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Original Article

Assessment of Neural Respiratory Drive Using Surface Electromyography Parameters of Parasternal Muscles in Three Different Body Positions Among Healthy Young Adults: A Cross-Sectional Study

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Abstract

Objectives: The neural respiratory drive (NRD) is a critical determinant of breathlessness, influenced by the balance between ventilatory load and respiratory muscle capacity. This study aimed to evaluate the impact of body positions on NRD in young healthy adults (18-50 years) and to identify the optimal position for assessing NRD among the healthy subjects. **Methods**: Surface electromyography (sEMG) data from the 2nd intercostal space parasternal muscle was collected in supine, sitting, and standing positions among young healthy adults. NRD parameters, including EMG Para max% and Neural Respiratory Drive Index (NRDI), were analysed and compared among positions using ANOVA. **Results**: Significant differences in NRD values were observed across body positions, with standing vs. supine vs. sitting yielding higher values in both sexes respectively (Males: 5.113±0.437, 4.404±0.576, 4.913±0.623; $P<0.001$ and Females: 7.444±0.416, 6.435±0.266, 6.748±0.390; $P<0.001$). Post hoc analysis reveals significant difference in standing vs supine vs sitting position. These findings highlight the influence of body position on NRD measurements. **Conclusions**: The study emphasizes the importance of considering body position when evaluating NRD in healthy individuals. These factors should also be taken into account in clinical assessments to ensure accurate interpretation of NRD and related respiratory functions.

Keywords: Breathlessness, Intercostal muscles, Neural Respiratory Drive, Supine position, Surface Electromyography

Introduction

The chemical and neural control of respiration maintains constant blood chemistry by the exchange of gases at the levels of lung alveoli[1]. There is a delicate balance between the Ventilatory load and capacity of respiratory muscles that determines the neural respiratory drive (NRD) at the moment and its mismatch results in the breathlessness[2]. Physiological and pathological challenges alter the neural respiratory drive so as to effect the changes in arterial blood chemistry. Conversely, changes in NRD can also effect changes in arterial blood chemistry as part of the body's regulatory mechanisms[3-5]. Increased Ventilatory load: capacity ratio drives the patient into breathlessness as evident in chronic obstructive pulmonary disease (COPD).

Surface electromyography (sEMG) is a non-invasive technique used to assess muscle activity by measuring the electrical signals generated during muscle contractions through electrodes placed on the skin. Its non-invasive nature makes it ideal for repeated and prolonged assessments without discomfort or risk to participants. sEMG was utilized to evaluate Neural Respiratory Drive (NRD) by recording activity from the parasternal muscles across different body positions (supine, sitting, and standing). This method allows for real-time monitoring and precise measurement of muscle

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The authors have no conflict of interest.

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function, providing valuable insights into how body posture affects NRD and enabling detailed, safe, and effective analysis of respiratory muscle performance.

Direct quantification of NRD is challenging one due to inaccessibility of respiratory centre neurons activity recording. However alternatively it can be assessed reliably by measuring the level of activation of respiratory muscles like diaphragm. (Diaphragmatic surface EMG). Indirectly parasternal external intercostal respiratory muscle EMG activity studied using surface EMG can be used to assess the NRD. Although the surface electromyogram (sEMG) measures of diaphragm are used as surrogate for NRD, its assessment is an invasive one as the electrodes are put into the oesophagus for recording diaphragmatic activity and is a source of discomfort to the subject[6]. Hence, the non-invasive assessment of NRD can be made from surface EMG recordings of 2nd Intercostal space parasternal muscles (EMG_{Para})[7,8]. The normalised RMS values of EMG_{Para} correlate well with the Surface EMG values of diaphragm[9]. NRD can be considered as an advance physiological biomarker that yields a parameter for the balance between respiratory muscle load and capacity.

It is well accepted that the PFT (Pulmonary Function Test) parameters like lung capacities, lung volumes as well as flow rates differ in erect sitting position as compared to supine[10,11]. Similarly, it is likely that the NRD might be influenced by the different body positions.

However as per Williams S, the NRD is not influenced by body positions like supine and sitting posture among healthy adults[12]. The effect of different body positions on NRD needs to be studied as the literature is also scarce in the healthy Indian population. The neural respiratory drive need to be assessed by surface EMG from 2nd ICS parasternal muscle activity in different positions respectively supine, sitting and standing position. The study shall enable to explore the optimum position (where the extreme values are not evident) for assessment of neural respiratory drive using the non-invasive surface EMG parameters from respiratory muscles. (EMG_{Para})

The present study is intended to compare the NRD at rest among the young healthy adults in different body positions. We hypothesized that body position (supine, sitting, and standing) significantly influences Neural Respiratory Drive (NRD) as measured by surface electromyography (sEMG) in healthy young adults. Specifically, it is expected that NRD would vary across these positions, reflecting differences in respiratory muscle activation among males and females in age range of 18-50 years. Since the lung volumes and capacities are affected the supine, sitting and standing postures so does it tend to also affect the neural respiratory drive.

The study is aimed to evaluate the impact of different body positions/postures on resting NRD in young, healthy adults and to identify the optimal position for recording the neural respiratory drive.

