Effect of Arm and Leg Exercise on Heart Autonomic Function in Children

Mehdi Ahmadian¹, Valiollah Dabidi Roshan¹*, Mozdeh Dabirian²

¹-Department of Sport Physiology, College of Physical Education and Sport Sciences, University of Mazandaran, Babolsar, Iran
²-Cardiology and Fellowship in Echocardiography, Department of Cardiology, Faculty of Medicine, Mazandaran University of Medical Science, sari, Iran

Corresponding Author, Email: vdabidiroshan@yahoo.com

Abstract

Purpose: The ability of the human organism to recover its autonomic balance soon after physical exercise cessation has an important impact on the individual's health status. Heart rate variability widely used as a non-invasive technique at rest, during and after exercise for the assessment of the autonomic nervous system activity on the heart and the balance between the sympathetic and parasympathetic systems. Thus, the purpose of the present study was to investigate the dynamics of HRV response during or the time course of HRV recovery following the arm crank and cycle ergometer protocols in active children.

Materials and Methods: Twelve active children volunteered to participate in this study and HRV was assessed from calculation of the mean R-R interval measured on ECG at each phases of exercise and recovery period. We analyzed the overall effect of training on HRV at rest and in the recovery period for each protocol separately by ANOVA with repeated measures. Also, we tested whether values at different time intervals by means of a Tukey’s post hoc test. A paired t-test was used to assess the differences between arm crank and cycle ergometer protocols. Statistical significance was set at p < 0.05

Results: HRV significantly decreased during and immediately after arm crank and cycle ergometers protocols. Moreover, HRV was significantly higher in the arm ergometer than leg ergometer protocols.

Conclusions: These results suggest that vagal reactivation and that restoration of autonomic HR control is faster in arm exercise than leg exercise.

Keywords: Hear rate variability, Arm exercise, Leg exercise, Children.

Introduction

The ability of the human organism to recover its autonomic balance soon after physical exercise cessation has an important impact on the individual's health status (De Oliveira et al., 2013). Heart rate variability (HRV) is widely used as a non-invasive technique at rest, during and after exercise for the assessment of the autonomic nervous system (ANS) activity on the heart and the balance between the sympathetic and parasympathetic systems (Bailón et al., 2010; Vuksanovic, 2005). It is an interesting tool in various situations such as physical exercise, overtraining, orthostatic tilt test or cardiovascular diseases, because it allows obtaining a reflect of the autonomic nervous system modulation (Leti and Bricout, 2013). Studies have shown that there is a decrease in HRV with advancing age and that this reduction is associated with the emergence or worsening of cardiovascular disease, increasing the risk of death from all causes (Trevisani et al., 2012). Furthermore, recent reports suggest impaired heart rate variability has been recognized as a marker of severity of heart disease and a predictor of cardiovascular mortality and morbidity (Bailón et al., 2010; Leti and Bricout, 2013).

Some studies indicate that HRV is linked with aerobic fitness and physical activity. In addition, it has already been observed that after an aerobic training period, subjects showed higher levels of aerobic capacity - as indexed by VO2max- and higher levels of vagally mediated cardiac control-as indexed by HRV (Leti and Bricout, 2013). While, the cardioprotective role of physical exercise is a consensus in the literature and is
considered important in maintaining health (Myllymäki et al., 2012; Leti and Bricout, 2013) in all age groups (Trevizani et al., 2012), effects of exhaustive aerobic exercise little is known on HRV in children. Furthermore, the studies have mostly focused on HRV during exercise (Myllymäki et al., 2012), post-exercise ANS activity or the time course of HRV recovery after the arm crank and cycle ergometer exercise have not been well investigated. On the other hand, few studies have shown that older adults engaged in physical activity have higher levels of HRV than sedentary ones.

