Effect of Overweight on Cardiac Autonomic Function after Harvard Step Test

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ABSTRACT

Background

Overweight in young adults may affect cardiac autonomic regulation before clinical cardiovascular disease becomes evident.

Methods

This comparative observational study included 200 medical students aged 17–25 years. They were divided into normal BMI group and overweight group with 100 subjects in each group. Anthropometry, resting ECG and heart rate variability were recorded. Harvard Step Test was used as a submaximal exercise stressor. HRV was analysed before and after exercise. Time domain and frequency domain indices were compared between groups. Additional calculated indices were derived from available values to assess adiposity load, chronotropic response, vagal withdrawal, sympathovagal imbalance and recovery burden.

Results

The overweight group showed higher calculated adiposity load. Waist-height ratio was 0.60 in overweight subjects and 0.47 in normal BMI subjects. Body adiposity index was 37.05 versus 27.63. At baseline, overweight subjects had 20.21% higher resting heart rate burden, 54.54% lower SDNN, 43.28% lower RMSSD and 55.87% lower HF power. LF/HF excess was 49.01%. After Harvard Step Test, post-exercise heart rate remained 7.86% higher in overweight subjects. Spectral imbalance after exercise was 4.11 in overweight subjects and 2.28 in normal BMI subjects. Physical Fitness Index was 15.36% lower in overweight subjects.

Conclusion

Overweight medical students showed higher central adiposity, reduced resting HRV, lower vagal modulation and greater post-exercise sympathovagal imbalance. These findings suggest early autonomic dysfunction and reduced recovery efficiency in overweight young adults.

Keywords: overweight, heart rate variability, Harvard Step Test, autonomic function, medical students, sympathovagal balance.

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Introduction

Overweight and obesity are now common in young adults also. They are not only disorders of body weight. They also affect cardiovascular regulation, metabolic function and autonomic balance. In adults, overweight is defined as body mass index (BMI) ≥25 kg/m². This BMI cut-off was used in the present study to classify overweight subjects.[1]

BMI is useful for screening but it does not show fat distribution. Central adiposity has more clinical value for cardiovascular risk. Waist circumference, waist-hip ratio and waist-height ratio are simple markers of abdominal fat distribution. Recent evidence shows that waist-based indices can predict cardiovascular and cardiometabolic risk better than BMI alone in many populations.[2,3] Hence, derived adiposity indices like waist-height ratio, body adiposity index and conicity index can add more physiological meaning to the study.

The autonomic nervous system maintains short-term cardiovascular stability. It regulates heart rate, vascular tone and recovery after stress. Heart rate variability (HRV) is a non-invasive method to assess cardiac autonomic modulation.[4,5] Time domain indices such as SDNN, RMSSD, NN50 and pNN50 reflect overall variability and vagal modulation. Frequency domain indices such as LF power, HF power and LF/HF ratio provide information about sympathovagal balance, though LF/HF should be interpreted carefully and along with other HRV indices.[4,6]

Obesity is associated with altered autonomic control. Most studies report lower parasympathetic activity, higher resting heart rate and relative sympathetic predominance in overweight and obese individuals.[7,8] Central obesity may have stronger relation with HRV than BMI alone. Banerjee et al.

reported that waist circumference and waist-hip ratio affected HRV independent of physical activity in young adults.[9] Gandhi et al. also showed that anthropometric predictors are related to HRV changes in overweight medical students.[10]

Resting HRV gives baseline autonomic status. Exercise response gives additional information about autonomic reserve. During acute exercise, heart rate rises and HRV falls due to vagal withdrawal and sympathetic activation. During recovery, vagal reactivation should occur. Delay in this recovery suggests reduced autonomic flexibility.[11,12] The Harvard Step Test is a simple submaximal exercise test. It can assess cardiovascular efficiency and physical fitness in young adults.