The objectives of the study were:

- To record the 2nd ICS parasternal muscle sEMG activity (EMG_{Para}) during quite breathing and inspiratory sniff manoeuvre ($EMG_{Para\ max}$) among young healthy males and females in age range of 18-50 years.
- To compare the NRD ($EMG_{Para\ max\%}$) among healthy males and females in age range of 18-50 years in 3 different body positions supine, sitting and standing position.

Despite the significant role of Neural Respiratory Drive (NRD) in respiratory function, research on how different body positions affect NRD, particularly in healthy individuals, remains limited. Understanding how body posture influences NRD is crucial, as it can impact both normal breathing mechanics and clinical assessments. Most existing studies focus on NRD in static positions or specific clinical conditions, leaving a gap in knowledge regarding its variability across common body postures. Our study aims to address this gap by examining NRD in supine, sitting, and standing positions using surface electromyography (sEMG). By exploring these variations in healthy individuals, we seek to enhance our understanding of how body position affects respiratory muscle activity and its implications for clinical assessments and interventions. This research has the potential to inform better clinical practices and improve the accuracy of NRD evaluations in diverse settings.

Materials and Methods

Study design: An observational crossectional study involving 40 (20 males and 20 females) healthy subject in the age group of 18-50 years were recruited.

Study setting: The study was conducted in tertiary care centre of Institution of National Importance (INI). The sEMG data was acquired in neurophysiology laboratory of the department of Physiology.

Sample size: Sample size for this study was estimated using G-power software. Our objective was to compare differences in resting neural respiratory drive with respect to 3 positions: supine, sitting and standing position respectively among healthy young adults. We anticipated small effect size of 0.252 for sample variance. Therefore sample size was calculated with type -1 error of 5%, and power of 80% and effect size of 0.252. Calculated sample size was 40 and accordingly 40 Healthy volunteers (20 males and 20 females) in the age group of 18 to 50 years were enrolled for the study. The study participants were enrolled using convenience sampling.

The study participants were explained the purpose and nature of the study. Informed and written consent was taken from those who were willing to give consent. The study participants underwent assessment of basic anthropometric measures (height, weight, BMI) and surface EMG_{Para} in all 3 positions using the Nihon Kohden Neuropack X1 MEB 2300.

The study participants underwent clinical examination and medical history was taken beforehand. Resting Pulse rate was assessed using digital pulse oximeter in sitting position; Blood pressure was recorded using calibrated sphygmomanometer in sitting position after period of 5 minutes rest, Respiratory rate was recorded using respiratory transducer applied over the chest and visual observation for 1 minute in sitting position. Surface EMG measurements were taken at least 2 hour following food or drink consumption like tea and caffeine.

The inclusion and exclusion criteria for the study participants are:

Inclusion criteria:

- Healthy male and female subjects in the age group of 18-50 years.
- Subjects free from chronic medical morbidities, cardio-respiratory illness.

Exclusion Criteria:

- Subjects below the age of 18 years and above 50 years old.
- Subjects with dyspnoea at rest of cardiorespiratory origin, cough, coryza.
- Subjects with history of obstructive and or restrictive lung diseases.
- Subjects with history of chronic medical illnesses like diabetes, hypertension, and Pulmonary Tuberculosis.
- Subjects with BMI greater than 25.
- Subjects with thoracic spinal column deformity, Subjects with history of Spinal cord injury, Brain injury.
- Subjects with history of Tobacco and smoking.
- Participants who exhibit artefacts in the EMG analysis that cannot be resolved, leading to unreliable data.
- Participants who do not complete the evaluation protocol or fail to attend follow-up sessions as required by the study.
- Participants who voluntarily withdraw from the study or express a desire to leave the study at any point.
- Participants who develop any acute illness, injury, or condition during the course of the study that may interfere with the assessment or compromise their safety.

Surface EMG parasternal (EMG_{Para}) measurement:

The EMG_{Para} and $EMG_{Para\ max}$ data as measure of neural respiratory drive was collected in each study subject under 3 different postures/positions viz. supine, sitting and standing. The recordings of surface EMG activity (EMG_{Para}) were done at the same time of the day (Morning hours 9:00 to 12:00) for each subject throughout the study to avoid any diurnal variations. Diurnal variations can affect physiological parameters, including respiratory function, due to natural fluctuations in circadian rhythms. For instance, respiratory muscle performance and neural drive might differ between morning and evening due to changes in metabolic rate and hormonal levels[13]. Before recording sEMG data participants were given rest for period of 10 minutes to acclimatise with laboratory conditions and to prevent any reactive changes in respiratory rates and breathing pattern. Participants were asked to maintain a consistent breathing pattern and avoid sudden respiratory rate changes during measurements. Lung volume was controlled through standardized breathing protocols, and heart rate was monitored for stability. External factors were managed by keeping ambient temperature constant (25° Celsius) and minimizing noise to reduce distractions, thereby enhancing the accuracy and consistency of the EMG measurements. Subject was asked to seat upright in a chair back supported, arms were placed on armrests and feet flat on the floor to minimise trunk movements. Subject was asked to remain still and breathe quietly. A marking was done on the subject's skin for placement of electrodes in an identical position. After skin preparation, using the alcohol swab the skin was gently rubbed for placement of electrodes. Two circular surface electrodes (10 mm diameter AgCl2 electrodes, Nihon Kohden, Japan) were be placed in the 2nd intercostal spaces, just 2 cm lateral to the sternum and parallel to the direction of intercostal muscle fibres with inter-electrode distance of 10 mm.

