak HR−HR at 1 minute of recovery). A secondary outcome variable was exercise performance (assessed as exercise duration on this standardized protocol and adjusted for age and sex).

STATISTICAL ANALYSIS

Children were divided into 3 equal groups (low, middle, and high SE groups) on the basis of their ranks relative to each other (tertiles) on composite SE scores. These groups were compared for distribution of demographic and exercise covariates, exercise duration, and 1-minute HR recovery by means of analysis of variance with Bonferroni correction for multiple comparisons and χ² tests, as appropriate. Because the range of healthy body mass index (BMI) varies with age and sex, we generated a percentile BMI value and a BMI z score for each child based on Centers for Disease Control and Prevention criteria. These values were then categorized as normal (<85th percentile) or high (≥85th percentile) for regression analysis.21,22 We performed multivariable linear regression analyses to assess the association of 1-minute HR recovery and exercise duration with SE position and other potential determinants. We used the coefficient of determination (R²) to assess the percentage of variance explained by each model. Additional analyses used BMI as a continuous variable (as z scores) and after dividing the patients into 4 equal groups (quartiles) on the basis of their composite SE scores. Statistical analyses were performed using SPSS statistical software (SPSS for Windows, version 15.0; SPSS, Inc, Chicago, Illinois). The results are expressed as mean (SD), median (range), or number (percentage), as appropriate. All analyses were 2-tailed. We defined statistical significance as $P < .05$.

RESULTS

STUDY COHORT

We included 480 children in the study, of whom 285 were boys (59.4%) and 195 were girls (40.6%). Their median age at exercise testing was 13.5 (range, 5.2-18.8) years. The indications for exercise testing were a history of chest pain in 243 participants (50.6%), palpitations in 87 (18.1%), family history of cardiac disease in 43 (9.0%),...
premature ventricular contractions at rest in 42 (8.8%), shortness of breath in 36 (7.3%), sports clearance in 14 (2.9%), fatigue in 6 (1.2%), and others in 9 (1.9%). According to age- and sex-specific values of BMI from the Centers for Disease Control and Prevention, 336 participants (70.0%) had a normal BMI and 144 (30.0%) had a high BMI (of whom 81 [16.9%] were overweight and 63 [13.1%] were obese). All children had normal results of the systemic physical examination. An echocardiogram was performed during evaluation in 316 children (65.8%) and demonstrated normal cardiac anatomy and function in all.

A comparison of demographic variables, exercise duration, and 1-minute HR recovery among the children in the 3 SE groups is presented in Table 1. Age distribution and BMI z scores were similar in the 3 SE groups. A higher proportion of children in the low SE group appeared to have a high BMI; this difference did not reach statistical significance (P = .07). The low SE group exercised for a shorter duration compared with the middle and high SE groups (mean exercise duration, 13.5 [2.8], 14.6 [2.9], and 14.7 [2.6] minutes in the low, middle, and high SE groups, respectively; P < .001). The differences in baseline HR, peak HR, and 1-minute HR recovery among the 3 groups were not statistically significant. The SE characteristics of the neighborhoods of residence of the 3 groups of children are compared in Table 2. The differences among the 3 groups were statistically significant for all SE variables (P < .001 for all comparisons).

MULTIVARIABLE MODELS

Table 3 lists the predictors of exercise duration in a multivariable model. After adjusting for age, sex, and BMI, the low SE group exercised for a significantly shorter duration at maximal exercise compared with the high SE group (P < .001).

