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Impact of Abdomen and Lower Back Muscle Relaxation on Sleep Quality in Pregnant Women

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Abstract:

Background: Ensuring proper care during pregnancy is vital, as inadequate care or heightened physical strain and stress can lead to complications. One significant issue during this period is sleep apnea, which can result in adverse outcomes near the end of gestation, including just before, during or after delivery, causing challenges for the mother. By identifying the most supportive sleeping positions, aided by support, can enhance sleep quality for pregnant women. This study incorporates innovative approaches using sleep modifications and adaptations using ergogenic aids, along with Trigno Avanti non-invasive EMG sensors, to promote muscle recovery, improve sleep quality, reduce sleep latency and extend sleep duration. These improvements can potentially decrease complications during pregnancy and enhance the safety and well-being of both mother and baby. **Method:** This experimental study utilizes PSQI methods sEMG tools. **Study Population:** Nulliparous pregnant women from the Karaikal district. **Results:** Pregnant women sleeping in side-lying pillow support (SLPS) positions showed reduced muscle activation and significantly improved sleep quality compared to those in SL and supine positions SS and SSPS ($p<0.05$) and validated with PSQI, which improves significant increment in sleep quality.

Keywords: Pregnant women, EMG, Pillow, sleep quality, abdomen, lower back, PSQI.

INTRODUCTION

Sleep is a vital biological function for maintaining overall physical and mental health, particularly during pregnancy. For expectant mothers, achieving quality sleep is crucial for their well-being and the healthy growth and development of the fetus. However, pregnancy often brings significant challenges to sleep, including hormonal fluctuations, physical discomfort, and an increased likelihood of conditions such as sleep apnea, all of which can lead to complications that negatively impact both maternal and fetal outcomes(Majewska & Wołyńczyk-Gmaj, 2022).

Sleep position and musculoskeletal alignment are key factors affecting sleep during pregnancy. Improper positions, such as sleeping on the back, can place excessive pressure on the gravid uterus, compress significant blood vessels and cause reduced blood flow, hypoperfusion and discomfort in the musculoskeletal system. In contrast, lateral sleeping positions are widely recommended for their ability to enhance circulation and reduce strain on muscles and joints, offering significant benefits to maternal health.

A review of existing literature reveals a gap in research on the muscle activation patterns in pregnant women, especially in bilateral abdominal and bilateral erector spinae during various sleeping positions. While sleep quality during pregnancy has been extensively studied (Bazalakova et al., 2014), there is limited focus on how muscle activation varies with different positions and how identifying the most supportive sleeping position can enhance sleep quality. Understanding these patterns is essential for developing targeted interventions to alleviate discomfort and reduce musculoskeletal strain and how these factors improve sleep quality in pregnant women. This study aims to fill this gap by analyzing muscle activation using advanced electrophysiology tools, offering valuable insights into optimizing sleeping positions for maternal health and fetal well-being during gestational progress.

During the gestational period, commonly faces several physical challenges, including lower back pain (LBP) and abdominal strain (AS), primarily due to the increasing weight and growth of the fetus (Itasaka et al., 2000). These issues are often exacerbated by additional factors such as gestational diabetes, which can influence metabolic health, lead to weight gain(Sudhan P, Babu Subbiah, Narendran Rajagopalan, Jahira Parveen, et al., 2023) and contribute to musculoskeletal discomfort. This will reduce using yoga and verma in some studies(Jagadevan et al., 2021; Sudhan P, Babu Subbiah, Narendran Rajagopalan, Rajeev Sukumaran, et al., 2023). The biomechanical stress on the body, coupled with hormonal changes, can further weaken the stability of joints, especially in the lower back and pelvic region, leading to pain and reduced mobility.

Sedentary lifestyles before or during prenatal can compound these issues by causing reduced muscle strength and flexibility(Manickavelu et al., 2022), resulting in greater strain on weight-bearing joints such as the spine, knees, hips and ankles(Anand babu Kaiyaperumal et al., 2022). This may lead to chronic discomfort, poor posture, and increased difficulty maintaining physical activity, which is vital for overall health. Additionally, improper sleeping positions can intensify these challenges, disrupting sleep quality and further affecting overall physical and mental well-being. Addressing these concerns through evidence-based strategies, including biomechanically optimized sleeping positions, is essential for alleviating pain, enhancing comfort and supporting maternal and fetal health throughout gestation.