In contrast, there is evidence that aerobic training programs do not exert significant influence on HRV indices in middle-aged individuals (Trevizani et al., 2012). However, to our knowledge no articles have yet been published investigating effect of the arm crank and cycle ergometer acute exercises on HRV during and after the aforesaid exercise in children. Despite the fact that more and more children are engaged in intensive training programs, the question arises if such intensive training abolishes the beneficial effects on the cardiac autonomic nervous system during childhood. From a preventive standpoint, it is important to know if beginning intensive training in childhood induces decreased HRV (Vinet et al., 2005) and also the circulatory response to exercise varies with the type of work and the muscle group involved. In particular, maximal cardiac output and maximal heart rate have been reported to be lower during upper body work when compared with lower body work and also demonstrated that peripheral vascular resistance is significantly higher during arm work than during leg work (Robergs and Roberts, 2000).

There is very limited evidence focusing on the beneficial effect of exercise training on HRV during childhood. Although, recent studies focused on the impact of training in pathological children, fewer studies investigated the effect of training on HRV in healthy children. Thus, the purpose of the present study was to investigate the dynamics of HRV response during or the time course of HRV recovery following the arm crank and cycle ergometer protocols in active children.

Materials and Methods

Subjects

The type of study was semi-experimental. The experimental protocol of the current study approved by department of physiology, university of Mazandaran. Twelve active children volunteered to participate in this study. All participants were in self-reported good health, without medications and had no medical histories from cardiovascular. Before the start of the study, the adolescents’ parents signed the written informed consent form. All parents completed a medical questionnaire to ensure that their children were not taking any drugs and/ or medications and were free of cardiac, respiratory, renal, or metabolic diseases. Participants were asked to avoid strenuous exercise for 2 days before the measurement sessions, follow their normal diet for 2 days before the tests, to abstain caffeine drinks on the day of the study, and to have sufficient rest the night before the study. Height, weight, BMI of Subjects were measured with a body composition analyzer (X-SCAN PLUS II, Jawon Medical, Kyungsan City, Korea). Furthermore, VO2peak and HRmax were estimate with 1 mile walking Rockport test.

Exercise protocols

Participants were familiarized with the testing equipment and procedures used in the study and provided informed consent prior to participation and after that, participants performed a continuous incremental protocol test on a cycle ergometers (monarkergometric 894 E, Monark, Varberg, Sweden) and after 1 hours recovery period, they performed an arm crank ergometer test (monarkergometric 891 E, Monark, Varberg, Sweden). The protocol for upper body was designed by Sawka et al (1983) and that for lower body was developed by Åstrand (1965). The test was preceded by a 10 minute warm up period. The initial power output was 25 W for the arm test and 50 W for the leg test. For both tests, power output was increased by 25 W every two minutes. The pedal rate was set at 50 rev/min for both tests; All Participants were verbally encouraged to continue exercise until volitional exhaustion. The termination criterion is simply when the subject fails to maintain a target crank frequency for 15 seconds.

Evaluation of heart rate variability

The measurements were performed in a quiet room with stable temperature and the same time of day between 0800 hours and 1400 hours. The participants rested quietly for 2 min in the seated position on ergometers and standard ECG and heart rate monitor (Custo Diagnostic , cardio 100,Germany) was used to collect continuous R-R intervals during the rest, tests and recovery period which were stored on computer for later analysis. Then after 2min of rest, participant carried out an incremental cycle ergometer tests as previously
described(Sawka et al.,1983, Åstrand,1965 ), HR from the ECG was monitored continuously and when participants finished the tests, they followed a period of 10min of inactive recovery. During this inactive recovery period, HR was monitored continuously from the ECG. Then for analyze of heart rate variability, every 1 min continuous R-R intervals (Rajendra et al., 2006) on the before, during, immediately, 5 and10 min after tests were exported to analyze with Kubios’s HRV analyze software (Finland, Kuopio, version 2.1) and in the time domain, mean RR was determined at rest, during and recovery period of the tests.

