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Comparison of Upright and Semi-Recumbent Postures for Exercise Echocardiography in Healthy Children

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This study was conducted in 20 healthy children to compare a semi-recumbent posture using back support with an upright posture for exercise echocardiography. It was found that a semi-recumbent position with back support is superior to an upright position, with no difference in physiologic measurements. ©2005 by Excerpta Medica Inc.

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Exercise echocardiography in children is difficult because of movement artifacts. We conducted this study to determine if a semi-recumbent posture with back support is superior to an upright posture for exercise echocardiography in children and to compare echocardiographic measurements from a semi-recumbent posture with measurements from an upright posture.

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The research protocol was approved by the institutional review board of the University of California, Irvine, Medical Center. We recruited 20 healthy children, 8 to 10 years of age from local elementary schools. Equal numbers of male (n = 10) and female children were recruited. All subjects were healthy, with no known neurologic, cardiac, pulmonary or musculoskeletal disease, or active infection. Parents/guardians and the subjects provided written consent and assent to participate in this study.

The study subjects performed exercise tests on electromagnetically braked cycle ergometers suitable for children. Each subject performed 2 constant work-rate exercise tests: 1 on an upright cycle ergometer (Ergoline 800, SensorMedics, Yorba Linda, California) and the other on a semi-recumbent cycle ergometer (Cat Eye EC 3700, Cat Eye Co., Inc., Osaka, Japan). The back support of the semi-recumbent cycle was at 70°. The order of the 2 exercise tests for each subject was determined in a random fashion. Echocardiograms were obtained at rest and during the steady state of constant work-rate exercise.

The exercise test protocol began with a 3-minute period of unloaded cycling, followed by initiating the work rate at 10 W. The work rate was continuously increased by 10 W every minute until the subject's heart rate reached 140 to 150 beats/min, which is approximately 70% of the peak heart rate for healthy children 8 to 10 years of age. Once the steady state

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TABLE 1 Comparing Echocardiographic Measurements at Rest Between Semi-recumbent and Upright Postures

Exercise Measure	Recumbent Posture	Upright Posture	p Value
LV end-systolic dimension (mm)	29 ± 3	29 ± 4	0.85
LV end-diastolic dimension (mm)	41 ± 4	40 ± 4	0.27
LV fraction of shortening (%)	31 ± 4	29 ± 3	0.19
LV ejection fraction (%)	67 ± 6	64 ± 5	0.15
Left atrial dimension (mm)	25 ± 7	24 ± 7	0.78
Ascending aorta diameter (mm)	21 ± 5	21 ± 5	0.90
Aortic valve annulus (mm)	17 ± 4	17 ± 5	0.63
LV end-systolic area (cm^2)	16 ± 3	15 ± 3	0.40
LV end-diastolic area (cm^2)	24 ± 5	23 ± 4	0.38
LV outflow peak velocity (m/s)	1.05 ± 0.17	1.05 ± 0.17	0.98
LV outflow mean gradient (mm Hg)	1.9 ± 0.7	2.0 ± 0.6	0.92
LV outflow time-velocity integral	0.17 ± 0.04	0.17 ± 0.03	0.69
Mitral E wave (m/s)	0.92 ± 0.13	0.86 ± 0.11	0.10
Mitral A wave (m/s)	0.57 ± 0.09	0.57 ± 0.12	0.89
Mitral E/A ratio	1.7 ± 0.3	1.6 ± 0.3	0.34
Stroke volume (ml)	48 ± 11	42 ± 12	0.11
Cardiac index ($L \cdot min^{-1} \cdot m^{-2}$)	3.5 ± 1.1	3.1 ± 1.1	0.22

TABLE 2 Comparing Echocardiographic Measurements During Exercise Between Semi-recumbent and Upright Postures

