Comparison of anthropometric parameters and polysomnographic data in obese, overweight and non-obese patients with obstructive sleep apnea syndrome

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Abstract:

Purpose: The present study was done to compare the anthropometric parameters and polysomnographic data as per Asian Indian revised Body Mass Index consensus among obese, overweight and non-obese subjects. These clinical parameters provide us with significant findings in subjects with Obstructive Sleep Apnea (OSA) to diagnose easily, early and cost effectively.

Methods: The study is cross-sectional observational study conducted on 98 subjects at AIIMS, New Delhi. Informed consent was taken before enrolment in the study. Subjects were then evaluated clinically with anthropometric analysis, oral measures and overnight PSG.

Results: 98 subjects were divided into three groups: non-obese (n-32), overweight (n-36) and obese (n-30). There clinical measures and Polysomnographic (PSG) parameters were analysed using R software. On analysis obese group showed significantly higher levels of clinical measures including BMI, WC, HC, NC and significantly lower TST, SE, REM sleep and AHI levels majorly in comparison with non-obese and overweight groups ($p<0.05$). In spearmen correlation analysis, it was observed that in all the three groups of subject with OSA, it clearly signifies decrease in the time of REM sleep in comparison with anthropometric parameters.

Conclusion: It is very clear from this study that OSA is way more severe in obese subjects in comparison with non-obese and overweight subjects on comparing clinical parameters with gold standard sleep study analysis characteristics using PSG. This study also states that clinical measurements are important markers in the identification of OSA.

Keywords: Obstructive sleep apnea (OSA), waist circumference (WC), hip circumference (HC), random eye movement (REM) sleep stage, obesity, polysomnography (PSG)

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Ethics approval and consent to participate: This study has been approved by the Institute Ethics committee, All India Institute of Medical Sciences, New Delhi and Santosh Deemed to be University, Ghaziabad, Uttar Pradesh. Before the start of the study, all participants provided written informed consent. Participants were informed that they had the right to discontinue their participation or withdraw from the study at any time. We confirm that all methods were performed in accordance with the relevant guidelines and regulations **(e.g., Declaration of Helsinki).**

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Author contributions:

HT, RG and SS conceptualized the study, determined methodology, recruited participants at AIIMS New Delhi, collated / analysed data and wrote the first draft of the manuscript.

HT contributed to participant recruitment at AIIMS New Delhi, data analysis and manuscript writing.

RR performed data analysis, creating the figures, tables, and manuscript editing.

All authors approved the final manuscript.

Introduction:

Sleep is a complex physiological process in which an individual become partial or completely unconscious of body and mind for a particular duration in a day. Sleep is divided into two stages i.e. non-rapid eye movement (NREM) and rapid eye movement (REM) for a duration of around 90 minutes in 1 cycle and it occurs around 4 – 6 times in healthy sleep [1]. NREM is again divided into three stages that is N1, N2 and N3 as per American Academy of Sleep Medicine (AASM) [2]. Good sleep health helps in restoration of energy and proper integration of body. In general, adults aged around 18 – 64 years have normal sleeping hours of 7-9 hours [3]. If an adult sleep less than 7 hours considered as short sleepers and if they sleep, more than 9 hours considered as long sleepers [4]. Any disturbances in the normal physiology of sleep lead to pathological conditions such as obstructive sleep apnea syndrome.

