RESEARCH ARTICLE

Sleep attenuates body mass index, cardiorespiratory fitness, and its effect on blood pressure in young adolescents: The cross-sectional lifestyle, biomarkers, and early risk of hypertension

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ABSTRACT

Background: From the past few decades, disturbed sleep pattern has grown to be a hallmark of modern-day society among the adolescents and in adults. Both are having disturbed sleep patterns with average sleep duration of 7 h per night. Smartphones, tablets, and television which are the remarkable source of information and entertainment have robbed sleep time and have led to voluntary sleep restriction as self-reported by them and it has become a serious barrier to health development. Along with it, high blood pressure (BP) levels are influenced by high body mass index (BMI) and low cardiorespiratory fitness which are among the most important cardiovascular disease risk factors. However, how sleep attenuates the individuals BMI, cardiorespiratory fitness and BP in adolescents are uncertain. Aims and Objectives: The aim of this study was to analyze whether the disturbed sleep pattern is a mediator between body composition, Cardiorespiratory fitness (CRF), and BP levels in young adolescents. Materials and Methods: This study was a cross-sectional study which involved students of MMIMSR (n = 500), of which 250 male and 250 female participants were recruited. Initial explanation about the aim and purpose of the study, test procedure, method of testing, and instruction of how to perform the test was given. All the participants were examined under similar laboratory conditions. Detailed history with thorough clinical examination were done. All basal parameters such as heart rate, BP, and respiratory rate were also measured. Results: In our study, disturbed sleep patterns were highly significantly (P < 0.01) associated with high BMI which acted as a mediator between low CRF and high BP in both the participants. Our results highlighted the importance of a sleep in maintaining a healthy lifestyle, CRF and to prevent hypertension in young adolescents. Conclusion: The findings of our study are consistent with the hypothesis that disturbed sleep might be one of the reasons which influence BMI and long-term cardiovascular health.

KEY WORDS: Sleep; Body Mass Index; Blood Pressure; Cardiorespiratory fitness

INTRODUCTION

College is a time when many adolescents experience sovereignty and independence for the 1st time in their life. Major changes take place in their lifestyle with variable schedules, academic performances with peer pressures, unbalanced diets, and also insufficient sleep which can be harmful for their
health and their well-being.\cite{1} Sleep can be defined on the basis of behavior of a person during asleep and also on various physiological changes related to it.\cite{5} In sleep, the behavioral criteria include slight or total lack of mobility, slow eye movement and decreased response to external stimulation, that is, increase in reaction time and cognitive dysfunction with increase threshold for arousal and an unconscious state that is reversible.\cite{3-5} For many years, poor sleep with improper sleep patterns has been common and self-reported by the adolescents. The feeling of fatigue developed due to chronic sleep deprivation leads to reduced physical activity and has been a major criterion for various cardiovascular health problems which are based on experimental studies. From the past studies, it has been reported that there is a strong association between adiposity and short sleep duration with disturbed sleep.\cite{6,7} Sleep modulates glucose metabolism and many neuroendocrine functions in adolescents and in adults. Poor sleep with disturbed sleep patterns alters metabolic as well as endocrine functions which lead to decreased insulin sensitivity, decrease in glucose tolerance, increased cortisol level at night, increased ghrelin hormone level, and decreased leptin levels.\cite{8} Overweight/obese have higher prevalence of sleep disturbances. Childhood obesity in relation to physical fitness is rising swiftly world widely and India is now no exception.\cite{9,10} Obesity is associated with wide range of diseases such coronary heart disease, stroke, obstructive pulmonary disease, and diabetes.\cite{11,12} Obesity led to the occurrence of heart diseases with poor cardiorespiratory fitness. Adolescents are prone to develop obesity and cardiovascular diseases at young age of their life.\cite{13} VO₂ max is a parameter to measure cardiorespiratory fitness, higher is the value of VO₂ max, higher is the cardiorespiratory fitness, so its predicts the intensity and duration of exercise in person who are well conditioned as compared to person who are not well conditioned.\cite{14} Along with-it, the early hypertension in young adults is growing world widely.\cite{15,16} Diagnosis of the early hypertension in young adults is measured by auscultatory method according to their anthropometric indices. High blood pressure (BP) in adolescents indicates the risk of development of coronary artery disease later in their life. In adults, high BP and coronary artery disease are linked with disturbed sleep, but the cause is not completely understood and very less is known about the interconnection between the disturbed sleep and the hypertension.\cite{17-22} Hence, in view of significantly increasing disturbed sleep patterns, obesity along with decreased cardiorespiratory fitness and prevalence of hypertension among young adolescents, this study was planned.