Specific anatomical landmarks were used to ensure consistent electrode placement across all participants. The electrodes were placed over the intercostal muscles, following standardized guidelines to ensure reproducibility. The placement was double-checked by a trained technician to ensure accuracy. The parasternal 2nd intercostal space was identified by locating sternal angle and after electrode placement the position was confirmed by recording sEMG during breathing. The same protocol as mentioned was followed for all participants.

The grounding electrode was kept over Manubrium. The surface EMG data was acquired with low pass filter of 10 Hz and high pass filter of 1 KHz at sampling frequency of 2 KHz. (Neuropack X1 MEB 2300,Nihon Kohden Inc. Japan) and stored in digital format as raw EMG signals. Raw EMG data was analysed using Labchart 8 software (AD Instruments) on a laptop in time domain parameter. (Amplitude in uV RMS (Root Mean Square) The peak root mean square (RMS) of EMG_{Para} activity for each inspiration was averaged over 1 min of tidal breathing and normalised to a value of $EMG_{Para\ max}$ obtained during a maximal inspiratory sniff manoeuvre obtained before each measurement across the positions viz. Supine, sitting and standing as described by Murphy PB[7].

The study utilized the maximal inspiratory sniff manoeuvre to measure $sEMG_{Para\ max}$, chosen for its specific advantages in assessing respiratory muscle activity. The maximal inspiratory sniff manoeuvre was selected due to its ability to elicit maximal activation of the parasternal intercostal muscles, providing a robust reference for normalizing electromyography (EMG) data. This technique involves a rapid, deep inhalation that effectively engages the respiratory muscles, allowing for precise measurement of their peak activity[12].

Similarly the sEMG data was recorded in supine and standing positions for all participants.

Artefact Detection: The phasic EMG activity signal was carefully monitored for the presence of electrocardiography (ECG) artefacts, which are common due to the proximity of the recording electrodes to the heart.

Artefact Filtering: Various filtering techniques were employed to remove ECG artefacts from the sEMG signal. This typically involved the use of band-pass filters to isolate the frequency range of the EMG signal from that of the ECG artefacts.

Table 1. Anthropometric Characteristics of the study Participants.

Study participants	Age (Years)	Height (cms)	Weight (Kg)	BMI
Male (n=20)	28±8.86	172±22.4*	73.20±3.4*	23.81±1.4*
Female (n=20)	27±7.74	158±16.5	58.61±2.4	21.53±1.8

Mean±SD, $p<0.01$, Student T test.

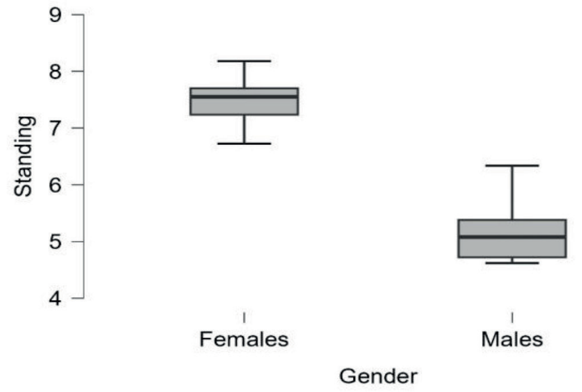

Figure 1. Distribution of NRD parameter with respect to standing position.

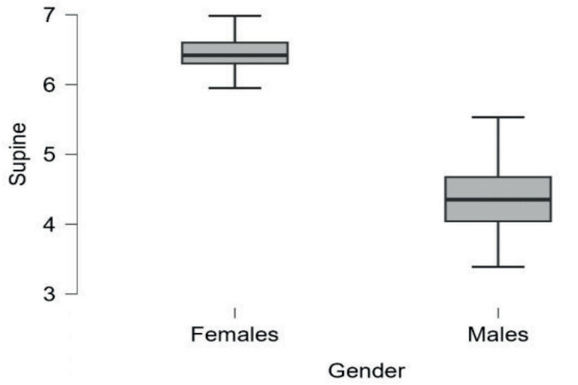

Figure 2. Distribution of NRD parameter with respect to Supine position.

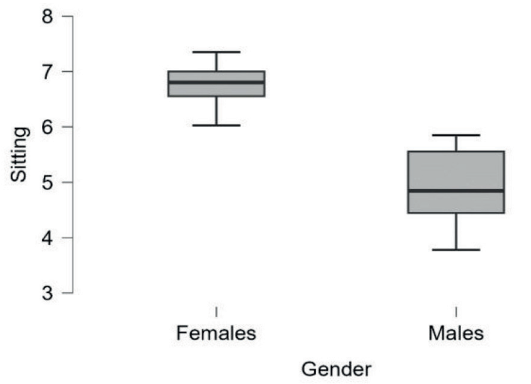

Figure 3. Distribution of NRD parameter with respect to Sitting position.