A multivariable model for demographic determinants of 1-minute HR recovery is outlined in Table 3 and included the following factors: age at exercise test (P < .001), sex (P < .001), and an interaction between SE position and BMI (P = .04). This model explained 36% of variance for 1-minute HR recovery. Thus, the SE group was a significant predictor of 1-minute HR recovery in children with a BMI at the 85th percentile or higher but not in those with a BMI less than the 85th percentile. Interpreted in another way, BMI was a significant predictor of 1-minute HR recovery in the low and middle SE groups but not in the high SE group. Based on this model, a boy aged 12 years from the high SE group is estimated to have a 1-minute HR recovery of 41 beats/min if he has a normal BMI (<85th percentile for age) and 40 beats/min if his BMI is high (≥85th percentile for age). In contrast, a boy aged 12 years from the low SE group is estimated to have a 1-minute HR recovery of 41 beats/min if he has a normal BMI but only 35 beats/min if his BMI is high. Similarly, a boy aged 12 years from the middle SE group is estimated to have a 1-minute HR recovery of 44 beats/min if he has a normal BMI but only 37 beats/min if his BMI is high. The proportions of children with

### Table 1. Baseline and Exercise Characteristics of Children by SE Group

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Low SE Group</th>
<th>Middle SE Group</th>
<th>High SE Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>12.9 (3.3)</td>
<td>12.8 (3.4)</td>
<td>13.3 (3.5)</td>
<td>.39</td>
</tr>
<tr>
<td>Male sex, No. (%)</td>
<td>106 (66.2)</td>
<td>95 (59.4)</td>
<td>84 (52.5)</td>
<td>.04</td>
</tr>
<tr>
<td>BMI z score</td>
<td>0.61 (1.00)</td>
<td>0.51 (0.83)</td>
<td>0.45 (0.82)</td>
<td>.28</td>
</tr>
<tr>
<td>BMI category, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal (&lt;85th percentile)</td>
<td>101 (63.1)</td>
<td>116 (72.5)</td>
<td>118 (73.8)</td>
<td>.07</td>
</tr>
<tr>
<td>High (≥85th percentile)</td>
<td>44 (27.5)</td>
<td>41 (25.6)</td>
<td>47 (28.1)</td>
<td></td>
</tr>
<tr>
<td>Baseline HR, beats/min</td>
<td>87 (17)</td>
<td>86 (16)</td>
<td>86 (18)</td>
<td>.76</td>
</tr>
<tr>
<td>Peak HR, beats/min</td>
<td>194 (12)</td>
<td>196 (11)</td>
<td>197 (9)</td>
<td>.08</td>
</tr>
<tr>
<td>Exercise duration, min</td>
<td>13.5 (2.8)</td>
<td>14.6 (2.9)</td>
<td>14.7 (2.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>1-min HR recovery, beats/min</td>
<td>35 (14)</td>
<td>38 (14)</td>
<td>35 (13)</td>
<td>.09</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; HR, heart rate; 1-min, first-minute; SE, socioeconomic.

### Table 2. Neighborhood Characteristics of Children by Socioeconomic (SE) Group

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Low SE Group</th>
<th>Middle SE Group</th>
<th>High SE Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>composite SE score</td>
<td>−5.9 (3.3)</td>
<td>0.03 (1.1)</td>
<td>5.9 (2.2)</td>
</tr>
<tr>
<td>Median household income, US $1000</td>
<td>40.0 (14.2)</td>
<td>66.5 (12.3)</td>
<td>100.4 (26.7)</td>
</tr>
<tr>
<td>Median value of houses, US $1000</td>
<td>167.2 (78.7)</td>
<td>222.0 (54.1)</td>
<td>414.0 (159.1)</td>
</tr>
<tr>
<td>Households with rental, dividend, or interest income, %</td>
<td>30.0 (13.0)</td>
<td>48.4 (8.2)</td>
<td>67.6 (8.8)</td>
</tr>
<tr>
<td>Residents who are high school graduates older than 25 years, %</td>
<td>75.3 (14.0)</td>
<td>91.4 (4.4)</td>
<td>96.0 (3.3)</td>
</tr>
<tr>
<td>Residents with college degree older than 25 years, %</td>
<td>18.8 (8.8)</td>
<td>38.2 (9.4)</td>
<td>66.2 (11.3)</td>
</tr>
<tr>
<td>Employed as manager, professional, or executive, %</td>
<td>29.1 (9.4)</td>
<td>45.2 (7.5)</td>
<td>63.8 (9.4)</td>
</tr>
</tbody>
</table>