Obstructive sleep apnea (OSA) is condition in which there is partial (hypoapneas) or complete (apneas) cessation of airflow due to collapse of upper airway lasting for 10 seconds or more leading to life threatening fatality [5]. OSA causing decrease of oxygen level in blood severely that causing awakening in the middle of sleep for the establishment of normal breathing. This occurs many times in the night leading to poor sleep health. The prevalence of OSA in adult Indian population has been estimated around 4.9% in men and 2.1% in women [6]. Major reason for poor sleep health in current urban and fast living society is obesity, which is also a well-marked risk factor for OSA [7]. Obesity is well demarcated with body mass index (BMI) of the human body which is if more than or equal to 30 (≥ 30) considered as obese, while BMI ≥25 to <30 are overweight and less than 25 are non-obese [8]. However, in this study we are considering revised Asian Indian BMI consensus if BMI ≥25 are obese, if between ≥23 to 24.9 are overweight and 18 to ≥22.9 are non-obese [9]. There are studies showing that around 60 – 90 % of OSA patients were obese [10] showing severe apnea-hypoapnea (AHI) index [11]. While overweight and non-obese patients were considered to have lesser severity or mild OSA. Polysomnography (PSG) is a gold standard investigation for diagnosis of OSA as per the American Academy of Sleep Medicine (AASM) [12]. Other than PSG, anthropometric parameters such as waist circumference (WC), neck circumference (NC), mallampati score (MPS) and others are clinical parameters that help in diagnosing the reason behind OSA. Neck circumference (NC) and waist circumference are one the strongest predictors of OSA [13,14]. PSG is a costly and complex procedure for many in developing countries where medical insurance does not concern OSA as life threatening but a lifestyle disorder. Therefore, to find a cost effective alternative for early diagnosis of characteristics of OSA among non-obese and overweight in comparison with obese is the need of the hour. Thus, we present this study to compare the anthropometric parameters and polysomnographic data as per Asian Indian revised BMI consensus among obese, overweight and non-obese subjects. These clinical anthropometric parameters will provide us predicting markers of OSA.

Methodology

The study is prospective cross-sectional observational study conducted in Department of Medicine, All India Institute of Medical Sciences (AIIMS), New Delhi. It was done to evaluate and compare the characteristics features of polysomnography in subjects with obstructive sleep apnea between three groups i.e. non-obese, overweight and obese subjects with clinical anthropometric parameters. The study was performed after approval by the Institute Ethics Committee of AIIMS, New Delhi and Santosh Medical College, Deemed to be University, UP. All subjects gave informed consent to participate in the study. Subjects were clearly informed regarding the study and were free to opt out of the study as per their consent.

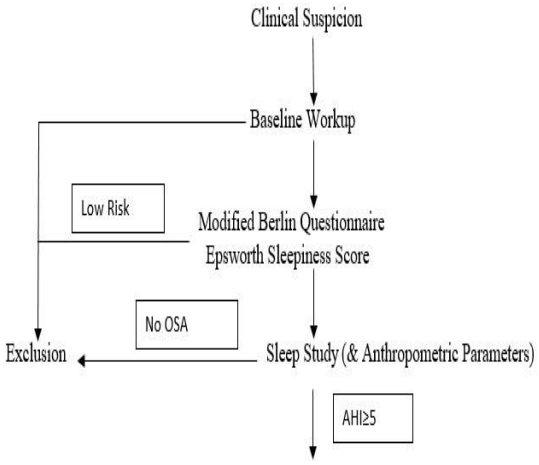
Subject Selection: This study was carried on 98 male subjects, out of which 32 participants were non-obese, 36 were overweight and 30 were obese participants stratified into three groups on the basis of BMI as per Asian Indian Criteria revised consensus. The distribution of selected demographic parameters of the participants presented in Table 1. The inclusion criteria were as follows: males, age >18 years, BMI ≥18, history of snoring, and apnea-hypoapnea index ≥5. Exclusion criteria for the study was included- any history of smoking, alcohol & drugs. Any other medical disorder of long standing respiratory, neurological and orthopedic history where excluded. A written consent taken from all participants before commencement of the study. All the participants assessed clinically through history taking and detailed clinical examination before the study. The study protocol approved by the Institutional Ethical Committee on the use of Human as an Experimental Subjects and experiment conforms to the principles outlined by the Declaration of Helsinki protocol, 1964.

Anthropometric measurements: The following data were collected from each subject: BMI, neck circumference (NC), waist circumference (WC), hip circumference (HC), thyromental distance (TD), Mallampati score (MPS) and neck length (NL) are major parameters while mid arm circumference (MAC), waist to hip ratio (WHR), percentage predicted neck circumference (PPNC), triceps skinfold thickness (TSFT), biceps skinfold thickness (BSFT), sub-scapula skinfold thickness (SSFT), supra-ileac skinfold thickness (SIFT) and chest circumference are some minor parameters.