This research focuses on innovative methods to enhance sleep quality during pregnancy by incorporating ergonomic aids like pillows and advanced technologies such as Trigno Avanti surface EMG sensors(Tiwari et al., 2023). By emphasizing muscle relaxation and optimal sleep position, the study aims to decrease sleep latency, extend sleep duration and minimize the risks of pregnancy-related complications. Using heartfulness techniques, this experimental study evaluates the effects of side-lying and supine sleeping positions on sleep quality among nulliparous pregnant women, providing valuable insights into more effective and safer prenatal care solutions(Li et al., 2016; Takelle et al., 2022). The detailed methodology of this study is illustrated in Figure 1.

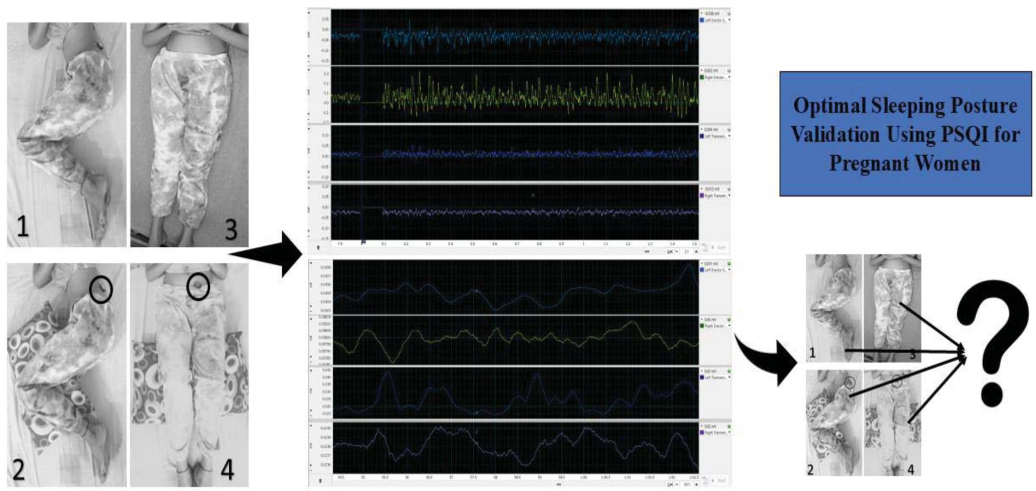

Figure 1: Data collection involved measuring sEMG muscle activation across four selected positions: (1) side-lying, (2) side-lying pillow support, (3) supine sleep and (4) supine sleep pillow support. The top panel displays raw sEMG data, while the bottom panel shows the smoothed and analyzed rms data. All four positions were compared to identify the optimal position, which was then validated using the PSQI questionnaire.

METHODOLOGY

Participants for this study were recruited through announcements in a local newspaper. To ensure the accuracy and reliability of data collected via surface electromyographic (sEMG) signals, the inclusion criteria required pregnant women to be in good physical health, with no history of chronic pain, unresolved muscle strain or systemic illnesses. Eligible participants were nulliparous women aged 18-30 with a BMI not exceeding 30 kg/m². These parameters were established to maintain a homogenous study population and to minimize potential variables that could influence muscle activation patterns during the analysis.

Data Collection Tools and Methodology

Data were gathered using sEMG sensors to monitor muscle activation patterns, complemented by pre and post testing with the validated Pittsburgh Sleep Quality Index (PSQI) questionnaire. Trained non-invasive EMG specialists conducted the sEMG assessments, ensuring participant safety with the assistance of a gynecologist. Physical education professionals administered the PSQI questionnaires after each testing session and again one month following the suggested final posture selection.

To support posture correction, participants received detailed guidance through a combination of instructional charts and video demonstrations through electronic materials. These resources facilitated proper sleeping position adaptation, with any questions addressed by the principal investigator to ensure clarity and compliance through proper follow-ups.