The tidal breathing EMG_{Para} data was normalised against $EMG_{Para\ max}$ data using following formula:

$$\text{Normalised } EMG_{Para\ max\%} = \frac{sEMG_{Para}}{(sEMG_{Para\ max})} * 100$$

The normalization of EMG_{Para} data allows inter-individual comparison and similarly it allows testing the repeatability within the same individual. Two measures of NRD were derived as mentioned bellow[12]:

1) $EMG_{Para\ max\%}$ the mean peak inspiratory tidal (EMG_{Para}) normalised to the maximal inspiratory sniff manoeuvre ($EMG_{Para\ max}$); and

2) Neural Respiratory Drive Index (NRDI): The product of $EMG_{Para\ max\%}$ and respiratory rate.

Peak RMS per respiratory cycle will be calculated and averaged over 1 min. The RMS of the EMG_{Para} (EMG parasternal) signal is the quantification of the total EMG_{Para} power. The maximal RMS value for respiratory muscle EMG activity will be recorded and compared against the normal Respiratory tidal effort. A single maximal inspiratory sniff manoeuvre followed by 1-minute normal tidal ventilation sequences for surface EMG_{Para} will be done. Each subject underwent 3 trials for the same, and the average of the three was taken as the final reading.

Data Analysis: The data was checked for correctness and completeness and was kept stored in digital format on computer. The study parameters were assessed for normality distribution and accordingly the statistical test of significance student's T test used for testing significance among sex wise anthropometric data, EMG_{Para}, $EMG_{Para\ max}$. The $EMG_{Para\ max\%}$ and NRD index was compared using the ANOVA for the 3 positions viz. Supine, sitting and standing positions. The statistical analysis of data was done using SPSS version 25 software.

Table 2. Descriptive Statistics for NRD parameters group wise.

Descriptive Statistics						
	Standing		Supine		Sitting	
	Females	Males	Females	Males	Females	Males
Mean	7.444	5.113	6.435	4.404	6.748	4.913
Std. Error of Mean	0.093	0.098	0.059	0.129	0.087	0.139
Std. Deviation	0.416	0.437	0.266	0.576	0.390	0.623
Shapiro-Wilk	0.925	0.897	0.988	0.971	0.951	0.948
P-value of Shapiro-Wilk	0.126	0.036	0.994	0.777	0.389	0.344
Minimum	6.726	4.619	5.950	3.388	6.027	3.778
Maximum	8.180	6.336	6.983	5.532	7.351	5.851

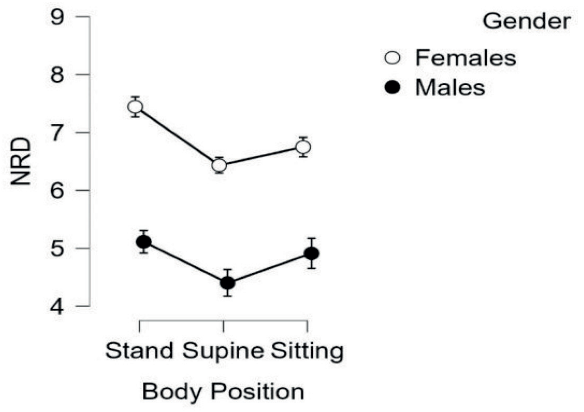

Figure 4. Descriptive plots.

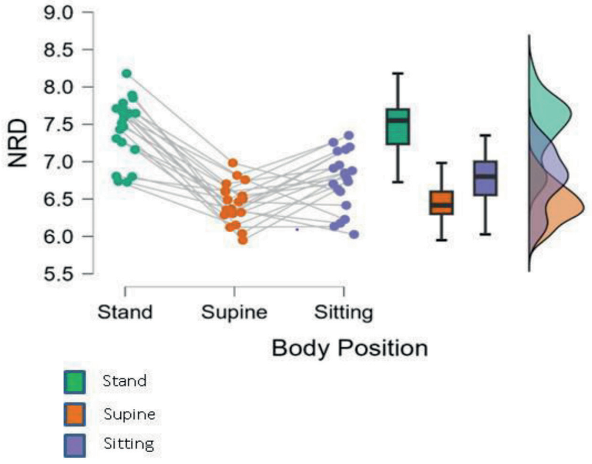

Figure 5. Neural Respiratory Drive Gender: Females.

Results

The anthropometric data of male and female study participants reveal significant difference in height, weight and BMI (Table 1). However there was no significant difference in age of these participants.

There were no outliers, as assessed by Figures 1, 2, 3. The data were normally distributed, as assessed by Shapiro-Wilk test of normality (p>0.05) (Table 2).

Females depicted higher NRD values across all body positions compared to males (Figure 4). While both males and females show the lowest NRD in the supine position, it is the standing position where highest NRD values for both genders were observed. However the sitting position causes a slight increase in NRD compared to the supine position but remains lower than standing for both genders. The difference in NRD between body positions is more pronounced in females than in males suggesting the postural influences on NRD with sex wise differences.