Polysomnographic recordings [15]: A full-night PSG was done for all the subjects. Recorded parameters as follows: electroencephalogram, oculogram, chin and bilateral anterior tibials electromyogram, nasal airflow, chest and abdominal movement, pulse oxygen saturation, snoring, and body position. All tracings scored manually according to the guideline of the American Academy of Sleep Medicine (AASM) in 2007. Apnea defined as a complete cessation (≥90 %) from baseline in airflow of ≥10s and hypopnea as a drop (≥30 %) in airflow of ≥10s accompanied by oxygen desaturation ≥4 %. Apnea-hypopnea index (AHI) expressed as a total number of episodes of obstructive apneas plus hypopneas per hour during sleep. Oxygen desaturation index (ODI) attained from the frequency of desaturations of ≥4 % per hour. The percentage of sleep duration with SpO2 < 90 % (TS90 %), and lowest O2 saturation (LaSO2), mean oxygen saturation (mean SpO2) will also be recorded. All of the subjects were asked to empty their bladder before the recording. Before applying the electrodes, the skin was prepared with spirit. Polysomnographic data, including the sleep stages, snoring index, arousal index, oxygen saturation parameters, and abnormal movements scored manually.

Figure:-1 Subject prepared for overnight PSG

Experimental Design:



98 subjects included and divided into three groups as per Asian Indian BMI criteria

Figure:-2 Showing experiment design and study protocol work flow

Statistical Analysis

Statistical analysis was performed using R software (v. 4.1.2). The data distribution was examined for each parameter using the Shapiro-Wilk test ($p > 0.05$). The Kruskal-Wallis test was used for non-normally distributed values, and one-way ANOVA was used to examine normally distributed parameters. Wilcoxon and the t-test were used to compare the groups for pairwise comparison. The Bonferroni adjustment was employed for post hoc analysis for multiple comparison correction. To evaluate the relationship between the parameters, Spearman rank correlation was used. $p<0.05$ was considered statistically significant.

Result:

The baseline demographic characteristics of 98 male subjects enrolled in the study are presented in Table 1. This includes 32 subjects in Non-obese group, 36 in Overweight and 30 in Obese group. BMI was significantly higher in the obese group as compared to the Non-obese and Overweight groups. All these 98 subjects underwent overnight PSG for sleep study analysis and were having obstructive sleep apnea syndrome with AHI ≥5.

Table 1: Baseline Demographic characteristics of subjects enrolled in the study.

Parameters	Non-obese (n=32)	Over weight (n=36)	Obese (n=30)	P-value
Age (Years)	40.5(32-47.5)	41.5(32.5-52.25)	47(35.25-55.25)	0.23
Height (cm)	165(161.5-171)	170(166.75-177.25)	165.5(162-172)	0.0217 $
Weight (kg)	58(51.1-65.25)	70.8(64.725-77.025)	84(74-96.2)	3.87E-14****,####,$$$$
BMI (Kg/m^2)	21(20.5-21.925)	24.4(24-24.8)	29.15(28.125-34.6)	1.98E-19****,####,$$$$

Note:Values are expressed as median (IQR)

Abreviations: BMI, Body mass Index; cm, Centimeters; Kg, Kilograms; m, meter

*=Normal vs. Over weight; #=Normal vs. Obese; $= Over weight vs. Obese

*=<0.05, **=<0.01, ***=<0.001, ****=<0.0001

The clinical characteristics of the 98 subjects are presented in Table 2. 53 subjects were found to have mild OSA (AHI ≥5 - <15), 23 subjects had moderate OSA (AHI>15 - <30) and 22 subjects had severe OSA (AHI ≥30) were divided in two three groups as per BMI. On comparing anthropometric parameters such as neck length, neck circumference, percentage predicted neck

circumference (PPNC), hip circumference, waist circumference, mid-arm circumference (MAC), triceps skin fold thickness (TSFT), biceps skin fold thickness (BSFT), subscapular skin fold thickness (SSFT), suprailiac skin fold thickness (SIFT) were significantly higher in Obese group as compared to non-obese group (Table 2). Furthermore, Waist to Hip ration (WHR) was also significantly higher in obese group when compared to Non-obese and Overweight group. On comparing oral parameters such as thyromental distance and malampati score among the non-obese vs overweight, non-obese vs obese and overweight vs obese groups showing statistical significant differences. PSG parameters such as total sleep time, sleep efficiency, N2, N3, REM sleep, apnea-hypoapnea index, oxygen desaturation index, respiratory disturbance index, respiratory arousal index and minimum oxygen saturation showed statistically significant differences among non-obese vs overweight, non-obese vs obese and overweight vs obese groups. N1, arousal index, delta oxygen saturation and titration levels showed statistically significant differences in non-obese vs obese and overweight vs obese group only. PLM arousal index showed statistically significant difference in non-obese vs overweight group only. Average oxygen saturation levels showed statistically significant difference in non-obese vs obese group only

Table 2: Comparison of clinical parameters (anthropometric measurements, oral parameters and sleep study analysis parameters) of subjects enrolled in the study.