Exercise Measure	Recumbent Posture	Upright Posture	p Value
LV end-systolic dimension (mm)	26 ± 3	25 ± 2	0.55
LV end-diastolic dimension (mm)	41 ± 5	41 ± 4	0.83
LV fraction of shortening (%)	39 ± 5	38 ± 3	0.45
LV ejection fraction (%)	77 ± 5	76 ± 4	0.56
Left atrial dimension (mm)	27 ± 7	26 ± 8	0.76
Ascending aorta diameter (mm)	21 ± 5	21 ± 5	0.93
Aortic valve annulus (mm)	17 ± 4	18 ± 4	0.78
LV end-systolic area (cm^2)	14 ± 3	13 ± 2	0.44
LV end-diastolic area (cm^2)	24 ± 4	23 ± 3	0.40
LV outflow peak velocity (m/s)	1.48 ± 0.26	1.53 ± 0.20	0.55
LV outflow mean gradient (mm Hg)	3.7 ± 1.5	3.8 ± 0.9	0.79
LV outflow time–velocity integral	0.20 ± 0.03	0.20 ± 0.03	0.65
Mitral E wave (m/s)	1.26 ± 0.10	1.29 ± 0.13	0.42
Mitral A wave (m/s)	0.71 ± 0.16	0.70 ± 0.19	0.84
Mitral E/A ratio	1.9 ± 0.5	1.9 ± 0.4	0.67
Stroke volume (ml)	55 ± 18	54 ± 15	0.77
Cardiac index ($L \cdot min^{-1} \cdot m^{-2}$)	7.7 ± 2.0	7.1 ± 2.8	0.45

was achieved, the subject continued pedaling the cycle at a rate 60 revolutions/min for about 5 to 10 minutes, during which echocardiograms were obtained. The recovery phase was recorded for up to 5 minutes.

Twelve-lead electrocardiograms were continuously recorded, and blood pressure was measured by sphygmomanometry every 2 minutes. Heart rate was measured beat by beat from the electrocardiograms. At the end of 2 exercise tests, the subject was asked which test (upright or semi-recumbent cycle) he or she preferred.

Echocardiograms were obtained at rest and during exercise using an Acuson Cypress portable echocardiographic system with a 2-MHz multifrequency transducer (Acuson, Inc., Mountain View, California). The Cypress system records digital images and signals into its internal hard drive. All echocardiograms were obtained by the same sonographer, who was a registered diagnostic cardiac sonographer with >3 years of pediatric experience. Standards for an adequate study from the parasternal and apical views were established. The sonographer was expected to obtain adequate images and signals of the defined views according to the specified standards in the shortest time possible. For each study, the time to obtain adequate image and signals was recorded.

The following specific echocardiographic measurements were done off-line on recorded images and Doppler signals: (1) from M-mode signals of the parasternal long-axis view, left atrium and ascending aorta dimensions, left ventricular (LV) posterior wall and ventricular septum thickness in systole and diastole, LV end-systolic dimension and LV end-diastolic dimension, and LV shortening fraction ([LV end-diastolic dimension − LV end-systolic dimension] / LV end-diastolic dimension × 100%); (2) from 2-dimensional images of the parasternal long-axis view, aortic valve annulus; (3) from apical 4- and 2-chamber views, LV end-diastolic area and LV end-systolic area using Simpson's rule; (4) from the apical 5-chamber view, aortic outflow pulse-wave Doppler signal for the calculation of the time–velocity integral; and (5) mitral valve inflow pulse-wave Doppler signal for determining the E-/A- wave ratio. Stroke volume (SV) was derived from the difference between LV end-diastolic and end-systolic volumes (SV = LV end-diastolic volume − LV end-systolic volume). Cardiac output was calculated on the basis of SV and heart rate.[1]

All echocardiographic studies were reviewed by a cardiologist who was blinded to the subject identifiers and in which posture the studies were performed. Each study was assigned a score from 1 to 5 for its image and signal quality and adequacy for the previously described measurements and analysis. A score of 1 indicated the worst quality study, in which no measurements could be made. A score of 2 indicated a bad quality study in which some measurements could be made. A score of 3 indicated an acceptable quality study in which most measurements could be made. A score of 4 indicated a good quality study in which all measurements could be made. A score of 5 indicated an excellent-quality study.

All variables were examined for distribution characteristics. Summary statistics, including mean, median, SD, proportion, and frequency, were calculated, depending on the distribution characteristics of the variables. Categorical data were analyzed using the chi-square test or Fisher's exact test. Continuous variables were compared between groups using the paired

Student's *t* test for comparing 2 groups. Statistical significance was determined at a p value of <0.05. Data analysis was assessed using SPSS version 11 for Windows (SPSS, Inc., Chicago, Illinois).

The time to acquire adequate images (a continuous variable) was compared between semi-recumbent and upright postures using a paired Student's *t* test. We compared the score of study quality between semi-recumbent and upright postures using the Wilcoxon rank-sum test. We compared children's preferences for the 2 postures for exercise using a chi-square test. Intraobserver variability was assessed by repeated measures and had a correlation coefficient of 0.96.

