Aerobic Fitness, Heart Rate Recovery and Heart Rate Recovery Time in Indian School Children

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Abstract

Data on aerobic fitness and heart rate recovery in children are limited. This study was done to evaluate the relation between them in Indian school going children. Three hundred children of 7 to 10.5 years were recruited and their aerobic fitness was predicted using modified Harvard's step test (VO2max) and 20 meter shuttle test (VO2peak). The heart rate was monitored for 12 minutes post modified Harvard's step test. The difference between the maximum and the 1st minute HR was noted as HRR1 and the time taken to reach the resting heart rate was also recorded. VO2max was inversely correlated with HRR1 (r = –0.64, p<0.001). However, the partial correlation of the two was not significant (r partial = –0.037, p=0.55), indicating children with higher basal HR had higher HRR1 and that accounted for the observed association with aerobic fitness. Cox regression analysis showed that the recovery rate per unit time was 3% greater with increasing VO2max (HR=1.03, 95% CI:1.01 to 1.05, p=0.013). The heart rate parameters did not show any associat with VO2peak. This study demonstrates that there is no relation between VO2max and HRR1 after 3 minutes of modified Harvard’s step test in Indian children of 7 to 10.5 years. However, aerobic fitness is a positive predictor of heart rate recovery time in this group.

Introduction

Aerobic fitness (VO2max) is one of the important measures of physical fitness. VO2max is not only associated with physical (1) and mental well-being (2), but also predicts mortality (3). Emerging evidence suggests that the non-communicable diseases are steadily increasing in India due to epidemiological transition (4). Improved aerobic fitness can attenuate the risk factors for non-communicable diseases (NCDs) (5). Similarly, aerobic fitness can attenuate the metabolic syndrome scores in children (6). Moreover, improved aerobic fitness in children track into adulthood (7) and thereby expected to attenuate the incidence of NCDs. However, VO2max has not been as extensively studied in children as in adults, especially in India. Heart rate parameters like the resting heart rate, heart rate variability (HRV) (8) and heart rate recovery (HRR) after exercise are indices of autonomic nervous function (9), and are

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influenced by aerobic fitness (10). Heart rate recovery (HRR) is defined as the fall in heart rate after a bout of maximal or sub-maximal exercise (11-13). HRR reflects the functional capacity of autonomic nervous system, predominantly the parasympathetic component which is known to be high in physically fit individuals (9, 10). HRR is attenuated in various diseases like congestive cardiac failure (14), diabetes (15) and obstructive sleep apnea (OSA) (16). Heart rate recovery besides being an index of fitness and a predictor of mortality (17) can also be used to evaluate the training load in athletes (18, 19). Both VO\textsubscript{2max} and recovery heart rate are, thus, indices of fitness and parameters of health, and adults with higher aerobic fitness were found to have faster heart rate recovery (9). Children are generally fit and have faster heart rate recovery than adults (20). Hence, we hypothesize that in children interaction between aerobic fitness and heart rate recovery will be different from adults and we explored the relation between these parameters in the present study in Indian school children.

Materials and Method

The baseline data of a double blinded randomized nutritional intervention study done at St. John's Research Institute (prior to randomization), Bangalore, India, (21) were used for the present study. Three hundred children, 150 boys and 150 girls, of 7 to 10.5 years with Hb \geq 8 gm%, without any medical complications, normal lung function and within the BMI Z score for age of \geq 4.2 to +1.4 were included for the study. After obtaining parental consent and assent, they were examined by the study physicians. Anthropometric measurements were obtained by trained research assistants. Height was measured to the nearest 0.1 cm, standing barefoot with heels, buttocks and back touching the custom made calibrated stadiometer and head in Frankfurt plane. Weight was measured to the nearest 0.1 kg with school uniforms standing barefoot using a digital weighing scale (Salter - 9016, Kent, U.K.). BMI Z scores for age of the children were calculated using WHO standard charts (22). Triceps and calf skin-fold thickness of the children were measured using a standardized skin fold caliper to the nearest 0.2 mm (Holtain Ltd., Crymych, UK). The mid arm circumference (MAC) was measured using a tape measured to the nearest 0.1 cm, midway between the acromion and the olecranon process, while the subject was standing with the elbow flexed at 90\textdegree. Skin-fold thickness and MAC were recorded by trained nutritionists. The body fat percent was calculated using gender specific prediction equations (23). The fat mass and fat free mass were calculated using body fat percentage and whole body weight.

Lung function test (LFT) was performed in the standing posture using a mobile spirometer (Micro GP, Spirometer, Micro Medical Ltd., U.K.) which was calibrated with a standard syringe of known volume (3L). Blood was drawn from anterior cubital vein and hemoglobin level was estimated using spectrophotometer measurement of cyanmethemoglobin on ABX Pentra 60C+ (Horiba Medica) within 4 hours of collection.

