Factors Associated With Increased Exercise in Adults With Congenital Heart Disease

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Despite the known benefits of regular exercise, the majority of adults with congenital heart disease (CHD) fail to meet recommended standards for physical activity. We aimed to evaluate the factors associated with exercise frequency in adults with CHD, which remain largely unknown. From September 2015 to December 2016, 446 adults with CHD completed clinical questionnaires regarding exercise frequency. Questionnaires also measured related demographic and psychosocial variables. Retrospective chart review was utilized to determine cardiac function and cardiopulmonary exercise capacity. Exercise frequency was classified as none (33%), low (<3×/month, 2%), occasional (<2×/week, 8%), or frequent (≥2×/week, 57%). Frequent exercisers were more highly educated (odds ratio [OR] 1.65, 95% confidence interval [CI] 1.06 to 2.57), reported improved sleep quality, with decreased nocturnal awakenings and sleep latency (OR 0.52, 95% CI 0.32 to 0.83), and had a lower prevalence of depression (OR 0.30, 95% CI 0.12 to 0.75). There was no significant association between exercise frequency and disease complexity or cardiac function. Of the original cohort, 74 patients completed exercise testing within 1 year of their visit. Frequent exercisers (n = 46) had better indicators of cardiovascular capacity, including higher peak maximal oxygen consumption [VO_2] (28.8 ± 8.5 vs 24.6 ± 8.4, p = 0.04). After controlling for exercise frequency, higher educational attainment independently predicted an improved exercise capacity (peak [VO_2]: OR = 1.09, 95% CI 1.01 to 1.18). In conclusion, frequent exercise in adults with CHD is associated with improved cardiopulmonary exercise capacity and psychosocial functioning, irrespective of underlying cardiac disease complexity and severity. Increased physical activity levels and improved exercise capacity were observed in more highly educated patients, highlighting the potential importance of socioeconomic influences on physical and mental functioning. **(Am J Cardiol 2019;124:947−951)**

The health benefits of regular exercise have been well established in those with underlying cardiovascular disease, including noted improvements in psychosocial functioning and an associated reduction in all-cause and cardiovascular related mortality.[1,2] However, approximately 50% of adults with congenital heart disease (CHD) do not achieve recommended levels of habitual exercise,[3] with unique challenges predominantly imposed by a significantly reduced baseline exercise capacity.[4] Previous studies analyzing quality-of-life related measures in adults with CHD have additionally shown a disproportionate incidence of poorer psychosocial functioning when compared with aged-matched peers,[5] which appears to be independent of cardiac performance,[6,7] and is potentially ameliorated by the effects of exercise training.[8] Therefore, adults with CHD represent a particularly vulnerable population who may benefit, in multiple domains, from interventions targeted at improving levels of physical activity. The aim of this study was therefore to further elucidate potential predictors of exercise frequency in adults with CHD, as well as analyze their related health benefits.

Methods

A single-center, cross-sectional study was performed in 446 adults with CHD within the Washington Adult Congenital Heart Program at Children's National Health System. Eligible patients were seen during routine outpatient visits between September 1, 2015 and December 31, 2016. The inclusion criteria were (1) age ≥18 years, (2) a diagnosis of CHD, (3) and the ability to complete a written questionnaire in English. Patients who did not complete the survey were excluded. The study was approved by our institutional research ethics board.

Exercise frequency was assessed using self-report, non-validated, questionnaires, which are given to all patients attending the adult congenital outpatient clinic on an annual basis. The most recently completed questionnaire within the designated study period was used for data analysis. The questionnaire was developed by the core faculty of the Washington Adult Congenital Heart Program program at Children's National Health System to gather relevant demographic, clinical, and psychological variables for assessment of a patient's general health status.

Socioeconomic parameters assessed included age, sex, race, education level (classified into: high school diploma or

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less, some college, associate degree, or bachelor's degree and higher), and living with a spouse and/or child. For subjective assessment of exercise patterns, questions were posed regarding exercise frequency ("how often do you exercise": classified as none/low if <2×/week and frequent if ≥2×/week), duration (average time per day), and type. Additional psychometric variables queried included perceived social supports, stress/anger levels (each scored on a scale of 0−9: none (0−1), mild (2−4), moderate (5−7), and severe (8−9)), and recreational substance use. Symptoms of depression and anxiety were assessed through scoring on validated PHQ-4 inventories, with scores (≥3) satisfying clinical criteria for diagnosis.