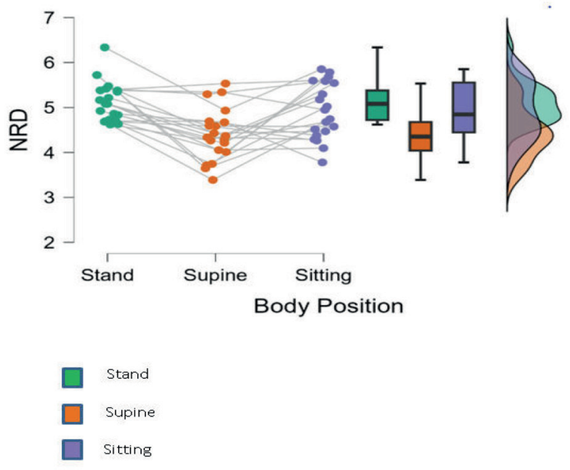

Figure 6. Neural Respiratory Drive Gender: Males.

Table 3. Assumption Checks.

Test for Equality of Variances (Levene's)				
	F	df1	df2	p
Standing	0.016	1	38	0.901
Supine	7.126	1	38	0.011
Sitting	7.350	1	38	0.010

Table 4. Test of Sphericity.

Test of Sphericity							
	Mauchly's W	Approx. X^2	df	p-value	Greenhouse-Geisser ε	Huynh-Feldt ε	Lower Bound ε
Body Position	0.948	1.969	2	0.374	0.951	0.999	0.500

Table 5. Repeated Measures ANOVA.

Within Subjects Effects								
Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
Body Position	None	14.772	2.000	7.386	41.229	< .001	0.087	0.361
	Greenhouse-Geisser	14.772	1.901	7.769	41.229	< .001	0.087	0.361
Body Position * Gender	None	1.245	2.000	0.622	3.475	0.036	0.007	0.034
	Greenhouse-Geisser	1.245	1.901	0.655	3.475	0.038	0.007	0.034
Residuals	None	13.615	76.000	0.179				
	Greenhouse-Geisser	13.615	72.255	0.188				

Note. Type III Sum of Squares.

Between Subjects Effects							
Cases	Sum of Squares	df	Mean Square	F	p	η^2	ω^2
Gender	127.994	1	127.994	432.866	<.001	0.758	0.847
Residuals	11.236	38	0.296				

Note. Type III Sum of Squares.

Gender wise comparison amongst male and females observed higher NRD in Standing positions as compared to sitting and supine (Figures 5, 6).

There was homogeneity of variances ($p>0.05$) as assessed by Levene's test of homogeneity of variances (Table 3). Mauchly's test of sphericity indicated that the assumption of sphericity was not violated ($p>0.05$) (Table 4). There was statistically significant interaction between body position and gender, $F(2,76)=3.475$, $p=0.036$, $w^2=0.034$, showing small effect.

There was statistically significant main effect for different body position $F(2,76)=41.229$, $p=<0.001$, $w^2=0.361$, showing a large effect (Table 5).

There was statistically significant main effect for gender and NRD was found to be higher for females in all three body positions $F(1,38)=432.866$, $p=<0.001$, $w^2=0.847$, showing a large effect.

Post hoc testing using Bonferroni correction revealed that NRD decreased significantly from standing to supine ($M=0.859$, $SE=0.095$, $p<0.001$), standing to sitting positions ($M=0448$, $SE=0.095$, $p<0.001$) and for supine to sitting ($M=-0.411$, $SE=0.095$, $p<0.001$) (Table 6).

The sEMG parameters EMG_{Para} and $EMG_{Para\ max}$ differ significantly between males and females study participants (Table 7). Similarly these parameters also differ with respect to three body positions. The higher values were obtained for standing positions among both genders. The NRD parameter that is ratio of normal tidal breathing sEMG activity (EMG_{Para}) and

Table 6. Post Hoc Tests within group significance.

Post Hoc Comparisons - Body Position										
		95% CI for Mean Difference					95% CI for Cohen's d			
		Mean Difference	Lower	Upper	SE	t	Cohen's d	Lower	Upper	p_{bonf}
Stand	Supine	0.859	0.627	1.091	0.095	9.078	1.840	1.128	2.552	< .001 ***
	Sitting	0.448	0.216	0.680	0.095	4.732	0.959	0.398	1.520	< .001 ***
Supine	Sitting	-0.411	-0.643	-0.180	0.095	-4.345	-0.881	-1.432	-0.330	< .001 ***
*** p < .001										
Note. P-value and confidence intervals adjusted for comparing a family of 3 estimates (confidence intervals corrected using the Bonferroni method).										

Table 7. sEMG parameters of the study Participants.

Study Participant	EMG_{Para} (RMS in μV)			$EMG_{Para\ max}$ (RMS in μV)		
	Supine	Sitting	Standing	Supine	Sitting	Standing
Males	3.84±0.94	5.64±0.86	8.22±1.35	89.09±2.31	115.33±3.34	160.47±2.68
Females	6.92±1.14**	7.94±0.66**	9.44±1.64*	107.28±3.21**	118.88±2.84**	172.34±2.40**
Mean ± SD, p<0.01, Student T test.						