The structured interview process was divided into two sections, enabling a comprehensive evaluation of participant experiences and outcomes. A trained assistant closely monitored participants throughout the procedure to ensure accurate data collection and safety. This included overseeing position maintenance, proper electrode placement and ensuring signal integrity without external interference. The selected muscles for analysis included the Erector Spinae (ES) and Transverse Abdominis (TA), specifically focusing on bilateral activation. Measurements were taken for the Erector Spinae Left (ESL), Erector Spinae Right (ESR)(Ando et al., 2020), Transverse Abdominis Right (TAR) and Transverse Abdominis Left (TAL), targeting the abdomen and lower back muscles for a comprehensive evaluation of muscle activation patterns.

EMG Measurement

The maximum voluntary isometric contraction (MVIC) for the selected muscles, such as transverse abdominis and erector spinae, was recorded one week before the analysis of sleeping positions. Electrode placement was guided by atlas-defined muscle innervation zones(Barbero et al., 2012), with markers applied to the body for accuracy. The skin at electrode sites was cleaned using isopropyl alcohol to ensure proper adhesion and signal quality and sensors were securely placed. Photographs were taken to document electrode placement and body measurements were recorded to account for changes due to fetal development as the pregnancy progressed(Lee & Gay, 2004). MVIC data was collected using Trigno Avanti EMG sensors (Delsys). Participants were then provided with cotton pillows, pillowcases, and detailed instructions on how to practice the four experimental sleeping positions with and without pillows. The primary data collection phase began following the completion of MVIC measurements for all participants. EMG sensors were applied to the same marked sites and participants rested in each sleeping position. Once muscle activation stabilized and the sEMG signal crossed the fixed recovery threshold, a 45-second epoch of sEMG data was recorded three times, with a 10–15-minute interval between recordings. The sleeping positions included: (1) side lying (SL), (2) side lying pillow support (SLPS), (3) supine sleep (SS), and (4) supine sleep pillow support (SSPS). Pillow support has been given in between the legs during side lying and under the knees during supine sleeping or resting positions. A trained assistant monitored sleeping position, electrode placement, and signal safety throughout the procedure to ensure accurate and interference-free data collection.

EMG Analysis

The collected data was analyzed using an eight-channel system with pre-amplified Ag/AgCl non-invasive surface electrodes connected to a wireless Trigno Avanti EMG sensor system (Delsys Inc., Boston, MA, USA) (Akshay et al., 2024). The system was interfaced with an amplifier and processor module, featuring a high common-mode rejection ratio (CMRR > 87 dB at 60 Hz) and input impedance of 15 Ω at 100 Hz. Impedance levels were verified before the analysis.

Raw sEMG signals for each muscle were processed using a 4th-order Butterworth bandpass filter with cut-off frequencies between 5 Hz and 650 Hz(Akshay et al., 2024; Subbiah et al., 2024). The filtered signals were analyzed using LabChart 8 software (ADInstruments, Dunedin, New Zealand). Following established protocols, the filtered signal's root mean square

(RMS) was calculated using a 45-millisecond moving window. The RMS values from the three 45-second epochs for each position were averaged to determine muscle activation levels for the transverse abdominis and erector spinae(Akshay et al., 2024).

The maximum sEMG amplitude recorded during the MVIC test was used as the reference value, expressed as 100% muscle activation to normalize the data. This normalization allowed for comparing relative muscle activation across the four sleeping positions. The results were then visualized and represented for further interpretation (Fig. 2).