Retrospective chart review was performed to obtain information regarding disease complexity, cardiac function, and exercise capacity. Disease complexity was classified as simple, moderate, or severe according to anatomic classifications derived from the Bethesda Conference.[9] Systemic ventricular function was assessed on transthoracic echocardiogram and cardiovascular magnetic resonance imaging, the latter utilized in the setting of a systemic right ventricle. Exercise capacity was determined through measurements of peak [VO_2] and percent predicted VO_2 on cardiopulmonary exercise testing. Peak [VO_2] measurements were obtained with maximal exercise testing, defined as a respiratory exchange ratio >1.1. Studies performed within 1 year of the clinical visit were utilized for purposes of statistical analysis.

Categorical variables are described as frequencies, with related percentages. Numerical variables are reported as means ± standard deviation. Comparisons between groups were performed using the student's *t* Test and chi-square test, as appropriate. Univariate and multivariate logistic regression was performed to evaluate factors associated with an increased exercise frequency. Patient questionnaires with incomplete or missing responses were included in the analysis, although the corresponding absent variables was excluded from the univariate analysis. Statistical significance was defined as a p value ≤0.05 (2-tailed) for all analyses. Analyses were performed using SAS (version 9.2. Cary, North Carolina).

Results

Of the eligible cohort, 446 adult patients with CHD completed questionnaires during the designated study period. Demographic and clinical characteristics of the study population are presented in Tables 1 and 2.

Overall, 254 patients (57%) reported frequent exercise and 188 patients (42%) reported absent or infrequent physical activity. Exercise levels were further subclassified as none (33%), low (<3×/month, 2%), occasional (<2×/week, 8%), and frequent (≥2×/week, 57%). Median exercise time for all patients was 45 minutes (range 10 to 120 minutes). There were no significant differences in the majority of queried demographic and psychosocial variables (Table 1). Similarly, there was no significant association with mean systemic ventricular function (p = 1.0), despite the majority (85%) of defects being of moderate-to-severe complexity in frequent exercisers.

The results of the univariate and multivariate regression analyses for variables associated with frequent exercise are presented in Table 3 and Figure 1, respectively. Notably, frequent exercisers were more highly educated (odds ratio [OR] 1.65, 95% confidence interval [CI] 1.06 to 2.57), and reported improved functioning concerning several mental health domains. Specifically, patients with habitual exercise reported improved sleep quality, being twice as likely to deny nocturnal awakenings and delayed sleep onset (OR 1.94, 95% CI 1.20 to 3.14), despite the same overall sleep duration (p = 0.49). Frequent exercisers were additionally 70% less likely to screen positive for depression (OR 0.30, 95% CI 0.12 to 0.75), with persistent association after controlling for self-reported chronic fatigue (OR 0.32, 95% CI 0.13 to 0.79) and higher educational attainment (OR 0.24, 95% CI 0.10 to 0.59).

Moderate and severe disease complexity were associated with exercise frequency in the univariate analysis, but did not reach statistical significance on multivariate analysis (moderate: OR 1.46, 95% CI 0.81 to 2.64; severe: OR 0.87, 95% CI 0.47 to 1.60), largely owing to the confounding influence of race. A similar trend was not observed in patients with simple disease complexity, acknowledging their relative underrepresentation in the present study.

Of the original cohort, 74 patients completed stress testing within 1 year of their visit. Frequent exercisers (n = 46) demonstrated improved maximal exercise capacity, with a higher peak [VO_2] (p = 0.04), percent predicted VO_2 (p = 0.02), and heart rate reserve (HRR) (p = 0.03). Notably, the observed improvement in peak [VO_2] in frequent exercisers persisted after controlling for potential confounding cardiac factors, including age and peak heart rate (OR 1.10, 95% CI 1.00 to 1.20), as well as ventricular function (OR 1.07, 95% CI 1.00 to 1.13).