Table 8. Comparison of NRDI ($EMG_{Para\ max\%}$ X Respiratory rate) with respect to Supine, sitting and standing position among the study participants.

Study Participants	NRDI ($EMG_{Para\ max\%}$)				
	Supine	Sitting	Standing	F score	P value
Male (20)	60.34±10.8	73.35±8.4	76.95±6.45	18.754**	0.001
Female (20)	103.23±6.24	107.52±9.76	112.2±7.35	15.34**	0.001
Mean ± SD, p<0.01, ANOVA.					

sEMG activity during Inspiratory sniff manoeuvre ($EMG_{Para\ max}$) revealed significant difference in these parameters in 3 different positions. The high values for NRD were recorded in standing position in both genders. The NRDI index was also found to be significantly different in females than in males (Table 8).

Table 9 shows that Age and anthropometric parameters do not show any statistically significant correlation with Supine, sitting, and standing position NRD parameters among healthy young adult males. However, a weak negative correlation was observed between the BMI and sitting positions in the NRD parameter amongst male participants. Age and Anthropometric parameters don't bear any significant correlations with supine, sitting, and standing position NRD parameters among female study participants (Table 10).

Discussion

The study aimed to compare various sEMG parameters recorded from 2nd ICS parasternal surface EMG (EMG_{Para}, $EMG_{Para\ max}$, $EMG_{Para\ max\%}$) among young healthy adults (18-50 years) in 3 different body positions. The primary objective

Table 9. Pearson's Correlation between Age, BMI, Height, Weight, and Supine, sitting, and standing NRD parameters among males.

Pearson's Correlations.								
		n	Pearson's r	p	Lower 95% CI	Upper 95% CI	Effect size (Fisher's z)	SE Effect size
Age	Standing	20	-0.025	0.918	-0.462	0.423	-0.025	0.243
Age	Supine	20	-0.323	0.165	-0.669	0.14	-0.334	0.243
Age	Sitting	20	0.165	0.487	-0.299	0.566	0.166	0.243
BMI	Standing	20	-0.402	0.079	-0.717	0.05	-0.426	0.243
BMI	Supine	20	-0.18	0.449	-0.576	0.286	-0.182	0.243
BMI	Sitting	20	-0.457*	0.043	-0.748	-0.019	-0.494	0.243
Height	Standing	20	-0.319	0.171	-0.667	0.144	-0.33	0.243
Height	Supine	20	0.081	0.736	-0.375	0.505	0.081	0.243
Height	Sitting	20	-0.165	0.488	-0.566	0.3	-0.166	0.243
Weight	Standing	20	0.232	0.326	-0.235	0.612	0.236	0.243
Weight	Supine	20	-0.011	0.963	-0.452	0.433	-0.011	0.243
Weight	Sitting	20	-0.037	0.878	-0.472	0.412	-0.037	0.243

** p < .05, ** p < .01, *** p < .001.*

Table 10. Pearson's Correlation between Age, BMI, Height, Weight and Supine, sitting and standing NRD parameters among Females.

Pearson's Correlations								
		n	Pearson's r	p	Lower 95% CI	Upper 95% CI	Effect size (Fisher's z)	SE Effect size
Age	Standing	20	0.287	0.22	-0.178	0.647	0.295	0.243
Age	Supine	20	0.404	0.077	-0.047	0.718	0.428	0.243
Age	Sitting	20	0.128	0.589	-0.333	0.54	0.129	0.243
BMI	Standing	20	0.334	0.15	-0.127	0.677	0.348	0.243
BMI	Supine	20	0.123	0.605	-0.338	0.536	0.124	0.243
BMI	Sitting	20	0.35	0.13	-0.109	0.686	0.366	0.243
Height	Standing	20	0.294	0.209	-0.171	0.651	0.302	0.243
Height	Supine	20	-0.191	0.42	-0.584	0.275	-0.193	0.243
Height	Sitting	20	-0.084	0.723	-0.508	0.372	-0.085	0.243
Weight	Standing	20	-0.292	0.212	-0.65	0.173	-0.3	0.243
Weight	Supine	20	0.107	0.653	-0.352	0.525	0.108	0.243
Weight	Sitting	20	0.39	0.09	-0.064	0.71	0.411	0.243

*p < .05, ** p < .01, *** p < .001.*

of this study was to record and compare the 2nd intercostal space parasternal muscle sEMG activity (EMG_{Para}) during quiet breathing and the inspiratory sniff manoeuvre ($\text{EMG}_{\text{Para max}}$) across three different body positions—supine, sitting, and standing—in healthy adults. Our hypothesis stated that body position would significantly influence Neural Respiratory Drive (NRD) as measured by sEMG. The findings support this hypothesis, as we observed that there were measurable differences in NRD across body positions. The variation in NRD, particularly the higher $\text{EMG}_{\text{Para max\%}}$ observed in the standing position compared to supine and sitting, suggests that body posture does play a role in respiratory muscle activation. However, the results also indicate that other factors, such as individual anthropometric parameters and potential gender differences, might have a substantial impact than initially hypothesized. These findings suggest that while body position is important, it interacts with other physiological factors to influence NRD, which could explain why the expected significant differences were not uniformly observed across all positions. The findings support the research hypothesis as there is significant difference in NRD parameters with respect to three different body positions. Similarly, the NRD and NRDI index during quiet breathing were assessed in young healthy individuals in 3 different body positions. NRD and NRDI measurements are non-invasive alternatives to analyse the activity of respiratory muscles[14,15]. Any imbalance in the respiratory muscles' Ventilatory load-to-capacity ratio can lead to increased levels of NRD.