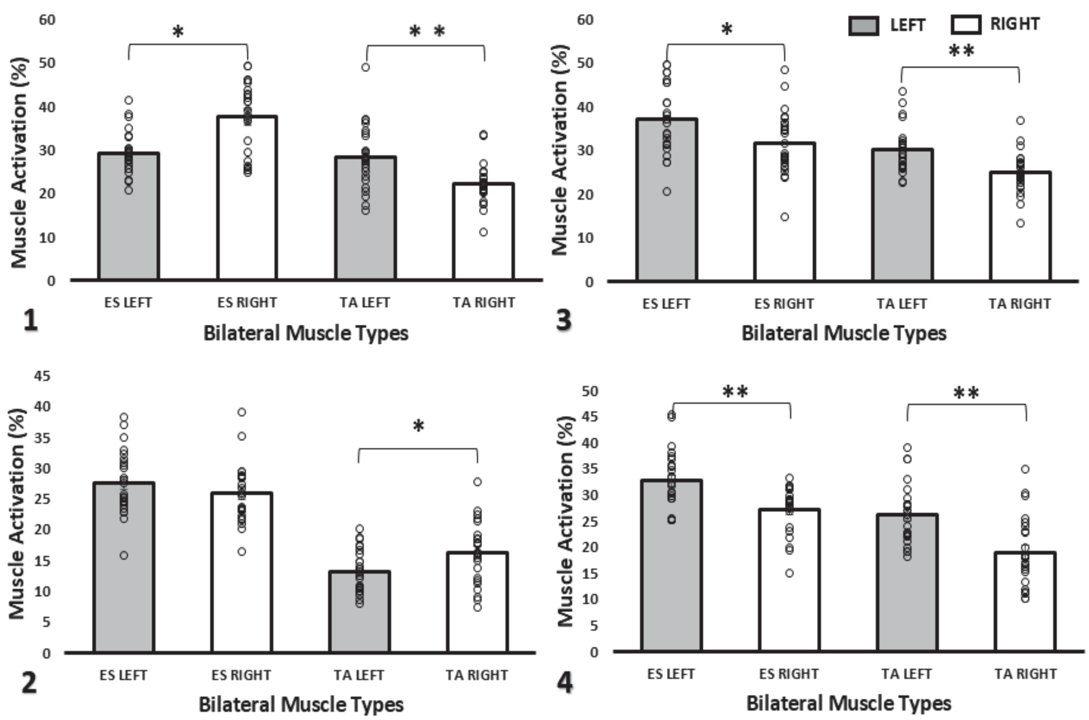

Figure 2: Mean ± SD of bilateral muscle activation of normalized EMG activity (%) for Erector Spinae and Transverse Abdominis across different sleeping positions. Observational data points are represented with circles, while the table highlights the results for the four positions: 1) Side-Lying (SL), 2) Side-Lying with Pillow Support (SLPS), 3) Supine Sleep (SS), and 4) Supine Sleep with Pillow Support (SSPS).

Note: *p ≤0.05, **p ≤0.01

Statistical Analysis

Statistical analysis for this study was done using SPSS Statistics 29.0. The raw surface EMG data, normalized with Maximum Voluntary Isometric Contraction (MVIC), was analyzed to calculate the Mean and Standard Deviation (SD) of the RMS values for each of the four sleeping positions. The normalized data was also expressed as a percentage, with the Mean and SD reported for all positions. A paired t-test with a two-tailed analysis ($P(T \leq t)$) was conducted to determine significant differences in bilateral muscle activation between the Erector Spinae and Tibialis Anterior muscles. A p-value of ≤ 0.05 was considered statistically significant.

Based on the analysis, the side-lying position with one pillow demonstrated the most favourable muscle activation patterns, making it the optimal sleeping position for pregnant women. The PSQI questionnaire was administered to validate this finding further. Sleep quality was measured as a pre-test before implementing the suggested position and re-evaluated one month later during a subsequent stage of gestation. Comparing pre and post-intervention, PSQI scores confirmed an improvement in sleep quality, thereby validating the effectiveness of the recommended position.

RESULTS

Bilateral sEMG Activation Analysis Across Different Positions

A total of 31 pregnant women participated in the study, yielding a response rate of 80.64%, while five participants were excluded due to personal and health-related issues. The results indicate that the Side-Lying Pillow Support (SLPS) position is the most favorable sleeping position, demonstrating the lowest levels of bilateral muscle activation compared to all other positions. This reduced activation is linked to decreased strain on the abdominal and lower back muscles, contributing to improved maternal comfort, enhanced sleep quality, and better overall health during pregnancy(Da Costa et al., 2010). Furthermore, this position may promote optimal fetal development by minimizing musculoskeletal stress.

A detailed analysis revealed significant differences in muscle activation patterns across the four positions: Significantly lower activation in SLPS compared to SL, SS, and SSPS. In the SLPS position, both ES and TA muscles exhibited lower activation levels. Specifically, the ESL and ESR showed reduced bilateral strain compared to other positions. Additionally, the TAL and TAR also demonstrated significantly reduced activity, supporting the effectiveness of this position.