**MATERIALS AND METHODS**

This cross-sectional study was done in MMIMSR, mullana, Ambala in the Department of Physiology. The study comprised 500 participants, of which 250 were male and 250 were female participants which were recruited randomly after taking a written informed consent. A proper approval was taken by the Institutional Ethical Committee under the project no.762 for this study.

**Inclusion Criteria**

Non-alcoholic and non-smoker male and female medical students of age group 18–25 years were taken.

**Excluding Criteria**

Medical students on a long-term medication or with any kind of acute or chronic illness were excluded from this study.

**Anthropometric Indices**

Weight and height were measured bare feet with minimal clothing and the subject heels, hip, shoulder, and head in neutral position with eye gazing forward. BMI was calculated by dividing weight in kilograms (kg) by square root of body height in meters (kg/m²). Normal weight was considered as BMI 18.5–≤22.9, overweight as BMI 23–≤24.9, and obesity as BMI ≥25 kg/m² according to Health Ministry and Diabetes Foundation of India in 2008.\cite{19}

**Sleep Pattern**

Sleep pattern was determined using standardized and validated Pittsburgh sleep quality index (PSQI) questionnaire which was filled by each participant.\cite{20}

**BP**

BP was measured by proper calibration and maintenance of mercury sphygmomanometer. Participants were allowed to rest in a quiet room before measuring BP. BP was taken according to the recommendation of the 4th report of national high BP in a sitting position with bared arm at the heart level.\cite{21,22}

**Statistical Analysis**

SPSS software and Microsoft Excel were used for statistics where Pearson correlation $P < 0.05$ considered as significant and $P < 0.01$ considered as HS.

**RESULTS**

In our study, 250 male and 250 female participants were recruited. Of 250 male participants, 85 participants were of normal weight, 82 participants were overweight, and 83 participants were obese. Of 250 female participants, 95 participants were of normal weight, 80 participants were overweight, and 75 participants were obese.

The mean sleep patterns, that is, global PSQI score among three male groups were taken and comparison was done. In
our study, we found a highly significant increase in disturbed sleep patterns among overweight versus obese male groups when compared to normal weight group, as shown in Table 1.

Our study showed a similar finding among the three female groups, also as shown in Table 2.

Cardiorespiratory fitness, that is, VO$_2$ max in all the three groups in male was measured as 56.5 ± 4.83 ml/kg/min, 46.7 ± 6.45 ml/kg/min, and 38.5 ± 3.9 ml/kg/min. In our study, VO$_2$ max, that is, cardiorespiratory fitness showed a highly significant decrease in normal weight versus overweight and overweight versus obese male groups, respectively, as shown in Table 3.

Cardiorespiratory parameters were also assessed in male participants and comparison was done in all the three groups of male participants. The mean respiratory rate (RR), mean pulse rate (PR), and mean pulse pressure (PP) showed no significant difference ($P > 0.05$), while systolic BP, diastolic BP, and mean arterial pressure (MAP) showed highly significant difference, that is, $P < 0.01$ in all the three groups in male participants, as shown in Table 4.

Similarly, mean cardiorespiratory fitness in female groups, that is, VO$_2$ max showed a highly significant decrease among all the three female groups respectively, as shown in Table 5. Cardiorespiratory parameters were also assessed in female participants and comparison was made in all the three groups.

Table 1: Comparison of Global PSQI in three different groups among male participants

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean Global PSQI (mean±SD)</th>
<th>Normal versus Overweight (P-value)</th>
<th>Overweight versus obese (P-value)</th>
<th>Normal versus obese (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight (n=85)</td>
<td>1.8±0.82</td>
<td>&lt;0.05S</td>
<td>&lt;0.01HS</td>
<td>&lt;0.01HS</td>
</tr>
<tr>
<td>Overweight group (n=82)</td>
<td>4.42±1.51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obese group (n=83)</td>
<td>8.92±1.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PSQI: Pittsburgh sleep quality index

Table 2: Comparison of global PSQI in three different groups among female participants