The composite SE scores ranged from −6.8 to −2.1 for the low SE group, −2.0 to 2.2 for the middle SE group, and 2.3 to 11.5 for the high SE group. P < .001 for overall comparisons across groups (analysis of variance) and for comparisons between individual groups. Data are expressed as mean (SD).
Table 3. Predictors of Exercise Duration, Demographic Predictors of 1-Minute HR Recovery, and Demographic and Exercise Predictors of 1-Minute HR Recovery in a Multivariable Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>β (SE)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictors of exercise duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>10.19 (0.50)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age at exercise test, y</td>
<td>0.30 (0.03)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>1.69 (0.22)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI ≥85th percentile</td>
<td>-1.48 (0.24)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Low SE group b</td>
<td>-1.21 (0.27)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Middle SE group b</td>
<td>-0.08 (0.27)</td>
<td>.77</td>
</tr>
<tr>
<td>Demographic predictors of 1-min HR recovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>59.81 (2.29)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age at exercise test, y</td>
<td>-2.09 (0.15)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>5.91 (1.03)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI ≥85th percentile</td>
<td>-0.67 (1.98)</td>
<td>.74</td>
</tr>
<tr>
<td>Low SE group b</td>
<td>1.03 (1.49)</td>
<td>.49</td>
</tr>
<tr>
<td>Middle SE group b</td>
<td>3.15 (1.42)</td>
<td>.03</td>
</tr>
<tr>
<td>Low SE group × BMI ≥85th percentile</td>
<td>-5.66 (2.68)</td>
<td>.04</td>
</tr>
<tr>
<td>Middle SE group × BMI ≥85th percentile</td>
<td>-5.79 (2.75)</td>
<td>.04</td>
</tr>
<tr>
<td>Demographic and exercise predictors of 1-min HR recovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>95.06 (9.22)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age at exercise test, y</td>
<td>-2.53 (0.16)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>3.50 (1.07)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI ≥85th percentile</td>
<td>0.87 (1.92)</td>
<td>.65</td>
</tr>
<tr>
<td>Low SE group b</td>
<td>1.45 (1.45)</td>
<td>.32</td>
</tr>
<tr>
<td>Middle SE group b</td>
<td>2.73 (1.37)</td>
<td>.047</td>
</tr>
<tr>
<td>Low SE group × BMI ≥85th percentile</td>
<td>-5.14 (2.57)</td>
<td>.046</td>
</tr>
<tr>
<td>Middle SE group × BMI ≥85th percentile</td>
<td>-5.25 (2.64)</td>
<td>.047</td>
</tr>
<tr>
<td>Baseline HR</td>
<td>-0.13 (0.13)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Peak HR</td>
<td>-0.14 (0.05)</td>
<td>.002</td>
</tr>
<tr>
<td>Exercise duration, min</td>
<td>0.75 (0.21)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; HR, heart rate; 1-min, first-minute; SE, socioeconomic.

A multivariable model for 1-minute HR recovery that added physiological predictors of 1-minute HR recovery (baseline HR, peak HR, and exercise duration) to the previously described variables, the interaction between SE group and BMI remained statistically significant (Table 3). This model explained 43% of the variance for 1-minute HR recovery.

ADDITIONAL ANALYSES

To assess the role of deconditioned skeletal leg muscles in explaining our findings, we compared the proportion of children in the low, middle, and high SE groups with a high BMI who had leg fatigue at peak exercise. Of 144 children with a high BMI, 8 children in the low SE group (13.6%), 3 in the middle SE group (6.8%), and 5 in the high SE group (12.2%) had leg fatigue as the major symptom at peak exercise. The difference among the groups was not statistically significant (P = .56, Fisher exact test). Furthermore, the children with a high BMI in the low, middle, and high SE groups were similar for baseline HR, peak HR during exercise, and change in HR from baseline to peak exercise (P ≥ .05 for all).