**Statistical analysis**

All data have been expressed as mean ± SD. The distribution of each variable was examined with the Kolmogorov–Smirnov normality test and after that we analyzed the overall effect of training on HRV at rest and in the recovery period for each protocol separately by ANOVA with repeated measures. Also, we tested whether values at different time intervals by means of a Tukey’s post hoc test. A paired t-test was use to assess the differences between arm crank and cycle ergometer protocols. Statistical significance was set at p < 0.05. All data analysis was carried out using Statistical Package for the Social Sciences (SPSS version 20.0 for Windows).

**Results**

Table 1 illustrates the anthropometric characteristics, \(\text{vo2peak}\) and \(\text{HR}_{\text{max}}\) of study population. Maximal heart rate at rest, during and immediately after exercise is shown in Figure 1. The heart rate increased significantly after arm crank and cycle ergometer protocols in during (114.3±16.9 Vs 145.7±15.5 beats min\(^{-1}\), p<0.05) and immediately (156.4±24 Vs188.8±13.7 beats min\(^{-1}\),p<0.05) after exercise compared to rest. Pair t-test revealed the increase in HR was higher during (p < 0.05, df=11, t= 6.701) and immediately (p < 0.05, df=11, t= 5.129) after exercise in the cycle ergometer than the arm crank protocols.

**Table 1: Anthropometric characteristics, \(\text{vo2peak}\) and maximal heart rate of study population**

<table>
<thead>
<tr>
<th>Subject Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age(years)</td>
<td>12.67±1.96</td>
</tr>
<tr>
<td>Weight(kg)</td>
<td>48.3± 15.9</td>
</tr>
<tr>
<td>Height(cm)</td>
<td>154.83 ± 11.56</td>
</tr>
<tr>
<td>BMI(kg/m(^2))</td>
<td>19.63± 3.86</td>
</tr>
<tr>
<td>(\text{HR}_{\text{max}}) (beats min(^{-1}))</td>
<td>207.3± 1.96</td>
</tr>
<tr>
<td>(\text{VO2peak}) (mL kg(^{-1}) min(^{-1}))</td>
<td>69.92± 6.81</td>
</tr>
</tbody>
</table>

BMI= Body mass index. \(\text{HR}_{\text{max}}\)= maximal heart rate .\(\text{VO2peak}\)=peak oxygen uptake.

**Figure 1: Maximum Heart rate in rest, during and immediately after arm crank and cycle ergometer protocols.* p<0.05 resting phase, #p<0.05 versus arm crank**
The results of variations in HRV at rest, during exercise, immediately after arm crank and cycle ergometer protocols reported in Figure 2. HRV in resting was similar between upper and lower body exercise. HRV was significantly decreased during (429.6±90.2 vs 323±29.2 milliseconds, \( p<0.05 \)) and immediately (495.5±93.4 Vs 362.6±38.5milliseconds, \( p=0.05 \)) after exercise compared with resting values before arm crank and cycle ergometer protocols.

In contrast, there was no significant difference in HRV between during (429.6±90.2 Vs 495.5±93.4milliseconds, \( p=0.359 \)) and immediately (323±29.2 Vs 362.6±38.5 milliseconds, \( p=0.507 \)) after exercise in both of protocols. Furthermore, Results of paired t-test Revealed, decrease in HRV was significantly higher in during (\( p<0.05 \), \( df=11 \), \( t=4.428 \)) and immediately (\( p<0.05 \), \( df=11 \), \( t=4.824 \)) after exercise compared to resting values on lower body exercise.

**Figure 2:** Heart rate variability at rest, during and immediately after exercise of arm crank and cycle ergometer protocol. *\( p<0.05 \) versus resting phase

Additionally, Figure 3 shows the variations of HRV during recovery period after arm crank and cycle ergometer protocols. There was no significant decrease at 5(600.9±114.9 millisecond, \( p=0.828 \)) and 10 (620.6±76 millisecond, \( p=0.987 \)) min of recovery times compared to resting values after upper body exercise in HRV. Whereas, HRV was significantly decreased at 5(538.3±65.5 millisecond, \( p<0.05 \)) and 10 (560.1±62.6 millisecond, \( p<0.05 \)) min of recovery period times after lower body exercise compared to rest values.