Significant differences among males and females were observed for EMG_{Para}, $EMG_{Para\ max}$, and $EMG_{Para\ max\%}$ values (Table 2). Females tend to have higher values of EMG_{Para}, $EMG_{Para\ max}$, and $EMG_{Para\ max\%}$ indicating prominent sex difference/variation.

This difference could be due to differences in anthropometric parameters. Females have smaller lungs, smaller airway diameters, relatively weaker respiratory muscles and lesser surface area for gas exchange relative to age, height and lung sized matched males[16,17]. Moreover these differences also may predispose them to respiratory system limitations during exercise. Height affects thoracic cavity dimensions and muscle recruitment patterns, while body weight, particularly fat distribution, can influence chest wall compliance and muscle strength.

These could be possible explanation for sex differences in NRD parameters as well. A further potential reason for the difference observed could have been due to adiposity and respiratory muscle strength differences between the male and female participants. Our findings are consistent with the findings of MacBean V[18]. The reported values by Macbean et al. were a median EMG_{Para} of 4.95 μV (3.35 to 6.93 μV), $EMG_{Para\ max\%}$ of 4.95% (3.39% to 8.65%), and NRDI of 73.62 AU in 63 healthy individuals, which were lower values than observed in the present study.

Moreover, females have smaller airways, smaller absolute lung volumes, and hence greater work of breathing[19]. This implies greater activity of respiratory muscles and consequently significant resting NRD parameters among healthy females than in males.

This may be the reason for the higher resting NRD which could lead to a plateau earlier in females when exercise stress is imposed and hence the dyspnoea onset could be earlier in females than in males.

As per indicated by earlier reports, there is greater ribcage muscle contribution to inspiration in women[20]. The findings of the current study support to the previous findings by demonstrating the presence of sex differences in NRD at rest.

There was a significant difference observed in NRD among 3 different positions in both males as well as females. The sitting position recorded significantly higher values than the rest of the two. The decrease in NRD in the Supine position could be attributed to a decrease in lung volume and capacities due to the pressure effect imposed by abdominal viscera on the diaphragm.

Further encroachment on pulmonary air space by increasing the amount of blood in the lungs in a supine position could also be the reason for reduced lung volume and capacities. This could be a putative reason for reduced NRD parameters in the supine position[21]. In standing position the NRD parameters are different than supine position (Tables 3, 4). Gravity aids in the downward pull-on abdominal viscera and the diaphragm position also are lower in the standing position[22]. This changes the lung volumes extensively during inspiratory efforts and hence is likely to favour greater action of respiratory muscles which may be the reason for higher NRD parameters in standing and sitting positions.

The ability to generate force as well as tension is dependent on muscle length, especially resting length.

The changes in muscle length are implied with respect to change in body positions. This also holds for respiratory muscles which have maximum pull in standing position which implies greater force and tension generation in the standing position. Further, it is a known fact that in patients with chronic obstructive pulmonary disease (COPD), in a supine position the respiratory muscle force is lower as compared to a sitting position.

These observations point towards the reason for higher NRD in standing position. This is substantiated by the findings of Costa R. It was reported that the PImax (Maximum Inspiratory Pressure), as well as PEmax (Maximum Expiratory Pressure), was greater in a sitting position than supine[23].

The decreased values for NRD observed in supine position might be related to the fact that in the supine position the diaphragm movement is hindered by abdominal content displacement during maximal inspiratory effort, which could compensate for the more favourable position of the diaphragm in standing position[24]. Furthermore, the sub-optimum length of inspiratory muscles in supine position. It has been reported that the supine position elicited a decrease in peak inspiratory activity of the parasternal and sternocleidomastoid muscles during maximal inspiratory effort as compared to the standing position.

Exercise capacity is determined by a neural respiratory Drive which in turn quantifies the mechanical load on the respiratory muscles and relates closely to propensity of breathlessness. Neural respiratory drive (NRD) is measured as tidal diaphragm electromyogram activity expressed as a proportion of maximum diaphragmatic activity during inspiratory sniff manoeuvre. Although gold standard for NRD assessment is diaphragmatic sEMG (Surface electromyography), its application is limited being an invasive procedure[25]. However, a reliable and non-invasive estimate can also be obtained from 2nd intercostal space parasternal muscle sEMG data. The neural output of the brainstem respiratory centres can't be quantified directly and easily.