On subgroup analysis, after controlling for the effects of age, race, and exercise frequency, higher educational attainment was independently associated with improved functional capacity, with a higher peak [VO_2] (OR = 1.10, 95% CI 1.01 to 1.19), attained metabolic equivalents (OR 1.66, 95% CI 1.24 to 2.22), and HRR (OR 1.03, 95% CI 1.01 to 1.07). There was no independent association between depression and HRR (OR = 0.99, 95% CI 0.95 to 1.04), and higher rates of depression were not significantly predicted by lower educational attainment (OR 2.13, 95% CI 0.97 to 4.66).

Discussion

In adults with CHD, frequent exercise is associated with improved cardiopulmonary exercise capacity and reported psychosocial functioning. In the present study, increased physical activity levels were observed in patients with higher educational attainment and were associated with a decreased incidence of self-reported depression. Exercise frequency was notably independent of underlying cardiac disease complexity, highlighting the important influence of socioeconomical factors, over traditional physiologic parameters, on mental and physical health.

As previously reported,[3] adults with CHD do not achieve recommended levels of physical activity, with just over half of the present study population reporting habitual exercise. Although there are known physiologic limitations inherent to each underlying cardiac lesion and its related repair,[4,11] at the population level, socioeconomical factors appear to contribute and may even predominate in influence. Specifically, in the

Table 1
Demographic and clinical variables of the patient population

Variable	Data points (number)	All patients (n = 446)	Frequent exerciser		p value
			Yes (n = 254)	No (n = 188)	
Male	446	209 (47%)	126 (49%)	83 (44%)	0.33
BMI (kg/m^2)	446	25 ± 4.7	25.4 ± 4.6	25.1 ± 5.1	0.54
Age (years)	446	32 ± 10	32.7 ± 10.4	31 ± 9.5	0.08
Race	442				<0.001
White		272 (62%)	174 (70%)	97 (52%)	
Black		98 (22%)	38 (15%)	58 (31%)	
Other		72 (16%)	38 (15%)	33 (17%)	
Disease complexity	446				0.04
Simple		70 (16%)	38 (15%)	31 (17%)	
Moderate		227 (51%)	142 (56%)	83 (44%)	
Severe		149 (33%)	74 (29%)	74 (39%)	
Education	437				0.003
High school		98 (22%)	45 (18%)	53 (29%)	
Some college		94 (22%)	44 (18%)	49 (26%)	
Associate degree		25 (6%)	13 (5%)	12 (6%)	
Bachelor's degree		220 (50%)	148 (59%)	71 (38%)	
Anxiety score (≥3)	437	50 (11%)	28 (11%)	22 (12%)	0.77
Depression score (≥3)	437	27 (6%)	6 (2%)	21 (12%)	<0.001
Sleep quality	427				
Sleep duration (hours)a		7.0 ± 1.4	7.0 ± 1.7	7.1 ± 1.1	0.49
Delayed sleep onset	437	70 (16%)	38 (15%)	41 (23%)	0.04
Nocturnal awakenings	436	67 (15%)	27 (11%)	40 (22%)	<0.001
CPET	74				
VO_2 Max (ml/min/kg)		27.2 ± 8.7	28.8 ± 8.5	24.6 ± 8.4	0.04
VO_2predicted (%)		75 ± 17.8	78.7 ± 16.6	68.4± 18.3	0.02
Heart rate reserve		87.1 ± 24.0	92 ± 22.1	79 ± 25.4	0.03
Cardiac function	438				
Ejection fraction (%)		60 ± 8	60 ± 8	60 ± 9	1.0

BMI = body mass index; CPET = cardiopulmonary exercise test; VO2 = measured oxygen consumption.
Data are represented as means ± standard deviation for continuous variables and n (%) for categorical variables.