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean Global PSQI (mean±SD)</th>
<th>Normal versus overweight (P-value)</th>
<th>Overweight versus obese (P-value)</th>
<th>Normal versus obese (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight (n=95)</td>
<td>2.04±0.9</td>
<td>&lt;0.01HS</td>
<td>&lt;0.01HS</td>
<td>&lt;0.01HS</td>
</tr>
<tr>
<td>Overweight group (n=80)</td>
<td>5.91±1.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obese group (n=75)</td>
<td>9.4±1.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Comparison of VO$_2$ max (ml/kg/min) in three different groups among male participants

<table>
<thead>
<tr>
<th>Groups</th>
<th>VO$_2$ max (ml/kg/min) (mean±SD)</th>
<th>Normal versus Overweight (P-value)</th>
<th>Overweight versus obese (P-value)</th>
<th>Normal versus obese (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight (n=85)</td>
<td>56.5±4.83</td>
<td>&lt;0.01HS</td>
<td>&lt;0.01HS</td>
<td>&lt;0.01HS</td>
</tr>
<tr>
<td>Overweight group (n=82)</td>
<td>46.7±6.45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obese group (n=83)</td>
<td>38.5±3.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION

In the present study, we found both male and female participants who were having poor sleep with sleep disturbances were overweight/obese. Most of the participants were found to have insomnia on the basis of PSQI scale. Participants were spending a lot of inactive time that included lack of exercise, sedentary lifestyle, and excessive accessing of media or entertainment sources which might have led to high BMI. Our study findings also showed that the participants male or female who were having higher BMI value had lower value of VO$_2$ max or decreased cardiorespiratory fitness. Moreover, in India, hypertension has turned into the most predominant chronic disease and is no longer an old age disease. Even those children who is having disturbed sleep patterns are at the risk of having higher BMI which may lead to early hypertension.

Our result correlates with findings of Cummings et al.[$^{23}$] and Kripke et al.,[$^{24}$] in which all have centered on the relationship between poor sleep quality along with short sleep duration results in high BMI in adults. Another study by Gangwisch et al.[$^{25}$] and Patel et al.[$^{26}$] found a direct relationship between short sleep and adiposity in adolescents. Cardiorespiratory
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<p>| Table 4: Comparison of VO₂ max (ml/kg/min) in three different groups among female participants |</p>
<table>
<thead>
<tr>
<th>Groups</th>
<th>VO₂ max (ml/kg/min) (mean±SD)</th>
<th>Normal versus Overweight (P-value)</th>
<th>Overweight versus obese (P-value)</th>
<th>Normal versus obese (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight (n=95)</td>
<td>43.1±1.3</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
</tr>
<tr>
<td>Overweight group (n=80)</td>
<td>37.2±2.3</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
<tr>
<td>Obese group (n=75)</td>
<td>34.7±1.2</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
</tbody>
</table>

<p>| Table 5: Comparison of Cardiorespiratory parameters in three different groups in Male participants |</p>
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Normal weight Group-I (n=85) (mean±SD)</th>
<th>Overweight Group-II (n=82) (mean±SD)</th>
<th>Obese Group-III (n=83) (mean±SD)</th>
<th>Statistical significance Group I versus Group II</th>
<th>Statistical significance Group I versus Group III</th>
<th>Statistical significance Group II versus Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR (beats/min)</td>
<td>14.1±1.94</td>
<td>14.63±1.65</td>
<td>15.6±2.01</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
<tr>
<td>PR (beats/min)</td>
<td>73.24±4.09</td>
<td>75.24±4.65</td>
<td>80.4±5.11</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>116.0±3.0</td>
<td>121.0±2.3</td>
<td>128.1±4.3</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>75.5±3.2</td>
<td>79.8±1.4</td>
<td>82.2±2.2</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
</tr>
<tr>
<td>PP (mmHg)</td>
<td>40.4±1.1</td>
<td>41.2±1.7</td>
<td>45.8±3.1</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>89.05±3.1</td>
<td>93.5±1.6</td>
<td>97.5±2.7</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
</tbody>
</table>