Medical students are a useful population for studying early autonomic changes because they are young and usually free from clinical cardiovascular disease. Detection of reduced HRV at this stage may indicate early physiological risk before overt disease develops. The present study was designed to compare autonomic function between normal BMI and overweight medical students before and after Harvard Step Test, and to assess derived adiposity, chronotropic response, vagal withdrawal and sympathovagal recovery indices.

Materials and Methods

This comparative observational study included 200 medical students aged 17–25 years. They were divided into normal BMI group (BMI 18.5–24.9 kg/m², n=100) and overweight group (BMI ≥25 kg/m², n=100). Students with cardiovascular disease, hypertension, diabetes, respiratory disease, anaemia, smoking, alcohol intake, regular exercise habit or other conditions affecting autonomic function were excluded. Written informed consent was taken.

Weight, height, waist circumference and hip circumference were measured. BMI and waist-hip ratio were calculated. Resting ECG was recorded after rest and HRV was analysed. Time domain indices included Mean RR, Mean HR, SDNN, RMSSD, NN50 and pNN50. Frequency domain indices included VLF, LF, HF, LF norm, HF norm and LF/HF ratio. All subjects performed Harvard Step Test using a 23 cm step. Post-exercise ECG was recorded during early recovery and HRV was analysed.

Additional calculated indices were derived from anthropometric and HRV values. These included waist-height ratio, body adiposity index, conicity index, heart rate load ratio, percentage heart rate rise, RR shortening, vagal suppression indices, LF/HF reactivity ratio, spectral imbalance index and fitness deficit. These were calculated from group mean values and used for descriptive physiological interpretation.

Results

Table 1: Derived adiposity indices according to BMIgroup

Calculated parameter	Formula used	Normal BMI group	Overweight group
Waist-height ratio	Waist / height	0.47	0.60
Body adiposity index	Hip / height$^{1.5}$ − 18	27.63	37.05
A Body Shape Index	Waist / BMI$^{2/3}$ × height$^{1/2}$	0.079	0.080
Conicity index	Waist / 0.109 × √weight/height	1.20	1.28
BMI excess	Difference from normal BMI group	0.00%	30.58% higher
Waist-height ratio excess	Difference from normal BMI group	0.00%	28.25% higher
Body adiposity index excess	Difference from normal BMI group	0.00%	34.10% higher
Conicity index excess	Difference from normal BMI group	0.00%	6.58% higher

The overweight group showed higher calculated adiposity load. Waist-height ratio was 0.60 in overweight subjects and 0.47 in normal BMI subjects. Body adiposity index was 37.05 versus 27.63. Conicity index was 1.28 versus 1.20. BMI excess was 30.58% in the overweight group. These derived values show greater central adiposity and altered body fat distribution in overweight students.

Table 2: Baseline autonomic deficit indices according to BMI group

Calculated parameter	Formula used	Normal BMI group	Overweight group
Resting heart rate burden	Group HR / normal group HR	1.00	1.20
Resting heart rate excess	Difference from normal group	0.00%	20.21% higher

Resting RR interval deficit	Difference from normal group	0.00%	8.38% lower
Baseline SDNN deficit	Difference from normal group	0.00%	54.54% lower
Baseline RMSSD deficit	Difference from normal group	0.00%	43.28% lower
Baseline NN50 deficit	Difference from normal group	0.00%	51.96% lower
Baseline pNN50 deficit	Difference from normal group	0.00%	37.60% lower
Baseline HF power deficit	Difference from normal group	0.00%	55.87% lower
Baseline LF/HF excess	Difference from normal group	0.00%	49.01% higher
Baseline LF norm excess	Difference from normal group	0.00%	21.79% higher
Baseline HF norm deficit	Difference from normal group	0.00%	20.63% lower

The overweight group had higher resting cardiac load and lower baseline autonomic variability. Resting heart rate burden was 1.20 times higher. Baseline SDNN deficit was 54.54% and RMSSD deficit was 43.28%. HF power deficit was 55.87%. LF/HF excess was 49.01%. These calculated indices indicate reduced vagal tone and higher sympathetic predominance at rest in overweight students.