Parameters	Non-obese (n=32)	Over weight (n=36)	Obese (n=30)	P-value
Neck length(cm)	9(9-10)	9(8-10)	8(7-8)	2.47E-07*,####,$$
Neck circumference (cm)	34(33-36)	37(36-38)	41(39-42)	1.51E-09****,####,$$$
PPNC[a]	84.32±6.28	91.69±5.60	99.94±10.76	<0.0001****,####,$$
Hip Cirumference (cm)	90(86.75-94.5)	98(95.75-101)	106(101-116.25)	1.26E-12****,####,$$$$
Waist circumference (cm)	85(80-90.75)	95(92-100)	106.5(101.25-120)	6.89E-13****,####,$$$$
W/H ratio	0.9(0.9-0.9325)	0.9(0.9-1)	1.03(0.965-1.05)	9.15E-08####,$$$$
MAC (cm)	26(25-29)	30(28-31.25)	34(31.25-36)	2.29E-09***,####,$$$
TSFT(mm)	10(6-15.25)	18(15-21)	24(15.5-29.5)	7.96E-08****,####,$
BSFT (mm)	6(5-9.25)	13(10-15)	16(10.25-22)	1.33E-08****,####
SSFT (mm)	17(14.75-25.25)	30(25.5-37.5)	40(34-45)	1.82E-11****,####,$$
SIFT (mm)	30(25-32.25)	42(34.5-45)	47(38-55.75)	7.37E-08****,####,$
TD	7(7-7)	6(5-6)	4(4-5)	1.97E-14****,####,$$$$
MPS	1(1-1)	2(2-2)	3(3-4)	5.71E-16****,####,$$$$
Total Sleep Time (min)	376.65(358.125-409.2)	217.95(198.75-248.15)	101.45(100-225.9)	5.47E-16****,####,$$$

Sleep efficiency (%)	94.4(92.975-96.425)	84.15(82.275-86.25)	74(71.125-75.175)	6.10E-19$^{****,\#\#\#\#,\$\$\$\$}$
N1 (min)	64(49.2-81.5)	40.15(34.6-45.75)	31.4(19.4-43.75)	1.44E-07$^{****,\#\#\#\#}$
N2 (min)	124.25(114-137.25)	110.75(91.65-125.125)	49.65(36.025-70.375)	5.75E-10$^{**,\#\#\#\#,\$\$\$\$}$
N3 (min)	74(68-82.5)	48(41.425-52.225)	29.7(18.15-44.025)	6.65E-11$^{****,\#\#\#\#,\$\$\$}$
REM (min)	118.5(95.25-125.025)	23.1(21.525-25.05)	10.25(5.425-16.85)	1.51E-17$^{****,\#\#\#\#,\$\$\$\$}$
AHI (events/hr)	6.1(5.2-6.8)	13.85(10-19.7)	56.65(26.975-77.175)	9.76E-17$^{****,\#\#\#\#,\$\$\$\$}$
RDI (events/hr)	6.4(5.2-13.425)	13.85(10-19.7)	56.65(26.975-77.175)	1.06E-12$^{***,\#\#\#\#,\$\$\$\$}$
ODI (events/hr)	5.15(3.9-8.325)	12.25(10-17)	51.7(24.1-67.8)	2.96E-11$^{**,\#\#\#\#,\$\$\$\$}$
Arousal index (AI) (events/hr)	10.1(5.075-23.375)	16.5(12.425-19.575)	25.2(20.325-41.45)	2.21E-06$^{\#\#\#\#,\$\$\$}$
Respiratory arousal index (RAI) (events/hr)	2.5(0.3-11.225)	5(1.75-12.5)	11.9(4.15-28.925)	0.000$^{\#\#,\$\$}$
PLM arousal index (events/hr)	0(0-0.625)	0.8(0-2.225)	1.05(0-2.65)	0.03*
Baseline SaO_2 (%)	96(94-96)	96(94.75-96)	95(93-96)	0.11
Minimum SaO_2 (%)	89(82.5-92)	84(81-88)	76(63.5-81)	3.59E-06$^{*,\#\#\#\#,\$\$\$}$
Average SaO_2 (%)	96(93.75-96)	94(93-96)	94(90-94.75)	0.01$^{\#\#}$
Delta SaO (Baseline - Minimum)	6(4-11.25)	10(8-14)	19.5(15-33)	1.13E-06$^{\#\#\#\#,\$\$\$}$
Titration (cmH_2O)	0(0-8)	7(0-8.25)	11(10-13)	5.24E-09$^{\#\#\#\#,\$\$\$\$}$