A multivariable model for 1-minute HR recovery that used BMI as a continuous variable (as BMI z scores) rather than as a categorical variable found a similar interaction of SE position with BMI (model R² = 0.37). Furthermore, when we divided the children into 4 equal groups (quartiles), we again obtained models with similar results. A multivariable linear regression model for determinants of 1-minute HR recovery found a significant interaction of SE position (the lower 2 SE groups) with BMI (R² = 0.36; P < .001). The addition of exercise duration, baseline HR, and peak HR to this model improved the predictive ability of the model (R² = 0.43; P < .001), but the interaction of SE position with BMI remained significant.

Because hard end points (such as all-cause mortality) are rare in children, surrogate end points are often used to identify, define, and study risk factors in the young. In this study, we used 1-minute HR recovery, a previously described marker of cardiovascular health in adults, as an outcome variable to study the impact of SE position on cardiovascular health in otherwise healthy children and adolescents. There were 2 main findings in this study. First, children from low SE neighborhoods had lower exercise endurance compared with those from high SE neighborhoods after controlling for age, sex, and BMI. Second, we found a significant independent association between SE position (based on neighborhood of residence) and 1-minute HR recovery in children with a high BMI. Among these children, those from low and middle SE neighborhoods had a
significant impairment of 1-minute HR recovery compared with those from high SE neighborhoods. There was no association between SE position and 1-minute HR recovery in children with a normal BMI. The association between SE position and 1-minute HR recovery in children with a high BMI was present even after controlling for physiological variables (baseline HR, peak HR, and exercise duration) known to be associated with 1-minute HR recovery. There was no significant difference in HR recovery between children with normal and high BMIs if they were from high SE neighborhoods. These findings suggest that children with a high BMI (overweight and obese children) in low and middle SE positions have worse cardiovascular health compared with children with a high BMI in a high SE position. These findings further suggest that, although maintenance of a healthy BMI should be a goal for all children, its potential benefits for cardiovascular health may be greatest in children in a low SE position.

In a previous study, children and adolescents living in low SE neighborhoods had poorer dietary habits, engaged in less physical activity, and were more likely to smoke. We did not have data on these behavioral variables in our study cohort. Furthermore, we did not find a difference among children with a high BMI in their baseline or peak HR or the proportion of children with leg fatigue across the 3 SE groups. Nonetheless, 2 potential mechanisms may explain the interaction of SE position and BMI noted in our study. First, children with a high BMI in a high SE position may have higher lean body mass compared with children with a high BMI in a low SE position. This may explain the longer exercise duration and the better 1-minute HR recovery in these children. Second, children living in high SE neighborhoods may have access to a healthier lifestyle with respect to physical activity and nutrition. Low SE neighborhoods have reduced access to recreational facilities, which is associated with decreased physical activity and a more sedentary lifestyle in these children. Living in lower-income neighborhoods has also been associated with decreased energy-adjusted intake of fruits, vegetables, and fish. In 1 study, low SE neighborhoods had 4 times as many grocery stores, half as many supermarkets, and fewer fruit and vegetable markets and natural food stores, suggesting a major difference in food environment based on SE position. Because supermarkets offer a broader choice of affordable healthy foods and because grocery stores provide easier access to inexpensive, energy-dense nutrient-poor foods, these patterns may have consequences for the diets of residents. These differences may also explain the difference in BMI distribution in SE groups in our study.