Moreover, there was no significant difference in HRV between 5(600.9±114.9 vs 620.6±76 milliseconds, \( p=981 \)) and 10 (538.3±65.5 vs 560.1±62.6 millisecond, \( p=904 \) ) min recovery times after arm crank and cycle ergometer protocols and also pair t-test shows significant difference in HRV during recovery period between arm crank and cycle ergometer protocols. The decrease in HRV was higher in cycle ergometer versus arm crank protocols at 5(\( p<0.05 \), \( df=11 \), \( t=2.738 \)) and 10(\( p<0.05 \), \( df=11 \), \( t=5.592 \)) min of recovery period times.
Figure 3: Heart rate variability at rest and recovery periods of arm crank ergometer protocols.* p<0.05 versus arm crank at same phase

It should be noted, decrease of HRV during exercise was higher than immediately after exercise and all recovery period times compared to rest values in both of protocols. By the way, in arm crank ergometer protocol, HRV just significantly decreased at during and immediately after exercise whilst in cycle ergometer protocol, HRV was decreased during and immediately after exercise and in all time of recovery period (Figure 4).

Figure 1: HRV at rest, midtest, immediately, 5 and 10 min recovery after arm crank and cycle ergometer protocols in children.

* p<0.05,**p<0.01 and ***p<0.001 versus resting phase. †P < 0.05, ††P < 0.01 and †††P < 0.001 versus immediately after protocol. #p<0.05##p< 0.01 and ###p<0.001 versus the same phase in arm crank.

Discussion and Conclusion

The assessment of HRV in response to exercise is a promising field in sports science. This study presented an assessment of HRV following two type of exercise (Arm Cranking and Cycling) in children. Our data demonstrate that HRV was significantly decreased during and immediately after exercise protocols compared to resting values.
These results are agree with previous studies that HRV was significantly decreased after high-intensity exercise (Fronchetti et al., 2007; Buchheit et al., 2007; Martinmaki and Rusko 2008). According to the literature, at the lower intensity level cardiac adjustments to exercise were mainly due to parasympathetic withdrawal. At the higher intensity level, parasympathetic outflow was negligible and sympathetic activation was substantially increased, but blood lactate still does not cumulate (Martinmaki and Rusko 2008). Furthermore, these results can be due to the increase in metabolic activity from mild or moderate dynamic exercise that leads to a decrease in the HRV during exercise (Muraki et al., 2004). Also these Results are Inconsistent with Yamamoto and Hughson (1991) and Nakamura et al (1993) who reported HRV (LF/HF ratio) increase during exercise. The controversial results may be due to differences in the units or methods or in the length of data collection (from 1 to 10 minutes). The sampling frequency during exercise is another important factor for accurate detection of beat-to-beat fluctuations in R-R intervals, which may contribute to the controversial findings.

Our finding also show HRV was higher in arm cranking compared to cycling exercise. These results are in line with Cottin et al (2004) who demonstrated that vagal measures of HRV were significantly greater during judo wrestling compared to cycling exercise at the same maximal HR (i.e. 182–184 beats min−1). However, this greater vagal activity seems unlikely as vagal modulations are absent at or near maximal exercise (Nakamura et al, 1993, Yamamoto and Hughson, 1991) with the reported HRV differences between modes possibly reflecting variations in non-neural factors such as respiration (Bernardi et al., 1990). Moreover, the greater HRV during upper body exercise may reflect greater respiratory-induced sinus arrhythmia as changes in respiration, particularly respiratory rate, have been reported to alter HRV (S. Leicht et al., 2008).

In conclusion, we demonstrated heart autonomic function during and immediately after cessation of arm and leg ergometers exhaustive protocols found a major influence of exercise intensity. HRV decreased during and immediately after exercise protocols. In addition, HRV was higher in arm ergometer than leg ergometer protocols. These results suggest that vagal reactivation and that restoration of autonomic HR control is faster in arm exercise than leg exercise.

References