Williams S investigated the influence of posture on parasternal intercostal muscle activity in a narrow age range of 17-28 years. Their study found no significant effects of posture on Neural Respiratory Drive (NRD) and EMG parameters, suggesting that posture does not substantially influence NRD in this specific age group[12].

In our study broad age group range 18-50 years was chosen and hence was found that body posture affect the

NRD in this specific age group.

The gender difference in respiratory physiology is well accepted and hence potentially the NRD parameters tend to differ in the males and females[26]. The differences observed between the genders could have many possible reasons. The central airway size is smaller in females as compared to same lung size in males[27]. Hence it also explain the greater work of breathing among the females as compared to males[28]. Males tend to have larger absolute lung volume than females; however relative lung volumes and capacities are similar in either sexes. Further females tend to have higher activation of activation of the diaphragm, scalene, and sternocleidomastoids than males[29,30].

The results of this should be interpreted with caution, as there was a non-random sample composed of young healthy subjects.

Influence of Anthropometric parameters on Neural Respiratory Drive:

The findings of influence of Age and anthropometric parameters on NRD reveal no statistically significant correlation in both males and females. Since the study population is healthy, normo BMI group and in age range of 18-50 years.

As per reports among healthy adults, resting tidal EMGdi (EMG diaphragm) is only 7–10% of maximum voluntary activation[31] with considerable variations in NRD parameters.

As per reports, among the obese subjects, the resting EMGdi can double to 22%max. due to increased ventilatory load and effort (Pes)[32].

These finding indicts significant impact of BMI on NRD while NRD tend to be higher in Obese population.

As per the findings of this study, the study population was normal BMI healthy subjects; hence, the impact of BMI in this study population can't be commented upon. However, a negative correlation of BMI with NRD parameters was observed in the sitting position.

Further healthy aging's impact on baseline inspiratory neural drive is also an important consideration. Many changes, particularly emphysema-like changes in the lung (increases pulmonary compliance) while decreasing chest wall compliance may result in alterations in inspiratory neural drive[33,34].

Aging further reduces inspiratory muscle strength, decreases diffusing capacity, decreases the proportion of Type II muscle fibers in the diaphragm, and decreases the number of phrenic motoneurons[35]. Further these impacts have been substantiated by recording 40% greater values in EMGdi in individuals more than 51 years than those less 50 years[36].

However paradoxically when normalised with maximal voluntary activation these values were reduced may be due to inability to achieve—or motivation to perform—truly maximal maneuvers)[37]. The study population in the present study is in range of 18-50 years and hence the impact of age on Neural respiratory drive parameter could not be evident in this particular age population.

Conclusion

The neural respiratory drive (NRD) can be effectively assessed non-invasively using second intercostal space (ICS) parasternal surface electromyography (sEMG) activity. Our study found that the seated position is optimal for recording NRD in healthy subjects, as it provides a stable and consistent baseline with minimal influence from posture changes and this is the positions were extremes of NRD parameter values weren't noted as compared to other two positions.

This position ensures accurate measurement of sEMG activity by minimizing potential artefacts and variations caused by different body positions.

However, in bedridden or ill patients, where maintaining a seated position may not be feasible, other positions such as the supine position could be considered. It is essential to account for how different postures, including supine, may influence NRD measurements in these individuals. Adjustments to the measurement approach or interpretation may be necessary to account for the effects of body position on respiratory muscle activity in clinical settings.

In summary, while the seated position is optimal for NRD assessment in healthy subjects, the choice of position should be carefully evaluated based on the patient's condition and practical considerations, especially in bedridden or critically ill patients.

Further future research shall focus on the effect of anthropometric indices PFT parameters and NRD with its correlation with Cardiorespiratory fitness parameters to get meaningful conclusions.

Limitations: The results of this study are pertinent with a smaller sample size, which is one of the limitations of our study. However, it provides valuable preliminary insight on the influence of body position on neural respiratory Drive. The convenience sampling followed is another limitation for cautious interpretation of the results. The potential errors could be considered considering the influence of position on NRD. The inter-individual variability can be addressed by normalizing sEMG data, which helps minimize errors and facilitates inter- and intra-individual comparison. Another limitation of this study is the small sample size and hence the results shall be perceived in view of the sample size with absence of impact of anthropometric parameters on NRD parameters which are likely to affect inspiratory muscle strength and may have influenced the results. This variability limits the generalizability of findings, particularly between male and female groups. Future studies with larger sample size to control for these factors and to enhance accuracy are the research need.

Ethics approval

The study protocol was approved by the RRB/IHEC of the institute-AIIMS Bhopal (IHEC-LOP/2022/IL047). This research work was carried out in compliance with the World Medical Association Declaration of Helsinki — Ethical Principles for Medical Research Involving Human Subjects.

Authors' contributions:

AT and PS were involved in the design and conceptualization of the research work. Drafting and critical revision were done by SW and RJ. VM provided final approval of the manuscript. SH contributed to drafting sections of the manuscript, ensuring data accuracy, and revising for clarity and coherence. All authors are accountable for every aspect of the work and the integrity of the data analysis. All authors read and approved the final version of the manuscript.

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