Table 3: Chronotropic response after Harvard Step Test

Calculated parameter	Formula used	Normal BMI group	Overweight group
Absolute heart rate rise	Post HR − pre HR	51.23 bpm	46.49 bpm
Percentage heart rate rise	HR rise / pre HR × 100	72.15%	54.47%
Heart rate load ratio	Post HR / pre HR	1.72	1.54
Percentage RR shortening	Pre RR − post RR / pre RR × 100	32.05%	31.62%
Post-exercise heart rate excess	Difference from normal group	0.00%	7.86% higher
Post-exercise RR deficit	Difference from normal group	0.00%	7.80% lower
Relative chronotropic reserve deficit	Difference from normal group	0.00%	24.51% lower

he percentage heart rate rise was 72.15% in normal BMI subjects and 54.47% in overweight subjects. The lower percentage rise in the overweight group was due to higher baseline heart rate. Post-exercise heart rate remained 7.86% higher in overweight subjects. RR shortening was almost similar in both groups. These values suggest higher cardiac load with relatively reduced chronotropic reserve in overweight students.

Table 4: Vagal withdrawal indices after exercise

Calculated parameter	Formula used	Normal BMI group	Overweight group
SDNN suppression index	Pre − post / pre × 100	66.79%	55.56%
RMSSD suppression index	Pre − post / pre × 100	65.42%	56.75%
NN50 suppression index	Pre − post / pre × 100	79.70%	79.76%
pNN50 suppression index	Pre − post / pre × 100	75.89%	80.49%
HF power suppression index	Pre − post / pre × 100	80.90%	79.12%
HF norm fall index	Pre − post / pre × 100	38.32%	50.38%
SDNN retention index	Post / pre × 100	33.21%	44.44%

RMSSD retention index	Post / pre × 100	34.58%	43.25%
pNN50 retention index	Post / pre × 100	24.11%	19.51%
HF power retention index	Post / pre × 100	19.10%	20.88%

Both groups showed marked vagal withdrawal after exercise. HF power suppression was 80.90% in normal BMI subjects and 79.12% in overweight subjects. SDNN and RMSSD suppression were lower in overweight subjects. This is likely because their baseline values were already low. HF norm fall was higher in overweight subjects, 50.38% versus 38.32%. This suggests poorer vagal reactivation after exercise in overweight students.

Table 5: Sympathovagal stress indices after exercise

Calculated parameter	Formula used	Normal BMI group	Overweight group
LF/HF reactivity ratio	Post LF/HF / pre LF/HF	2.29	1.95
LF/HF percentage rise	Change / pre LF/HF × 100	129.14 %	94.67%
LF norm percentage rise	Change / pre LF norm × 100	41.43%	34.06%
HF norm percentage fall	Change / pre HF norm × 100	38.32%	50.38%
Normalized spectral imbalance at rest	LF norm / HF norm	0.99	1.52
Normalized spectral imbalance after exercise	LF norm / HF norm	2.28	4.11
Spectral imbalance rise	Post − pre value	1.28	2.59
Percentage rise in spectral imbalance	Change / pre value × 100	129.30 %	170.18%
Post-exercise imbalance excess	Difference from normal group	0.00%	80.80% higher

The overweight group showed higher spectral imbalance after exercise. Normalized spectral imbalance increased from 1.52 to 4.11 in overweight subjects. In normal BMI subjects, it increased from 0.99 to 2.28. The percentage rise in spectral imbalance was 170.18% in overweight subjects and 129.30% in normal BMI subjects. Post-exercise imbalance was 80.80% higher in overweight students. This indicates sustained sympathetic predominance during early recovery.