In the SS and SSPS positions, however, higher muscle activation levels were observed. Notably, the SSPS position showed greater variability in activation between the ESL and ESR (Table 1) and higher activation levels in the TAL. These findings suggest that supine positions, even with pillow support, may place additional strain on critical muscle groups and are less optimal for pregnant women.

The SLPS position was identified as the most beneficial, as it demonstrated reduced bilateral muscle activation, particularly in the ES and TA muscle groups. This reduction in muscle activation may contribute to improved physical well-being (Paulraj Manickavelu et al., 2022) and enhanced sleep quality for pregnant women. While a significant difference was observed between the TAL and TAR ($p \geq 0.05$) in the SLPS position (Table 2), the overall muscle activation levels in this position remained lower compared to all other positions. For a detailed comparison of the normalized muscle activation data in bilateral muscles across all four positions, refer to Figure 2.

Table 1: Mean ± SD of Normalized EMG Activity (%) for Erector Spinae

SLEEPING POSITION	BILATERAL MUSCLES		P-value
	ES LEFT	ES RIGHT	
SIDE LYING	29.36 ± 4.9	37.70 ± 8.4	≤ 0.01**
SIDE LYING PILLOW SUPPORT	27.52 ± 5.3	25.91 ± 4.9	P = 0.28
SUPINE SLEEPING	37.22 ± 8.1	31.57 ± 7.4	≤ 0.05*
SUPINE SLEEP PILLOW SUPPORT	32.67 ± 5.7	27.19 ± 4.4	≤ 0.01**

*p ≤0.05, **p ≤0.01

Table 2: Mean ± SD of Normalized EMG Activity (%) for Erector Spinae

SLEEPING POSITION	BILATERAL MUSCLES		P-value
	TA LEFT	TA RIGHT	
SIDE LYING	28.37 ± 7.4	22.11 ± 4.8	≤ 0.01**
SIDE LYING PILLOW SUPPORT	13.16 ± 3.6	16.25 ± 5.1	≤ 0.05*
SUPINE SLEEPING	30.07 ± 5.4	24.98 ± 4.9	≤ 0.01**
SUPINE SLEEP PILLOW SUPPORT	26.13 ± 5.8	19.03 ± 6.6	≤ 0.01**

*p ≤0.05, **p ≤0.01

SLPS and Sleep Quality

Based on the findings, the Side-Lying Pillow Support (SLPS) position was identified as optimal for minimizing muscle activation during sleep and rest. Participants were advised to adopt this position for four weeks, with the first week as an adaptation period. Following this intervention, the PSQI (Valentin & Licka, 2016) questionnaire was administered to assess improvements in sleep quality.

The results revealed a significant improvement in sleep quality among the participants after adopting the Side-Lying Pillow Support (SLPS) position. The PSQI global score decreased notably from 8.68 ± 5.24 to 5.25 ± 2.39 ($p \leq 0.05$). Significant progress was also observed in sleep latency and sleep disturbance(Facco et al., 2010) parameters ($p \leq 0.05$). At the start of the study, 84% of participants experienced poor sleep quality due to disrupted sleep patterns(Al-Musharaf, 2022; Polo-Kantola, 2022) and muscle strain associated with improper sleeping positions, when they adapted to SLPS, the overall sleep quality increased, and the 19 participants with 76% had good quality sleep.

These findings confirm that the SLPS position is effective and biomechanically beneficial for pregnant women(Cifrek et al., 2009). This position facilitates improved musculoskeletal alignment, reduces physical discomfort, and enhances overall well-being and sleep quality during pregnancy by alleviating muscle strain in critical regions such as the Erector Spinae (ES) and Transverse Abdominis (TA).