Note: Values are expressed as median(IQR); [a]Values are expressed as mean±SD.

Abbreviations: PPNC, Percentage Predicted Neck Circumference; W/H ratio, Waist-Hip Ration; MAC, Mid Arm Circumference; TSFT, Triceps Skin Fold Thickness; mm, millimetres; BSFT, Biceps Skin Fold Thickness; SSFT, Subscapular Skin Fold Thickness; SIFT, Suprailiac Skin Fold Thickness; TD, Thyromental Distance; MPS, Malampati Score; min, minutes; %, percent; N1, Non-REM stage 1; N2, Non-REM stage 2; N3, Non-REM stage 3; REM, Rapid Eye Movement; AHI, Apnea Hypopnea Index; RDI, Respiratory Disturbance Index; ODI, Oxygen Desaturation Index; PLM,

Periodic Limb Movement; SaO_2, arterial oxygen saturation;

*Non-obese vs Overweight, #Non-obese vs Obese, $Overweight vs Obese, * p< 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001; *∋ {*,#,$}

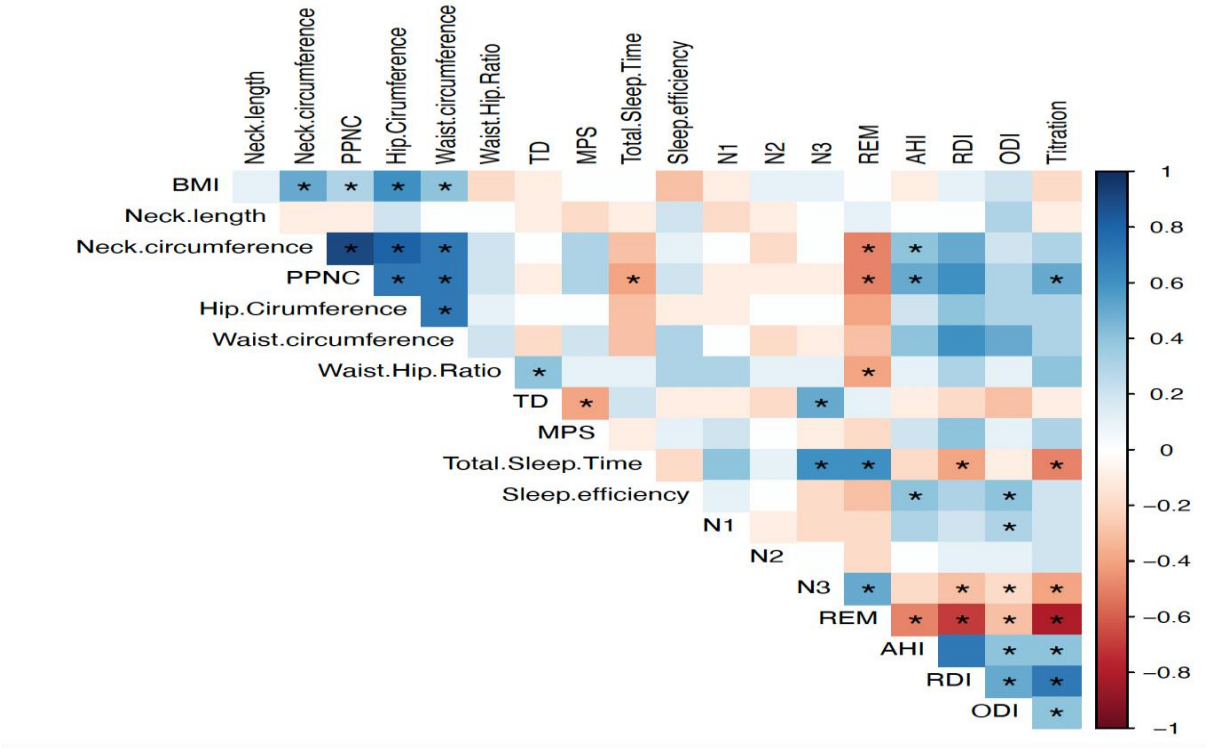


Figure 3. Correlation of non-obese subjects anthropometric parameters with sleep study parameters.

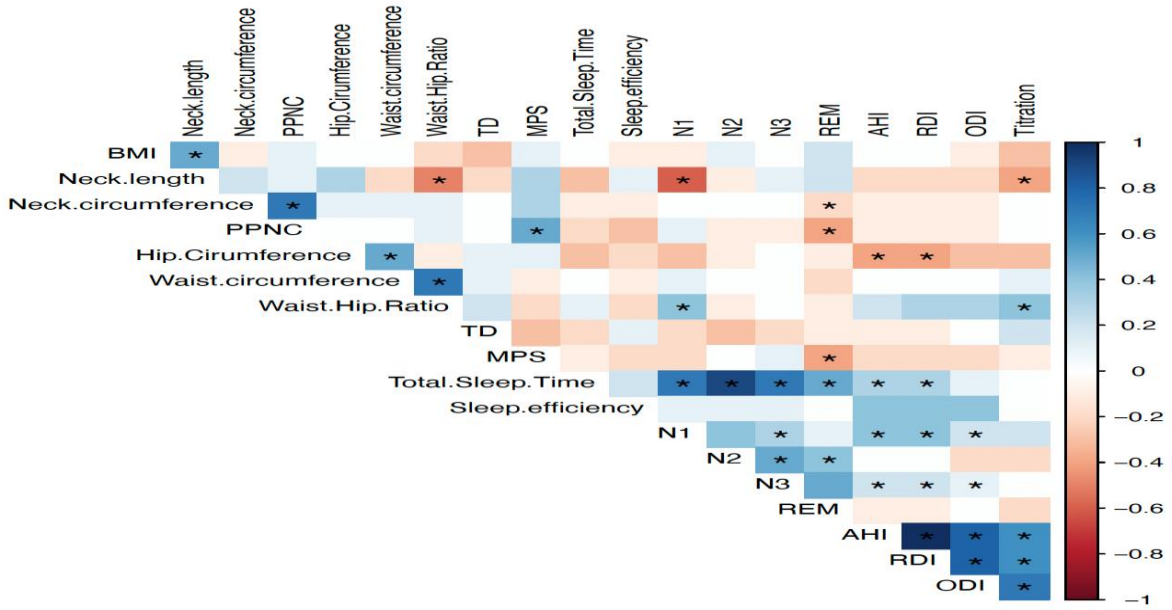


Figure 4. Correlation of overweight subject's anthropometric parameters with sleep study parameters.

