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Influence of Body Mass Index on Heart Rate Variability (HRV) in evaluating cardiac function in adolescents of a selected Indian population

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Abstract

Background: Heart Rate Variability (HRV) analysis is easy to perform, has good reproducibility and provides prognostic information about Coronary Heart Disease.

Objective: This work was devised to correlate exercise induced HRV with BMI and compare gender variability among healthy Indian children aged 13-20 years.

Methods: The Heart Rate Variability of sixty-five students in the 13-20 years age group was assessed by time-domain methods during resting and after exercise. On the basis of BMI, the subjects were grouped into T_1 group (BMI<18) and T_2 group (≥18). The HRV of these groups were analyzed. In addition, based on gender, male students were divided on the basis of BMI as follows: M1 group <18 and M2 group ≥ 18. Likewise females were grouped into F1 and F2 groups. The HRV of 3 male groups and 3 female groups were also separately analysed. A paired t- test was used for the dependent variables and an unpaired t-test was carried out for normally distributed variables using Statistical Package for Social Sciences (SPSS) 11.0 for windows.

Results: Females showed higher HRV than males during resting condition. But immediately after exercise, the HRV increased in all groups and there was no difference in HRV based on gender and BMI. When recorded 5 minutes after exercise, the HRV decreased further regardless of gender and BMI. However, the HRV taken 30 minutes after exercise behaved more like the resting condition. The HRV recorded 30 minutes after exercise increased from the "5 minutes after exercise" value but still remained lower in all groups regardless of gender and BMI.

Conclusions: The results demonstrate that, in healthy adolescents, the parasympathetic activity is higher in females than in males during the rest period. Exercise induced sympathetic activity lasts longer in females with higher BMI and lower age, resulting in decreased HRV.

Key words: Heart Rate Variability, Body Mass Index, nervous system, autonomic

Introduction

Heart Rate Variability (HRV) analysis has become an important tool in cardiology, because its measurements are non-invasive and easy to perform, have good reproducibility and provide prognostic information about Coronary Heart Disease (CHD) [1]. Many studies have demonstrated a linear, longitudinal relationship between obesity and CHD [2, 3] despite uncertainties about the relationship between obesity and CHD. The nutrition committee of the American Heart Association has identified obesity has an independent risk factor [4, 5].

The BMI is the most practical way to evaluate the degree of excess weight in adults but it is a poor predictor in children as it varies during childhood [6-8]. BMI is age, gender, maturation stage and ethnicity specific [7, 9]. In adults, over weight is defined as BMI between 25 to 30 Kg/ m^2 and obesity as a BMI greater than 30 Kg/ m^2. It would be appropriate investigate the influence of BMI on Heart Rate Variability (HRV) when evaluating cardiac function.

Objective

To assess the influence of BMI on exercise induced HRV in a selected healthy student population. To compare gender variability in exercise induced HRV.

Methodology

The population under study was comprised of 65 students aged between 13 and 20 years [31 males and 34 females] from schools in and around Mangalore, Karnataka, India. The data recorded were age, sex, height, weight, and ECG. The subjects were instructed not to eat or drink caffeinated beverages for 3 hours prior to testing

[10]. BMI was calculated from the weight and square of the height [2].

The HRV examination complied with the following testing protocol:

- The examination began between 8 and 9 a.m. Subjects had to a lay in a quiet room with their eyes closed for the purpose of isolating their sensual perception. A 5-minute ECG was recorded after five minutes of lying in the rest position on a table. ECG was recorded in two breathing conditions: spontaneous and deep breathing [11-13].
- Before beginning the test, the subjects were taught to take deep inspirations and expirations. All measurements were performed by the examiner, who raised his hand to signal the start of each inhalation and lowered it to signal the start of each exhalation.
- The subject was instructed on how to perform the Harvard step test and the same was demonstrated. The subjects performed the step test for 5 minutes or until onset of an ischaemic response, whichever occurred first [14, 15].
- ECG was recorded immediately after stopping exercise or at the onset of an ischaemic response, 5 minutes and 30 minutes after stopping exercise in the recovery phase.
- Heart Rate Variability (HRV) was assessed by time-domain methods [11-19].To perform the analysis, the RR interval was measured manually with a scaled calliper to the nearest 0.5mm. The measurements were checked by another observer so as to minimise errors.
- Heart rate variability was calculated as the difference between the maximum and minimum heart rate.