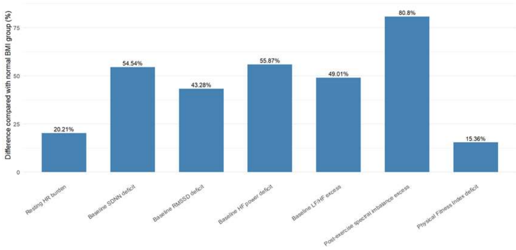
Table 6: Fitness deficit and autonomic recovery load

Calculated parameter	Formula used	Normal BMI group	Overweight group
Physical Fitness Index	Harvard Step Test value	76.76	64.97
Fitness deficit	Difference from normal group	0.00 points	11.79 points lower
Percentage fitness deficit	Difference / normal PFI × 100	0.00%	15.36% lower
Heart rate load per fitness unit	Post HR / PFI	1.59	2.03
Excess HR load per fitness unit	Difference from normal group	0.00%	27.44% higher
LF/HF burden per fitness unit	Post LF/HF / PFI	0.045	0.067
Excess LF/HF burden per fitness unit	Difference from normal group	0.00%	49.56% higher
HF norm recovery per fitness unit	Post HF norm / PFI	0.40	0.30
HF recovery deficit per fitness unit	Difference from normal group	0.00%	24.55% lower

Physical Fitness Index was 76.76 in normal BMI subjects and 64.97 in overweight subjects. The overweight group had 11.79 points lower PFI, which was 15.36% lower than the normal BMI group. Heart rate load per fitness unit was 27.44% higher.

LF/HF burden per fitness unit was 49.56% higher. HF norm recovery per fitness unit was 24.55% lower. These derived results show reduced exercise recovery efficiency in overweight students.

Figure 1: Calculated HRV and fitness differences according to BMI status



Discussion

The present study showed clear anthropometric separation between normal BMI and overweight students. Age and gender distribution were comparable between the groups. This is important because HRV is affected by age, sex, fitness and body composition. The overweight group had higher weight, BMI, waist circumference, hip circumference and waist-hip ratio. The calculated indices also showed higher waist-height ratio, body adiposity index and conicity index in overweight students. This supports higher central adiposity in this group, not only higher BMI. Similar importance of central obesity markers has been reported by Darbandi et al. and Banerjee et al.[2,9]

Baseline autonomic profile was poorer in the overweight group. Resting heart rate was higher and RR interval was lower. SDNN, RMSSD, NN50 and pNN50 were also lower. This shows reduced overall HRV and reduced vagal modulation. HF power and HF norm were lower, while LF norm and LF/HF ratio were higher. These findings suggest parasympathetic withdrawal with relative sympathetic predominance at rest. Similar observations were reported by Soumya et al. in obese young adults, where HF nu was lower and LF/HF ratio was higher in obese subjects.[13] Muthukrishnan et al. also reported reduced HRV in overweight and obese young individuals.[14]

The derived baseline autonomic deficit indices make the result more clinically understandable. The overweight group showed 20.21% higher resting heart rate burden, 54.54% lower SDNN and 43.28% lower RMSSD compared with normal BMI subjects. HF power deficit was 55.87% and LF/HF excess was 49.01%. These values suggest that overweight students had lower resting autonomic reserve even before exercise. This finding is relevant because reduced HRV is considered an early marker of altered cardiac autonomic control.[4,5]

After Harvard Step Test, both groups showed significant chronotropic response. Heart rate increased and RR interval shortened. This is an expected physiological response to exercise. However, overweight subjects had higher post-exercise heart rate and lower post-exercise RR interval than normal BMI subjects. The calculated heart rate rise was 72.15% in normal BMI students and 54.47% in overweight students. This lower percentage rise does not indicate better response. It is mainly because overweight subjects already had higher resting heart rate. This indicates higher cardiac load at baseline and during recovery.