<p>| Table 6: Comparison of cardiorespiratory parameters in three different groups in female participants |</p>
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Normal weight Group-I (n=95) (mean±SD)</th>
<th>Overweight Group-II (n=80) (mean±SD)</th>
<th>Obese Group-III (n=75) (mean±SD)</th>
<th>Statistical significance Group I versus Group II</th>
<th>Statistical significance Group I versus Group III</th>
<th>Statistical significance Group II versus Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR (beats/min)</td>
<td>13.85±1.49</td>
<td>15.1±2.0</td>
<td>15.6±1.99</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
<tr>
<td>PR (beats/min)</td>
<td>71.62±3.13</td>
<td>74.2±2.14</td>
<td>76.08±2.38</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>114.7±4.7</td>
<td>119±4.6</td>
<td>126.3±5.86</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>72.94±5.3</td>
<td>77.05±3.94</td>
<td>80.8±2.83</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
<td>&lt;0.01 HS</td>
</tr>
<tr>
<td>PP (mmHg)</td>
<td>41.76±3.48</td>
<td>41.9±2.15</td>
<td>45.5±4.9</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
<td>&gt;0.05 NS</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>86.87±4.84</td>
<td>91±3.9</td>
<td>96±3.38</td>
<td>&gt;0.01 HS</td>
<td>&gt;0.01 HS</td>
<td>&gt;0.01 HS</td>
</tr>
</tbody>
</table>

PR: Pulse rate, PP: Pulse pressure, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure

fitness has long been shown an association with BMI, that is, overweight or obese participants had decreased value of VO₂ max. Our study results showed that cardiorespiratory fitness, that is, VO₂ max was significantly different in normal participants when compared with overweight and obese participants. VO₂ max is one of the most valid indices for measuring cardiorespiratory fitness. It indicates the transport of oxygen to the working muscle. Cardiorespiratory fitness (VO₂ max) showed a highly significant decrease from normal to overweight and obese group in male and female group participants. Our study agrees with the studies by Welch et al.,[27] Rowland et al.,[28] and Ozcelick et al.,[29] in their research a highly significant correlation which was found between high BMI and low VO₂ max. In a study done by Bandopadhyay, a cardiorespiratory fitness in overweight/obese girls was comparatively much less when compared to normal weight girls.[30] Setty et al. 2012 in their study also found a significant association between high BMI and low cardiorespiratory fitness in their participants.[31]

Our study showed that males and females are at risk for cardiovascular disease of same age group. Some of the recent studies use 24 h ambulatory BP monitoring system, which showed that BP was high in males when compared to females of the same age group. Our study correlates with the studies done by Winmer et al. and Khoury et al., in which they found a significant rise in BP with aging in both male participants as well as in females participants, but male participants were having higher mean BP than women participants by approximately 6–10 mmHg.[32,33] Our findings were also similar to meta-analysis done by Staessen et al. and the 3rd National Health and Nutrition Evaluation Survey, in which it was shown that men had higher BP than women through their middle age.[34,35] Anastos et al., in his study, found that incidence of hypertension in men was higher when compared to women of same age.[36] Archbold et al., in their study, found a direct correlation between adiposity and short sleep with increased BP.[37] <8 h of sleep was also directly associated with the risk of prehypertension among
the adolescents according to a study done by Kuciene and Dulskiene.[38]

Limitations should be considered before making generalizations in the study. The participants in the study were limited to medical students of same college which could be expanded by including students of other fields and of different areas. The findings can also be implemented on the other population in a generalized way. In our study, sleep patterns and quality were questionnaire based which can be improved using a well-equipped sleep laboratory. A monitoring on the effect of lifestyle modifications and use of exercise in the study group should also be done. Along with it, daily calorie intake and physical activities should also be monitor so as to improve cardiorespiratory fitness.

**CONCLUSION**

In our study, a highly significant positive correlation between disturbed sleep pattern (PSQI scale) and BMI was found. Increased BMI may be due to disturbed sleep patterns which reduce the amount of physical activity as disturbed or decreased sleep makes an individual lethargic. Thus, the results of our study promote a positive association between disturbed sleep with the overweight/obesity. Cardiorespiratory fitness also showed a valid significant decrease in overweight an obese group, respectively, among both male and female groups. Thus, the result of our study showed that the cardiorespiratory fitness was affected significantly among young obese participants when compared to normal participants of both groups. Hence, overweight and obese participants are at the greater risk of hypertension and cardiovascular comorbidities. Hence, in view of current obesity trend which is due to abnormal sleep patterns, poor sleep quality, and increasing cardiovascular diseases, it is advisable to take proper sleep, limit energy intake from total fats, sugars, and do regular exercise for at least 1 h each day.

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