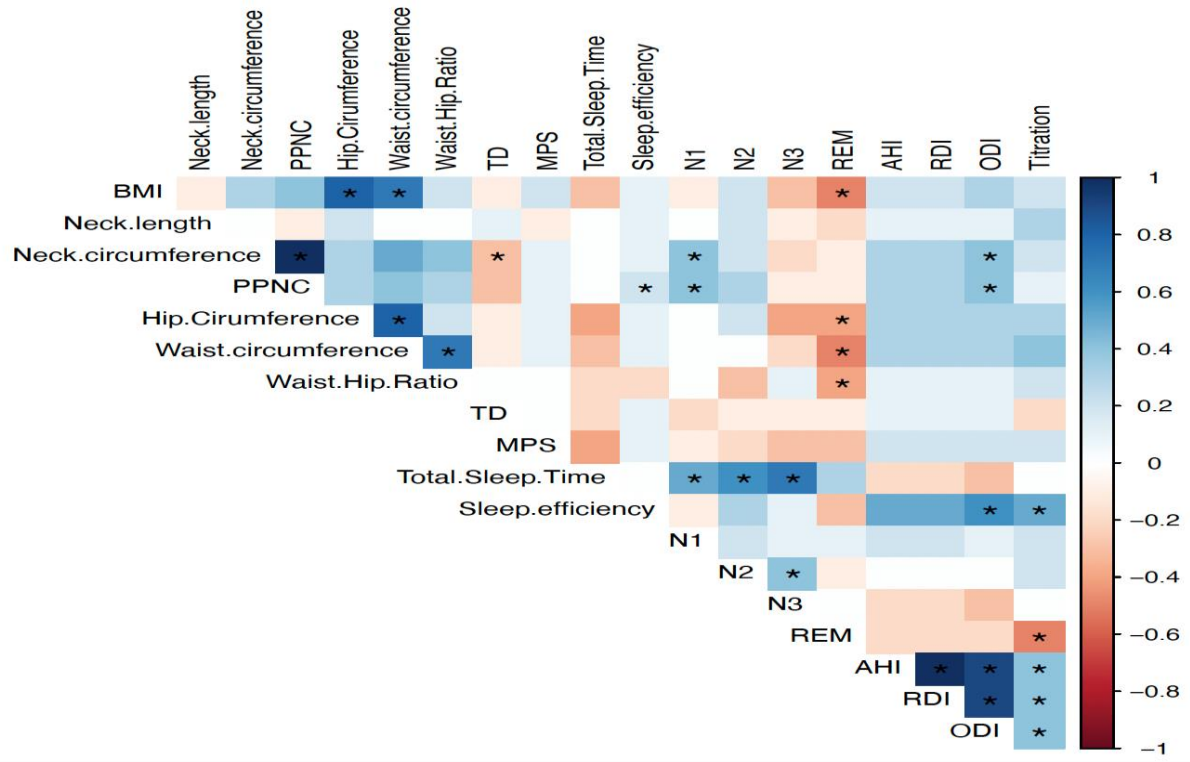


Figure 5. Correlation of obese subjects anthropometric parameters with sleep study parameters.

In addition, we have evaluated the spearmen correlation among the clinical parameters of non-obese, overweight and obese subjects (Figure 3, 4, 5). Non-obese subjects showed statistically significant positive correlation between BMI vs NC, PPNC, HC and WHR, NC vs PPNC, AHI, HC and WHR, PPNC vs HC, WC and AHI, HC vs WC, TST vs N3 stage and REM sleep (Figure 3) ($p<0.05$). Non-obese subjects showed statistically significant negative correlation between NC vs REM sleep, PPNC vs TST and REM sleep, WHR vs REM sleep, TST vs RDI and titration levels, REM sleep vs AHI, RDI, ODI and titration levels (Figure 3) ($p<0.05$). Overweight subjects showed statistically significant positive correlation between BMI vs NL, NC vs PPNC, PPNC vs MPS, HC vs WC, WC vs WHR and TST vs N1, N2, N3 and REM sleep stages (Figure 4) ($p<0.05$). Overweight subjects showed statistically significant negative correlation between NL vs WHR, N1 sleep stage and titration levels, NC vs REM sleep stage, PPNC vs REM sleep stage, HC vs AHI and RDI, MPS vs REM (Figure 4) ($p<0.05$). Obese subjects showed statistically significant positive correlation between BMI vs HC and WC, NC vs PPNC and NL, PPNC vs NL and SE, HC vs WC, WC vs WHR, TST vs N1, N2, N3 sleep stage (Figure 5) ($p<0.05$). Obese subjects showed statistically significant negative correlation between BMI vs REM sleep stage, NC vs TD, HC vs REM sleep stage, WC vs REM Sleep stage, WHR vs REM sleep stage and REM vs Titrations levels (Figure 5) ($p<0.05$). Apart from this other parameters didn't show statistical significant correlation with each other.

Discussion and Conclusion:

Out study analysed various anthropometric measurements including oral measures and their association with the sleep study parameters in adult population having obstructive sleep apnea syndrome. Our adult population with OSA are divided into three groups as per Asian Indian BMI revised consensus [9]. There are many studies done on comparison of anthropometric parameters and sleep study analysis but to our best knowledge, this is the first study to compare the parameters among groups as per revised

Asian Indian BMI consensus. In the present study, the anthropometric parameters and sleep study characteristics have shown significant difference in comparison among non-obese, overweight and obese subjects.