The time domain HRV response after exercise showed marked vagal withdrawal in both groups. SDNN, RMSSD, NN50 and pNN50 fell after exercise. In normal BMI students, SDNN suppression was 66.79% and RMSSD suppression was 65.42%. In overweight students, SDNN suppression was 55.56% and RMSSD suppression was 56.75%. This apparently lower suppression in overweight students should not be interpreted as better response. Their baseline vagal indices were already low. This may represent a floor effect, where further reduction is limited because resting values are already depressed.

Post-exercise HRV remained significantly poorer in overweight students. SDNN was 15.10 ms in overweight students compared with 24.82 ms in normal BMI students. RMSSD was 11.79 ms versus 16.62 ms. pNN50 was also lower. These values indicate delayed vagal reactivation and poorer autonomic recovery after physical stress. Similar findings were reported by El Agaty et al., where overweight and obesity were associated with reduced heart rate recovery and delayed vagal reactivation after exercise.[15]

Frequency domain findings also support this interpretation. HF power after exercise was much lower in overweight students. LF norm was higher and HF norm was lower. LF/HF ratio was 4.38 in overweight students and 3.46 in normal BMI students. The derived spectral imbalance after exercise was 4.11 in overweight students and 2.28 in normal BMI students. Post-exercise imbalance was 80.80% higher in overweight students. This shows sustained sympathetic predominance during early recovery.

The Physical Fitness Index was lower in overweight students. The difference was 11.79 points, which was 15.36% lower than normal BMI subjects. Heart rate load per fitness unit and LF/HF burden per fitness unit were also higher in overweight students. This means that for a lower fitness output, overweight subjects had higher cardiac and autonomic load. Nataraj et al. studied young overweight adults and reported that cardiorespiratory fitness and HRV may not always show simple correlation.[16] This supports that both fitness and HRV should be assessed together rather than using only one parameter.

The correlation analysis showed strong relation between BMI and HRV across all subjects. BMI had negative correlation with baseline SDNN and HF power, and positive correlation with LF/HF ratio. This suggests that increasing BMI is associated with lower vagal activity and higher sympathovagal imbalance. Within the overweight group, BMI correlation was weaker, probably because the BMI range was narrow. Weight showed significant relation with baseline SDNN and ΔSDNN within overweight subjects. This supports that even within overweight range, increasing body mass may worsen autonomic regulation.

These findings are consistent with recent reviews. Sinha et al. reported that obesity is linked with reduced HRV, but physical activity and HRV relationships vary across studies because of differences in activity measurement and HRV protocol.[17] Mattos et al. reported that lifestyle weight loss may improve cardiac autonomic control in overweight and obese subjects.[18] Villafaina et al. also showed that physical exercise interventions can improve HRV in obese children and adolescents.[19] Hence, the present findings support early lifestyle intervention in overweight students.

The strength of this study is that HRV was recorded both at rest and after standardized exercise. The study also included equal sample size in both groups. Derived indices give additional physiological meaning to the results. They show adiposity load, autonomic deficit, vagal withdrawal and recovery burden in a simpler way. However, these derived values should be interpreted as calculated indices based on available data. If individual raw data are available, these indices should be calculated for each participant and compared statistically.

Overall, overweight medical students showed reduced resting HRV, higher resting heart rate, lower vagal modulation and greater post-exercise sympathovagal imbalance. The findings suggest early autonomic dysfunction even in young adults without known cardiovascular disease. This is not a clinical disease diagnosis. It is a physiological risk pattern. Regular physical activity, weight control and early screening may help in improving autonomic health in this group.

Conclusion

Overweight medical students showed higher adiposity burden and poorer autonomic profile compared with normal BMI students. Resting heart rate was higher and HRV indices related to vagal tone were lower in the overweight group. After Harvard Step Test, overweight students had higher post-exercise heart rate, greater spectral imbalance and lower Physical Fitness Index. The calculated indices also showed reduced chronotropic reserve, poorer vagal recovery and higher autonomic load per fitness unit. These findings suggest early impairment of cardiac autonomic regulation in overweight young adults. Weight control, regular physical activity and early lifestyle correction may help in improving autonomic health in this group.

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