The data obtained were compiled and compared as follows:

- Age with Heart rate variability
- Body Mass Index with Heart rate variability

The mean Body Mass Index (BMI) of the students as a whole (n=65) was 18. The students were grouped on the basis of their mean BMI: the lesser group (T_{b1}) having n= 38, (BMI <18) and higher group (T_{b2}) having n= 27 (BMI ≥18). The HRV of these groups was analyzed during resting and during different exercise periods (immediately, 5 minutes and 30 minutes after exercise). Males were grouped on the basis of BMI as follows: M_{b1} group <18, n= 19 and M_{b2} group ^{3} 18, n= 12.Likewise, females were grouped as F_{b1}, n=19 and F_{b2}, n=15.

Statistical Analysis

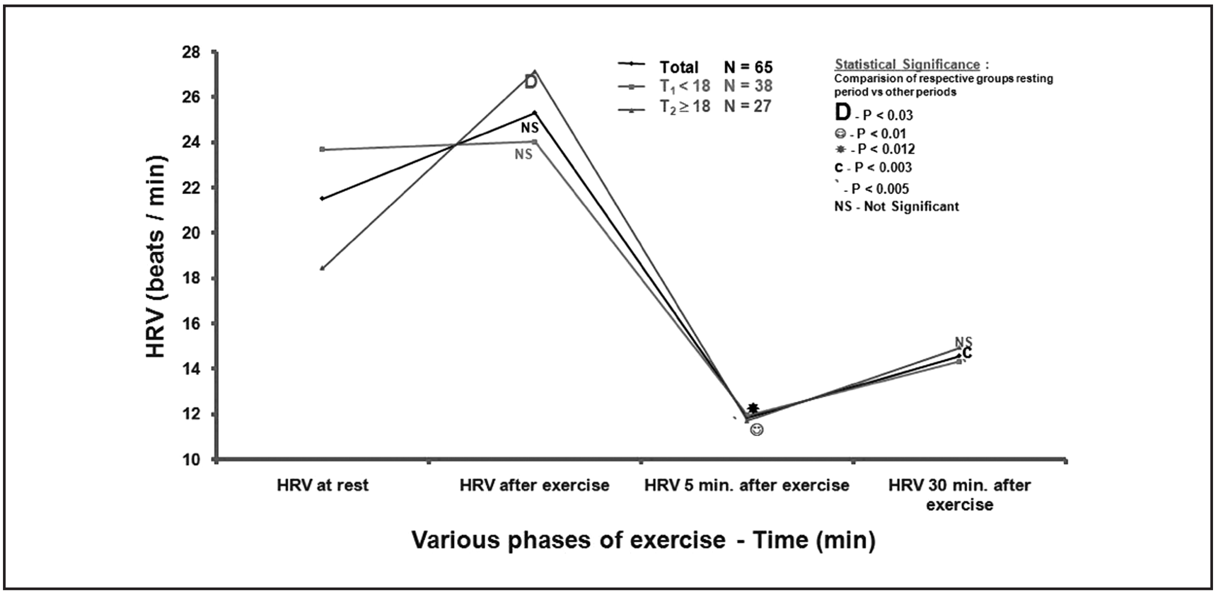
The independent variables analyzed were age, sex, BMI, and HRV. The data was analyzed using Statistical Package for Social Sciences (SPSS) 11.0 for windows. All variables are expressed as mean and 95% SE (mean ± SE). A paired t- test was used for the dependent variables. An unpaired t-test was carried out for normally distributed variables. Differences were considered significant when a P value <0.05 was observed.