Physical activity levels (PAL) in the children were ascertained using a modified physical activity questionnaire which was published earlier (24). Forearm muscle strength was assessed both in non-dominant and dominant hand using Jamar hydraulic hand dynamometer (SI instruments, Hilton, Australia) after adjusting the grip width for each child. After the above preliminary measurements, the aerobic capacity was estimated using 20 meter shuttle test (VO\textsubscript{2peak}) and modified Harvard’s step test (VO\textsubscript{2max}), with 48 hours of rest in between the tests, as described earlier (25).

20 meter shuttle test: Two cones were kept apart at 19 meters distance and two lines were drawn one meter from the cones with 17 meter distance between them. A custom made tape signal gave external pacing to complete each lap. The children walked at an initial speed of 4 km/hr and after each minute it increased by 0.5 km/hr. They ran in groups of 3 to 5 in order to give their full effort. When the child stopped voluntarily or unable to cross the lines two consecutive times, the time duration was noted. The aerobic fitness was estimated using the formula:

\[ \text{VO}_{2\text{peak}} = 31.025 + (3.328 \times \text{speed}) - (3.248 \times \text{age}) \]

(ml/kg/min) (25)
Speed: The speed at which last lap was run by the child and age is the age of the child in years.

Modified Harvard’s step: The test was performed on a custom made step of 15 cm height with 22 steps per minute for 3 minutes. The pacing was given using a metronome. Heart rate was manually recorded for 15 seconds within 5 seconds of completion. The aerobic fitness was estimated using the formula:

\[ VO_2 = (0.2 \times \text{stepping rate}) + (2.4 \times \text{stepping height} \times \text{stepping rate}) + 3.5 \]

\[ VO_{2\text{max}} = \frac{VO_2 \times \text{HR max}}{\text{HR observed}} \text{ (ml/kg/min)} \]

Where HR max = 220-age. (25)

Heart rate recovery and Heart rate recovery time: Pulse was manually recorded for the last 15 seconds of every minute and heart rates (in beats per minute) were calculated for twelve consecutive minutes post modified Harvard’s step test. The differences in the immediate HR and the first minute HR was noted as HRR1.

\[ \text{HRR1} = \text{maximum HR attained immediately post-test} - 1^{st} \text{ minute HR} \]

The difference between the consecutive heart rates were also calculated for the twelve minute to evaluate the trend in the heart rate fall. The time taken by each child to reach their corresponding basal heart rate was calculated and noted as heart rate recovery time.

Ethical clearance was obtained from the institutional ethical board, St. John’s National Academy of Health Sciences, Bangalore, India. Ref No. IERB/1/303 108 dated 09.05.2008.

Statistical analysis

Independent student “t” test was used to analyze the gender difference in age, physical characteristics, aerobic fitness, basal heart rate and first minute heart rate recovery. The association of anthropometric parameters and aerobic fitness with first minute heart rate recovery was examined using Pearson’s correlation coefficient. The confounding effect of basal heart rate in the association of aerobic fitness and first minute recovery heart rate was examined using partial correlation. Cox proportional hazard models were used to evaluate the factors involved in HR recovery time. The hazard ratio (95% Confidence Interval) is reported. Statistical significance was considered at p<0.05. Data was analyzed using SPSS version 17.

Results

The descriptive data of 274 children on whom complete and valid data obtained are given in Table I. The mean age of boys and girls were comparable. The height as well as the weight between boys and girls was not statistically different. However, boys had significant lesser BMI Z scores (p<0.001)

<table>
<thead>
<tr>
<th>TABLE I : Descriptive characteristics of the study population.</th>
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<tbody>
<tr>
<td><strong>Pooled</strong> (n=274)</td>
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<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Height (cms)</td>
</tr>
<tr>
<td>Weight (kgs)</td>
</tr>
<tr>
<td>BMI Z scores</td>
</tr>
<tr>
<td>FFM (kgs)</td>
</tr>
<tr>
<td>Fat percentage (%)</td>
</tr>
<tr>
<td>Basal Heart Rate (bpm)</td>
</tr>
<tr>
<td>VO_{2\text{max}} (ml/kg/min) *</td>
</tr>
<tr>
<td>VO_{2\text{peak}} (ml/kg/min) #</td>
</tr>
</tbody>
</table>

All data are expressed as mean and standard deviation, p value of independent sample test between genders.

FFM - Fat free mass, bpm - beats per minute.

* VO_{2\text{max}} – Aerobic fitness measured using modified Harvard’s step test.

# VO_{2\text{peak}} – Aerobic fitness measured using 20 meter shuttle test.
compared to girls. Boys had significantly higher fat free mass (p=0.002) and lower fat percentage (p<0.001) than girls. The basal heart rate of boys and girls were comparable. There was no significant gender difference in aerobic fitness estimated from both Harvard step test and 20 metre shuttle test. The other parameters which were measured for the primary study are out of scope for this paper.