Table 2
Overview of cardiac diagnoses in frequent and nonfrequent exercisers

Cardiac diagnosis	Number (%)	Frequent exerciser	
		Yes (n= 254)	No (n = 188)
Anomalous pulmonary venous return/sinus venosus atrial septal defect	19 (4%)	14	4
Isolated atrial or ventricular septal defect	33 (7%)	19	13
Atrioventricular septal defect	30 (7%)	17	13
Coarctation of aorta	30 (7%)	21	9
Transposition of the great arteries	29 (7%)	16	13
Congenitally corrected transposition of the great arteries	7 (2%)	5	2
Coronary artery anomalies	12 (3%)	9	3
Double outlet right ventricle/double inlet left ventricle	11 (2%)	5	6
Ebstein anomaly	11 (2%)	8	3
Hypertrophic obstructive cardiomyopathy/septal hypertrophy	3 (<1%)	1	2
Isolated aortic valve disease	42 (9%)	23	19
Isolated mitral valve disease	12 (3%)	5	7
Repaired patent ductus arteriosus	1 (<1%)	1	0
Isolated pulmonary valve disease	18 (4%)	11	7
Truncus arteriosus	5 (1%)	2	3
Tetralogy of Fallot	74(17%)	38	36
Univentricular physiology	41 (9%)	19	21
Ventricular septal defect with related defects	31 (7%)	20	10
Other lesions	37 (8%)	20	17

present study, higher educational attainment was found to be a strong predictor of exercise frequency, as well as was independently associated with improved exercise capacity.

Although this association has not been previously well-studied, similar findings were noted in a British cohort of adults with CHD, which documented a strong and independent

Table 3
Univariate model of factors associated with frequent exercise

Variables	Odds ratio	95% confidence interval	p Value
Race			
White	2.15	1.45-3.18	<0.001
Black	0.40	0.25-0.64	<0.001
Other	0.84	0.50-1.40	0.51
Disease complexity			
Simple	0.89	0.53-1.49	0.66
Moderate	1.60	1.09-2.34	0.01
Severe	0.63	0.42-0.94	0.02
Associate degree or higher	2.13	1.45-3.15	<0.001
Depression (score ≥3)	0.19	0.07-0.47	<0.001
Delayed sleep onset	0.60	0.37-0.97	0.04
Nocturnal awakenings	0.41	0.24-0.70	0.001

correlation between educational attainment, peak [VO_2], and HRR. The observed effect on peak [VO_2] was additionally incremental, with a more than 10% difference in peak [VO_2] noted between the extremes of economic status.[12] When extrapolated to patients with acquired heart disease, a similar relation is observed between education attainment and exercise capacity.[13] Further, this association additionally appears to hold prognostic significance in acquired heart disease, as a higher HRR was found to exert disproportionate influence on the observed association between socioeconomic status (SES) and all-cause mortality.[14]

The relation between SES, of which educational attainment remains a key abiding measure,[15] and exercise tolerance, is likely complex, encompassing the effects of differential social mobility, with resultant chronic psychosocial stress,[16] and physical deconditioning.[17] In broader terms, the association between SES and functional capacity may reflect changes in overall self-efficacy, of which exercise is a modifiable variable.[18] Namely, advanced education not only facilitates improved comprehension of traditional cardiovascular risk factors,[19] but is also associated with more positive illness perceptions, improved coping strategies, and better self-reported quality of life.[9] This ultimately results in improved perceived health status, which is known to be independently and positively correlated with exercise self-efficacy.[20,21]

Improvements in self-efficacy may additionally contribute to the improved psychosocial functioning observed in frequent exercisers. It has previously been shown that adults with CHD experience significant psychologic stress, with 1 in 3 patients reporting symptoms of anxiety and depression.[22] In the present study, the overall incidence of reported depression mirrored that of the general population; however, there was a noted discrepancy with respect to physical activity levels, with frequent exercisers being nearly 70% less likely to have positive depression screens.[23] Although this effect could be confounded by the simultaneous higher rates of educational achievement observed in frequent exercisers, especially given the known inverse relation between education level and major depression within the general population,[24] this association remained significant even after controlling for educational attainment.