Results

HRV and effect of BMI

During rest, the mean HRV of the total students as a whole (Figure 1a) was 21.51 ± 0.74, but in the lesser group (T_{b1}) it was 23.69 ± 2.57, whereas in the higher group (T_{b2}) the mean HRV was 18.44 ± 2.05. The HRV of all these groups during resting were not significantly different

Fig 1a. BMI, gender and effect of exercise on HRV in total group.



from one another. Females had higher HRV (26.08 ± 2.32.) than males (16.50 ± 2.35) and this difference was statistically significant ($P < 0.005$). The HRV of all the male and female groups during resting were not significantly different from one another (Figures 1b and 1c).

HRV during exercise and effect of BMI

The HRV obtained in the whole group immediately after exercise (HRVx) was increased with respect to resting condition, though not significantly. The HRV of total, T_{b1}, T_{b2} taken immediately after exercise (HRVx) were 25.31 ± 1.87, 24.01 ± 2.52 and 27.14 ± 2.79 respectively. Furthermore, the HRV observed during this period were not significantly different from one another. But when compared to their respective resting condition, the increase in HRV seen in the whole group and T_{b1} groups were not significantly varying. On the other hand, the HRV of Tb_2 group showed a significant increase ($P<0.01$) compared to its resting value. HRVx showed an increase in HRV in the male group as a whole ($P<0.01$) and M_{b2} group ($P<0.03$) whereas the M_{b1} group showed a non-significant increase. The differences in HRV during rest and immediately after exercise (HRVx) in males and females were not significantly different from one another except for group F_{b1} which showed a significant decrease ($P<0.02$) respect to its resting value.

Fig 1b. BMI, gender and effect of exercise on HRV in males.

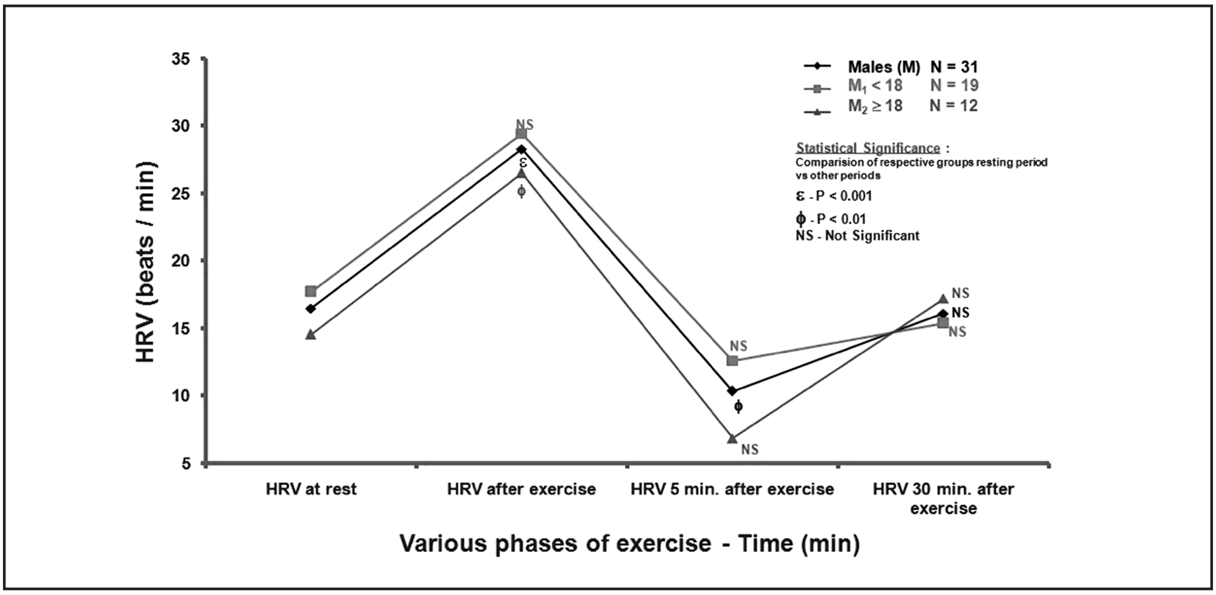
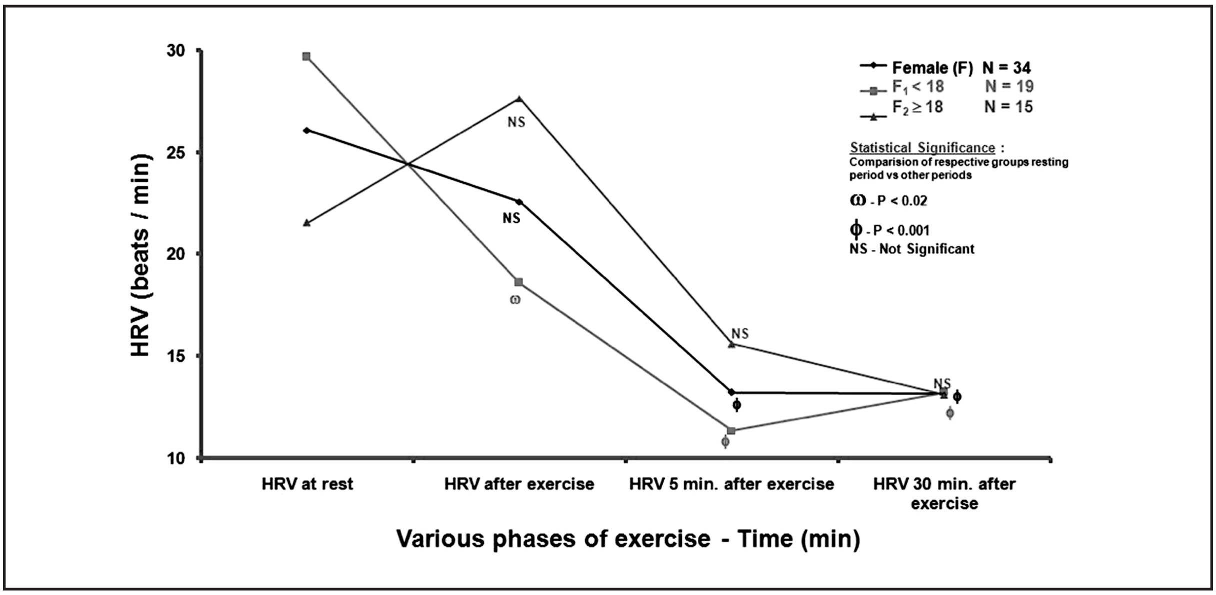