The median values of the difference in two consecutive heart rates are depicted in the Fig. 1. The median value of differences between immediate and the first minute heart rate was 36 and the first and second minute was 4 bpm. The median values of the differences in consecutive heart rates reached zero from the third minute onwards. Age, body weight, fat free mass, and resting heart rate had a weak positive correlation with the first minute heart rate recovery (r<0.19, p=0.05 to p=0.001). There was no significant gender difference in the first minute heart rate recovery. $\text{VO}_{2\text{max}}$ was inversely correlated with the first minute recovery heart rate (r=0.64, p<0.001).

However, the partial correlation of the two was not significant ($r_{\text{partial}} = 0.037$, p=0.55), indicating children with higher basal heart rate had higher recovery and that accounted for the observed association with aerobic fitness. $\text{VO}_{2\text{peak}}$ measured from the 20 meter shuttle test also did not correlate with the first minute heart rate recovery.

Figure 2 shows the pattern of heart rate recovery time after the modified Harvard’s step test. From the total children of 274, 238 (86.9%) reached basal heart rate within the measured twelve minutes. There were 36 children who did not reached their basal heart rate within the observed twelve minutes accounting for 13.1% of analyzed data. 139 (50.7%) children reached basal heart rate within three minutes after completing the step test. Cox regression analysis showed that the recovery rate per unit time was 3% greater with increasing $\text{VO}_{2\text{max}}$ estimated using modified Harvard’s step test (HR=1.03, 95% CI:1.01 to 1.05, p=0.013). The recovery period was not associated with $\text{VO}_{2\text{peak}}$ measured from 20 meter shuttle run test.

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**Fig. 1**: The median value of the difference in heart rate between consecutive time points post modified Harvard’s step test.
Discussion

Gender difference in aerobic fitness had been elucidated in children, though very small (26). In our study this gender difference was not found, using both modified Harvard’s test and 20 meter shuttle test, and this could be due to the coefficient of variance associated with the prediction equations, random errors associated with manual heart rate measurements in predicting aerobic fitness and may also due to the homogeneity of the study population. The heart rate recovery after a bout of exercise is due to vagal reactivation (9), sympathetic withdrawal (9) and reduced venous return to the right heart, which in itself will reduce the direct stretch on SA node, thereby reducing the heart rate. Children have a faster recovery heart rate than adults after exercise and this could be due to their higher central cholinergic activity and lower circulating catecholamine (27). However, whether aerobic fitness is an independent determinant of recovery heart rate in children is unknown. Although this relation in children is conceivable, children are generally more physically fit than adults and the spread of data in children is restricted, making such associations more difficult to demonstrate. In adults studies had shown positive correlation between the aerobic fitness and heart rate recovery (9, 28). In training athletes after sessions of high intensity training (HIT) heart rate recovery is considered as a positive predictor of performance parameters (18). In our study though the children were found to have an inverse relation with the first minute heart rate recovery and aerobic fitness, when measured using modified Harvard’s step test, it did not persist after resting heart rate was included in the partial correlation model. The 20 meter shuttle test, which is a maximal exertion test, is a robust test and it also showed no correlation with the first minute heart rate. However, based on the literature review both these prediction equations are not validated in Indian children. Regression analysis showed that the chances of reaching basal heart rate increased by 3% with increasing aerobic fitness measured using modified Harvard’s step test. The aerobic fitness predicted using 20 meter shuttle test had no association with heart rate recovery time.

Resting HR was found to be a significant predictor of first minute heart rate recovery (HRR1) with weak positive correlation in the present group of children. This was contradictory, since vagally mediated resting heart rate and first minute heart rate recovery were
expected to be inversely correlated. Similarly, the chances of recovery to the basal heart rate were 2% greater with increasing basal heart rate. We are unable to explain these contradictory results. Studies in adults showed subjects returned faster to the basal heart rate if they had higher aerobic fitness after a maximal exercise (9, 10). This was considered as an index of fitness (10). However, these data could not be compared to the present study due to the differences in exercise intensity. In adults most of the studies done to evaluate heart rate recovery were on maximal exertion protocols (11, 12,). There are limited studies with submaximal protocols to evaluate heart rate recovery in adults (13), and this is even scarce among children. When prescribing submaximal exercise to study heart rate recovery, it would be appropriate to scale the intensity of exercise to each individual, based on their aerobic capacity. Fixed load exercise can have a confounding effect on heart rate recovery as well as on heart rate recovery time in subjects with different fitness levels. The lack of association between the aerobic fitness and the first minute recovery heart rate in this study could have been due to the limited spread of data and due to the confounding effect of fixed load exercise protocol. The other limitations of this study were manually recorded heart rates with random errors and predicted aerobic capacity rather than measured.

Conclusion

This study demonstrates that there is no relation between aerobic fitness and first minute heart rate recovery after a three minute modified Harvard’s step test in Indian children aged 7 to 11 years. However, the chances of reaching the basal heart rate increase by 3% with increasing aerobic fitness in this group.

Acknowledgments

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References

15. Neves VR, Kiviniemi AM, Hautala AJ, Karjalainen J, Piira...