The subjects in obese group have higher levels of BMI, NC, WC, HC, WHR, MAC, TSFT, BSFT, SSFT, SIFT, MPS, AHI, RDI, ODI, AI, RAI, titration levels and lower levels in TD, NL, TST, SE, N1, N2, N3, REM in comparison with non-obese and overweight subjects which is in accordance with other study done by Reddy et al., 2017 and Kang et al., 2014 [16]. Kang et al., 2014 reported that increased in anthropometric measurements significantly associated with severity of OSA characteristics [17]. Reddy et al., 2017 reported that obese are more common with OSA and non-obese may also have OSA and should not be under evaluated. If we see clinically measurements, BMI, NC and WC are known to be the strongest predictors of OSA, which we have seen in this study also where both these parameters have shown statistically increasing trend in obese group vs overweight vs non-obese subjects[16 , 18, 19]. Also these parameters like NC, HC, WC, WHR are negatively correlated with REM sleep stage which clearly signifies that increase in these anthropometric parameters causing decrease in sleep duration or decrease in deep sleep [20]. Further PPNC is an emerging factor which shows negative correlation with REM sleep, total sleep time in this study in non-obese and overweight group which may help in predicting OSA and similarly seen in other studies also [21]. BMI was also seen in this study to have negatively correlated with REM sleep stage in obese group as seen in other study [22]. BMI was one of the traditional marker for predicting obesity and its risk associated with OSA [19,23].

In oral measures such as TD and MPS; TD show statistically significant decreasing trend on comparing non-obese with overweight or non-obese with obese or overweight with obese. MPS show statistically significant increasing trend on comparing non-obese with overweight or non-obese with obese or overweight with obese. This shows similarity with other studies that mallampati indices and thyromental distance are useful in predicting OSA [21, 24]. As lesser the thyromental distance lesser will be the open tissue space and more difficulty in breathing causing OSA. Similarly increase in MPS lead to increase in narrowing of oral space that may be due to thickening of tongue or large uvula decreasing upper airway space that may origin OSA [25, 26]. In our study, MPS was significantly negative correlated with REM sleep stage that shows increase in MPS class and decrease in REM sleep. This shows that upper airway fat deposition is one of the major reason in the narrowing of upper airway space causing sleep disordered breathing.

In this study on comparing clinical measurement with gold standard sleep analysis technique, this can be clearly seen that increase in the one group will reversely lead to decrease in the other group which is seen in case of sleep efficiency, total sleep time, REM sleep and also in oxygen saturation levels. These are the clear indicators of sleep deficiency or poor sleep health causing sleep breathing disorder particularly OSA. While treating this disorder the level of oxygen or titrations levels were also to be kept at higher range to keep airway open for the maintenance of blood oxygen level.

There were some possible limitations to this study, firstly it is a cross-sectional observational study, result in possibility of confounding factors that might be unaccounted, may have biased results. Secondly was pandemic situation (COVID-19), due to which less number subjects were recruited and underwent overnight PSG. Third, the findings of the present study need to be confirmed using a larger sample size. Another, we have used anthropometric dimensions such as the neck circumference, hip circumference, waist circumference, thyromental distance and Mallampati score for the cephalometric analyses despite the availability of many gold standard multiple imaging techniques including cephalometric radiography, computed tomography and magnetic resonance imaging. Although, we selected the above mentioned anthropometric measurements rather than imaging, as they are easy and inexpensive to perform and correlate well with the severity of OSA. Another limitation was female sample size was very less which we were not able to include in the present study due to low prevalence and more comorbidities.

In conclusion, it is very clear from this study that OSA is way more severe in obese subjects in comparison with non-obese and overweight

subjects. Further, OSA is not limited to obesity but also need to be evaluated in non-obese subjects with clinical symptoms of daytime sleepiness. Therefore, when a non-obese person presents with the clinical characteristics of OSA, the diagnostic possibility should not be under estimated and should be evaluated thoroughly including oral profile, anthropometric parameters and sleep study characteristics. This also concluded that deep sleep (REM stage) is deficient not only in obese group but also in non-obese and overweight group causing awakening in the night and daytime sleepiness.

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