Fig 1c. BMI, gender and effect of exercise on HRV in females.



5 minutes after exercise (HRV5x)

The entire group showed significantly decreased HRV values compared with their respective resting and "immediately after exercise" values ($P<0.001$ for all). The mean HRV5x for the total students as a whole was 11.85 ± 1.19; for Tb_1 it was 11.95 ± 1.65 and in T_{b2} it was 11.71 ± 1.71, However, in this period, the HRV of the different groups showed no significant difference among themselves. The male group showed a significantly decreased HRV value compared to their respective resting values ($P<0.03$ for all the male group and $P<0.001$ for the M_{b2} group).In the M_{b1} group, the decrease was not significant. When compared with their "immediately after exercise", values, a significant decrease was seen ($P<0.001$) for all groups except M_{b2} which was not significant. The mean HRV 5x in the total female sample, F_{b1} andF_{b2} groups were 13.22 ± 1.83, 11.34 ± 2.98, and 15.59 ± 1.65 respectively. The whole female group and F_{b1} group showed significantly decreased HRV values compared to their respective resting ($P<0.001$) and "immediately after exercise" values ($P<0.001$ for whole group and $P<0.03$ for F_{b1}group) while the decreased HRV in for the F_{b2} group was not significant from the HRV of their resting condition. However, it showed a significant decrease ($P<0.01$) when compared with the value recorded "immediately after exercise".