How attenuated HR recovery mediates increased cardiovascular risk in adults is not entirely understood. Attenuated HR recovery implies impaired activity of the parasympathetic autonomic nervous system and thus a relative sympathetic dominance. Whether this autonomic imbalance increases the risk of cardiovascular events (making attenuated 1-minute HR recovery a risk factor) or whether it is simply a marker of worse cardiovascular health is not settled. The role of HR recovery as a marker of cardiovascular health is supported by multiple lines of evidence. Heart rate recovery is accelerated in athletes and is attenuated in heart failure. In a longitudinal study of healthy young adults who underwent a second exercise test 7 years after the first test, HR recovery on average was slower during the second test. This normal age-related decline in HR recovery was blunted in those who were most physically active by self-report. Patients with the metabolic syndrome have impaired HR recovery that follows rather than precedes the development of metabolic syndrome. Heart rate recovery improves after participation in a cardiac rehabilitation program. Attenuated HR recovery is associated with higher levels of inflammatory markers (C-reactive protein and white blood cell count) and with carotid atherosclerosis. Although these data all support 1-minute HR recovery as a marker of cardiovascular health, the association of 1-minute HR recovery with outcomes independent of traditional cardiovascular risk factors has been argued to support its position as a risk factor rather than just a physiological marker.

There are no data to relate HR recovery in children to clinical outcomes such as mortality or incident atherosclerosis on follow-up. Previous studies in children have described the physiological correlates of HR recovery, measured HR recovery to assess autonomic innervation after congenital heart surgery or heart transplantation, described its inverse association with metabolic risks, and shown that a rehabilitation program improves HR recovery in children with congenital heart disease. Thus, although these data do not support attenuated HR recovery as a risk factor for children, the association of 1-minute HR recovery with various health states in children support the concept that, as in adults, HR recovery may also be considered a marker of cardiovascular health in children.

The results of this study suggest that children with a high BMI living in low and middle SE neighborhoods have inferior cardiovascular health. The importance of maintaining and improving the cardiovascular health of children early in life cannot be overstated. Programs directed at promoting a healthy lifestyle may improve long-term cardiovascular and overall health in these children. These interventions should promote frequent physical activity and incorporate nutrition education. Several recent studies have demonstrated that HR recovery is modifiable by participation in regular, organized physical activity. The potential benefits of participation in frequent, age-appropriate physical activity include improved caloric balance and weight loss (or weight maintenance during linear growth), improved endothelial function, and improvement in autonomic balance leading to overall improved cardiovascular health.

This study has limitations. First, it is a retrospective study, and the study cohort is clinic based rather than community based. Although all children were declared healthy and normal, they do not represent a random sample from a community-based pediatric population. Second, we did not assess lean body mass in these children and were unable to differentiate children with a high BMI who had high and low body fat content. Third, no respiratory exchange data to measure exercise performance or fitness were collected during these symptom-limited tests. All tests were defined as maximal on the basis of observed effort and peak HR. Exercise duration was thus the only measure of exercise performance (or endurance) available in these children. Although exer-
cise duration on the Bruce protocol is routinely used to
define endurance/performance in adult exercise labora-
tories, its use for this purpose is less common in pediat-
rics. Finally, the contribution of other risk factors, such
as lack of physical activity, smoking, lipid profile, insu-
lin resistance, or family history of atherosclerosis, on HR
recovery could not be assessed in this analysis.

In conclusion, this study sought to relate SE position
in children with their postexercise 1-minute HR recov-
ery. The results suggest that SE position affects the
association of a high BMI with cardiovascular health in chil-
dren. One-minute HR recovery was similar in children
with high and normal BMIs from high SE neighbor-
hoods but was significantly attenuated in children with
a high BMI from low and middle SE neighborhoods.
Interventions directed at these children may improve their
cardiovascular health.

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data in the study and takes responsibility for the integ-
ricity of the data and the accuracy of the data analysis. Study
concept and design: Singh. Acquisition of data: Singh and
Evans. Analysis and interpretation of data: Singh. Draft-
ing of the manuscript: Singh. Critical revision of the manu-
script for important intellectual content: Singh and Evans.
Statistical analysis: Singh. Administrative, technical, and
material support: Evans. Study supervision: Singh.

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