Ten male children and 10 female children completed the study. The mean age was 9.2 ± 0.8 years, the mean height was 136.2 ± 6.6 cm, the mean weight was 34.1 ± 8.6 kg, and the mean body surface area was 1.13 ± 0.15 m^2. For the order of the tests, 11 subjects started with the semi-recumbent ride first and 9 subjects with the upright ride first, by random selection.

The work rate required to maintain a heart rate of 140 to 150 beats/min was similar between the upright and semi-recumbent cycles (38.5 ± 9.9 and 38.9 ± 12.1 W, respectively, p = 0.90). There was no difference in blood pressure at rest between the upright and recumbent postures. Peak systolic blood pressure during exercise was 127 ± 17 mm Hg for the semi-recumbent cycle and 123 ± 14 mm Hg for the upright cycle (p = 0.60). Thirteen subjects (65%) preferred the semi-recumbent cycle, and 7 subjects preferred the upright cycle (35%), but the difference was not statistically significant (p = 0.14). There was no relation between the order of rides and preference for the rides. Echocardiographic acquisition time was significantly shorter for semi-recumbent studies (129 ± 26 seconds) than upright studies (151 ± 30 seconds, p = 0.02). The quality of echocardiograms at rest was similar between the semi-recumbent and upright studies (p = 0.16), but the quality of exercise echocardiograms in semi-recumbent studies was significantly better than in upright studies (p = 0.03).

When comparing echocardiographic measurements at rest, we found no statistically significant differences in all the measurements listed in Table 1 between the upright and semi-recumbent postures. The exercise echocardiographic measurements were also compared between the upright and semi-recumbent postures. As listed in Table 2, there were no statistically significant differences in the measurements between the upright and semirecumbent postures. It is important to note that some of the measurements, such as echocardiographic mitral E wave and SV at rest, approached statistical difference. The sample size of 20 in the present study may have been underpowered to show the differences in some of the measurements.

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Exercise echocardiography is a common clinical practice to assess cardiac response to exercise.[2,3] Although the "American College of Cardiology/American Heart Association Clinical Competence Statement on Echocardiography"[4] provides general guidelines for the knowledge and training required to perform and interpret stress echocardiography, the clinical practice of stress echocardiography may vary significantly among pediatric cardiology programs. Furthermore, the physiologic measures of stress echocardiography may also differ between exercise stress and pharmacologic stress.[5] For example, peak heart rate is generally higher in exercise stress than pharmacologic stress,[5] and there are more ventilatory responses in exercise stress tests. Therefore, echocardiography during exercise may provide more clinically relevant information than dobutamine stress tests.

Echocardiographic studies in children during exercise are more complicated because of the difficulties in maintaining a stable position, faster respiration, and an inability to cooperate with sonographers. Of these factors, the performance of exercise echocardiography may be improved by changing the exercise settings. For example, studies performed while subjects are on cycle ergometers are generally better than studies performed on treadmills because the upper body is more stable.[6] For the same reason that the upper body is more stable in a semi-recumbent posture with back support, exercise studies on semi-recumbent cycle ergometers may be better than in an upright posture.

Cardiac physiology may change with different postures by affecting the loading condition of the heart.[7,8] Studies have compared echocardiographic measurements between upright and supine postures. Pulmonary venous return may also be affected by the body position of the subject.[9] In a study of 10 male trained cyclists, Franke et al[10] found that the peak ejection velocity and acceleration measured by continuous-wave Doppler at LV outflow was significantly greater in the supine position than in the upright position. In the present study, we did not find a difference in LV outflow peak velocity or the time–velocity integral between the semi-recumbent and upright positions. The study by Franke et al[10] was in young adults who were trained cyclists, and the comparison was between supine and upright positions. Therefore, differences in study design may make the results not generalizable to other population in different settings.

In the present study, we chose a 70° semi-recumbent posture, which is only 20° from an upright angle, to compare with an upright posture and found no differences in echocardiographic measurements. However, with this semi-recumbent posture and back support, we found that children were able to maintain torso stability to allow the acquisition of better quality images in a shorter period of time. Therefore, the clinical implication for these findings was that children tolerate semi-recumbent exercise well, with better study quality and no difference in echocardiographic measurements compared with upright exercise.

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