30 minutes after exercise (HRV30x)

The HRV of the total group was 14.57 ± 1.21, for Tb_1 it was 14.31 ± 1.59 and for Tb_2 was 14.93 ± 1.91.The HRV taken during this period, too, did not show any significant variation when compared with one another. Though the HRV of this group during this period showed an increasing tendency, the variation in HRV was not significant when compared to their respective "5 minutes after exercise" value. Also, HRV after 30 minutes for these groups was still significantly lower than their respective "immediately after exercise" value and resting value ($P<0.05$) for both. The mean HRV5x in all males was 10.36 ± 1.47; in M_{b1} it was 12.57 ± 1.52 and in M_{b2} it was 6.86 ± 2.70 However, the HRV of the different groups during this period also showed no significant differences among themselves. The mean HRV taken 30 minutes after exercise (HRV30x) was 16.11 ± 1.94 in males as a whole, 15.40 ± 2.44 for M_{b1} and 17.21 ± 3.28 for M_{b2}. The HRV taken during this period, too, did not significantly vary among these subgroups when compared with one another. The HRV of the male group during this period showed a return towards resting condition, but it was still lower than the resting condition though the difference was not significant. The HRV of the male group during this period showed a significant increase when compared to their respective "5 minutes after exercise" value $P < 0.02$. Also, HRV after 30 minutes in these groups was still significantly lower than their respective "immediately after exercise" value ($P<0.001$). The HRV of the M_{b1} group (15.4± 2.44) during this period showed a recovery towards resting condition, though it was still lower than the resting condition and showed no significant difference. It was significantly lower than that of "immediately after exercise" ($P<0.01$) and not significant when compared with that of "5 minutes after exercise".

The HRV of the M_{b2} group during this period (17.21 ± 3.28) showed a return towards resting condition from the previous "5 minutes after exercise" value, and also overshot the resting value. However, it was still significantly higher than the HRV seen "5 minutes after exercise" ($P<0.03$). But the difference between HRV seen in resting and "immediately after exercise" was not statistically significant when compared with one another. The mean HRV taken 30 minutes after exercise (HRV30x) was 13.17 ± 1.49 in the whole group, 13.22 ± 2.06 for F_{b1} and 13.10 ± 2.21 for F_{b2}. The HRV taken during this period too did not show significant variation between these groups when compared with one another. Though the HRV of the total group and F_{b2} during this period showed a decrease, this was not significant when compared to their respective "5 minutes after exercise value". Also, HRV after 30 minutes for the whole group was still significantly lower than their respective "immediately after exercise" and resting value ($P<0.001$). Though the HRV of the F_{b1} group during this period showed an increase, this increase was not significant when compared to their respective "5 minutes after exercise" value. Also, HRV after 30 minutes for this group was still significantly lower than their respective "immediately after exercise" value and resting value ($P<0.001$). In the F_{b2} group, the HRV recorded 30 minutes after exercise more or less remained the same like the previous "5 minutes after exercise" value and hence showed a significant decrease compared to the "immediately after exercise" value ($P<0.001$) and was not significantly different from the resting value. Thus, on the basis of gender and BMI, overall analysis of the results of HRV under various conditions showed the following results: females showed a higher HRV than males during resting condition. But immediately after exercise, the HRVx increased in all groups and there were no differences in HRV based on gender and BMI. When recorded 5 minutes after exercise, the HRV decreased further regardless of gender and BMI. In addition, the HRV recorded 30 minutes after exercise behaved more like HRV at rest. The HRV recorded 30 minutes after exercise increased compared to the "5 minutes after exercise" value but still remained lower in all groups regardless of gender and BMI.

Discussion

Heart rate variability is a measure of the naturally occurring beat-to-beat changes in heart rate and is an established non-invasive technique to assess the cardiac function and an indicator of neurocardiac fitness [20-25]. Analysis of HRV and complexity can provide useful information about the autonomic control of the CVS. Thus, HRV is the measure of the integrity of the autonomous nervous system. Increases in HRV indicate parasympathetic activity and decreases in HRV result from sympathetic activity. The HRV is influenced by age, sex and BMI [26]. As there is little to correlate the HRV and BMI in adolescent groups, this study was undertaken in adolescents between the age group of 13-20 years [27]. It has been established that exercise improves cardio respiratory functions and alters the autonomic status of individuals. In this study, the students were subjected to exercise to elucidate higher sympathetic activity. It is well known that enhancement of sympathetic activity is an indication of CHD. [20, 28-33]. In this study, by correlating HRV and BMI during resting and various phases of exercise, an attempt has been made to evaluate and predict possible autonomic over activity.