The benefits of regular physical activity on mental health outcomes have previously been well-established in adults with CHD.[10,18] Additionally, psychosocial variables appear to exert an even stronger influence on perceived health status when compared with traditional cardiac variables,[7] as was reproduced in the present study. Specifically, there was no observed association between exercise frequency, cardiac lesion complexity, and systemic ventricular function. Although there is a known reduction in baseline exercise capacity in adults with CHD,[3,4] this effect appears to be independent of underlying cardiac performance,[25] highlighting the likely complex interactions of other

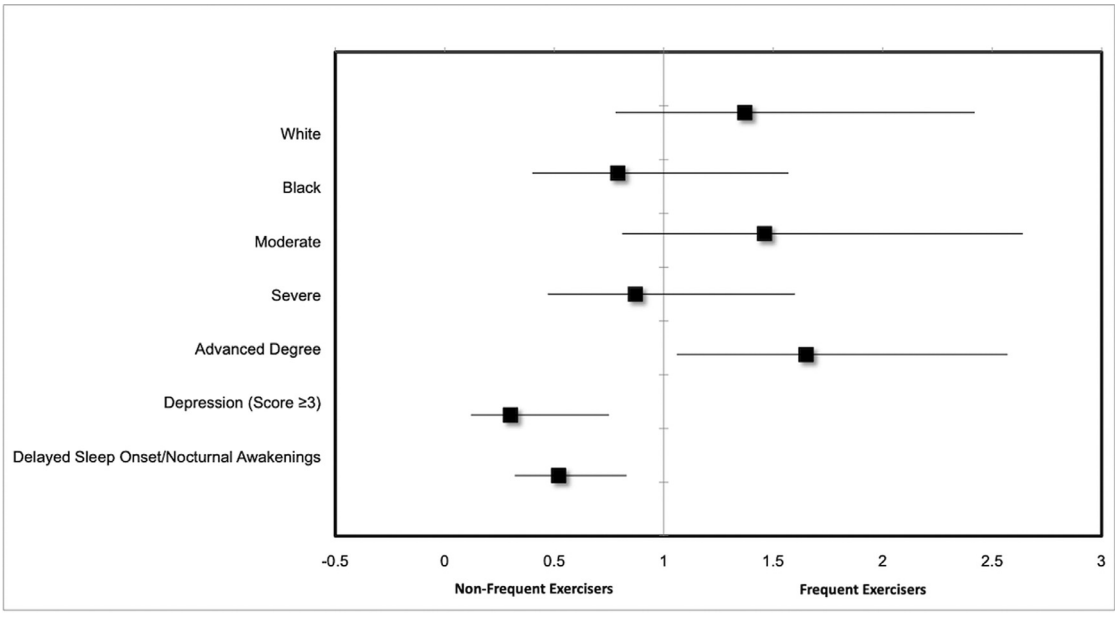

Figure 1. Multivariate model of factors associated with frequent exercise. Values depicted as odds ratios with 95% confidence intervals. Frequent exercisers were more highly educated, had a decreased prevalence of depression, and reported improved sleep quality. Exercise frequency was not associated with race or cardiac disease complexity.

physical and psychosocial variables on exercise tolerance. Given the baseline reduction in both functional capacity and self-reported quality of life in adults with CHD, these findings highlight the important role providers can have as educators, improving patients' self-efficacy with prescriptions for regular exercise. Although the characteristics of an optimal and effective prescription still require further elucidation, adults with CHD stand to benefit from interventions that are individualized, repeated, and multidisciplinary in nature.

The limitations of this study are largely related to study design, with its cross-sectional nature limiting potential causal inference. There is an additional potential for recall bias, with associated implications for external validity, when utilizing patient-reported outcomes. However, self-report questionnaires have well-documented validity in assessing discrete levels of physical activity and are routinely used in clinical investigations.[26] Similarly, as the study was performed at a tertiary care center and consisted of a convenience sample, it may lack generalizability to the general adult congenital population. Lastly, given that only a minority of patients from the original cohort had undergone cardiopulmonary exercise testing within the specified time period, the potential influence of other variables on exercise capacity cannot be excluded.

In conclusion, frequent exercise in adults with CHD is associated with improved cardiopulmonary exercise capacity and psychosocial functioning, irrespective of underlying cardiac disease complexity and severity. Given the benefits of habitual exercise in this population, additional counseling and education should be provided to all patients with CHD regarding the importance of regular exercise.

Disclosures

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