In the present study of an adolescent group, the HRV among students did not vary during the resting conditions regardless of age and BMI. But, the resting HRV of females is more than that of males, indicating that under normal conditions females might have higher parasympathetic activity. According to Silvetti, Drags et al, HRV measures increase with age [26]. This is in striking contrast with the present study. As far as gender differences are concerned, this study is in agreement with their study. Discrepancies in age related variation might be due to the differences between the age group of the sample in both studies. However, our observations concurred with that of previous investigators, who have observed that in adults, HRV decreased with ageing, but in children there are a variety of changes [12, 34]. The findings of this study reveal that HRV is not affected by BMI and hence supports previous studies [20, 27, 34, 35].

Results of this study for the resting condition showed that the parasympathetic activity in females is greater, and that the sympathetic activity in males increases with age. Thus, strong age and gender effects were evident from this study. Physical exercise has been observed to be associated with parasympathetic withdrawal and increased sympathetic activity [36]. During exercise, usually the sympathetic activity increases leading to increases in BP. To find out whether there is any correlation with autonomic activity, these subjects were asked to perform exercise and the parameters were taken immediately at different time intervals: after cessation of exercise, 5 minutes after exercise and 30 minutes after exercise. The HRV calculated immediately after exercise showed that the male group had an increase in HRV whereas females had a decrease in HRV during this period compared to their respective resting condition. Among females, the HRV is comparatively more in the higher BMI group. This further supports the notion that the sympathetic activity in males is higher even at resting states whereas in females it is lower.

Thus, the findings arising from the five-minute recordings, in the resting condition showed that the parasympathetic activity in females was greater. The HRV taken 5 minutes after exercise decreased drastically in all the groups from the previous "immediately after exercise" value, regardless of age, sex and BMI. The HRV in this period was also significantly lower than that of the resting value regardless of age, BMI and sex. This suggests that the increased sympathetic activity due to exercise was evident only 5 minutes after exercise. In the lower age and higher BMI female group, the HRV after 30 minutes was lower than the other groups showing that the exercise induced sympathetic activity in these groups had not yet been nullified, and this effect was more proportionate to BMI in the female group. The HRV calculated 30 minutes after exercise increased compared to the previous "5-minute" value in all groups except in the lower age female group. Also, the higher female BMI group showed a decrease in HRV whereas all other BMI groups showed an increase in HRV. The HRV taken during this period was still significantly lower than the resting value except in the M_2 male group, based on both age and BMI, where it showed a non-significant increase over the resting value [36]. This shows that males in the higher age group and with higher BMI return to their resting value within 30 minutes. The results showed that the vasomotor tone readjusted after exercise within 30 minutes in all the groups, though was more marked in the male and higher BMI group. This suggests that the restoration of sympathetic activity after the metabolic activity of exercise is more evident quickly in males and in higher BMI groups. The results of the present study demonstrate that, in healthy adolescents, the parasympathetic activity is higher in females than in males during the rest period. Exercise induced sympathetic activity is more pronounced only in the early post exercise recovery phase (5 minute after exercise). Available reports suggest that Heart rate rapidly declines during the first 1-2 minutes after the cessation of exercise, and gradually thereafter [26, 34, 36]. The sympathetic activity proportionately increases with BMI and age in males. Exercise induced sympathetic activity lasts longer in females of higher BMI and lower age groups. Thus, annotations of this study show that, in higher BMI, sympathetic activity is increased resulting in decreased HRV.

Limitations of the study

The normal heart rhythm varies according to respiration (respiratory sinus arrhythmia). However, since this affects everyone equally in the study group, this variation may be ruled out. Exercise was performed by the subjects for 5 minutes or until onset of fatigue, though which of these occurred first (the power output) was not known. The properties of BMI vary during childhood, and factors such as age and sex contribute to the interpretation of the BMI.

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