Table 3: Mean ± SD of PSQI Scores Pre-Test and Post-Test Using SLPS

PSQI VARIABLES	PRE-TEST	POST-TEST
PSQI TOTAL SCORE	8.68 ± 5.24	5.25 ± 2.39*
SLEEP QUALITY	1.46 ± 0.53	1.04 ± 0.28*
SLEEP LATENCY	1.90 ± 1.36	1.11 ± 0.44*
SLEEP DURATION	0.88 ± 0.91	0.54 ± 0.64
SLEEP EFFICIENCY	1.74 ± 1.12	1.01 ± 0.75
SLEEP DISTURBANCE	1.82 ± 0.61	0.82 ± 0.69*
SLEEP MEDICATION	0.28 ± 0.44	0.24 ± 0.77
DAYTIME DYSFUNCTION	0.60 ± 0.66	0.39 ± 0.68
PSQI TOTAL SCORE ≥ 5	21 (84 %)	4 (16 %)
PSQI TOTAL SCORE < 5	6 (20%)	19 (76 %) **

*p ≤0.05, **p ≤0.01

DISCUSSION

This study identified a notable improvement in sleep quality among pregnant women, transitioning from poor to good sleep with enhanced muscle recovery and global PSQI result(Buysse Charles F Reynolds Ill et al., n.d.). The findings suggest that the SLPS sleeping position is the most effective and validated position for pregnant women to achieve improved sleep quality. Several factors, including the stage of pregnancy, gestational period, mental health conditions and significant physical strain on muscles(Kamysheva et al., 2010), were found to have a strong association with poor sleep quality among nulliparous pregnant women. This emphasizes the importance of addressing these variables to enhance maternal well-being during pregnancy.

Even during a healthy pregnancy, dysfunctions in the pelvic floor(Kirby A et al., 2011) and lower back muscles can arise, leading to a noticeable decline in overall quality of life. Addressing and mitigating these issues is a critical area of focus. Strategies to enhance sleep quality by reducing muscle tension and promoting relaxation have shown promise in managing such conditions. Among these approaches, biofeedback training has been identified as an effective method for regulating muscle activity(J. M. Dick et al., 2024). Interestingly, comparative analysis revealed that women who were physically active before pregnancy, attended childbirth preparation classes and maintained supportive relationships experienced notably lower levels of stress and anxiety compared to their physically inactive counterparts. These findings highlight the importance of adopting a healthy lifestyle and engaging in supportive practices during pregnancy. Furthermore, incorporating an optimal sleep position for the mother's health, such as SLPS, may further alleviate physical discomfort and muscle strain, reducing muscle pain and improving sleep quality. This suggests combining physical activity(Anand babu Kaiyaperumal et al., 2023), emotional support, and appropriate sleeping positions may collectively enhance maternal well-being during pregnancy.

Previous studies suggest that even a single biofeedback session targeting the sEMG activity of pelvic floor muscles may yield positive outcomes for pregnant women (Błudnicka et al., 2020). Building on this premise, the present study utilized surface EMG to assess muscle activation patterns in the Erector Spinae and Transverse Abdominis, during different sleeping positions to explore its potential for improving maternal well-being. Some studies have highlighted the potential of systems that allow women to monitor their health comfortably at home, with data being seamlessly transmitted to healthcare providers for evaluation and diagnosis (Takelle et al., 2022). Such advancements have demonstrated significant promise in improving continuous monitoring and promoting better maternal and fetal well-being during labor. Inspired by this approach, our study incorporated similar principles for assessing and enhancing sleep quality. By utilizing sEMG data, we aimed to provide actionable insights into muscle activation patterns and their relationship to sleep position and the selected muscles, offering a practical framework for improving a mother’s health during pregnancy (Tiwari et al., 2023). The quadrant-based method leveraging EMG signals has proven effective in delivering detailed spatial and temporal insights into uterine contractile activity(Escalona-Vargas et al., 2015). This technique shows promise in enhancing abdominal EMG recording protocols, paving the way for more practical and clinically applicable solutions (Escalona-Vargas et al., 2015).

To the authors' knowledge, no prior studies have explored the relationship between muscle activation and sleep quality in pregnant women or measured sEMG data during rest and sleep recovery periods. This study represents a novel approach to identifying the optimal sleeping position to enhance maternal and fetal health throughout the two trimesters of pregnancy. Focusing on muscle activation patterns during different sleep positions provides unique insights into reducing musculoskeletal strain and improving sleep quality, which are critical factors for the well-being of both mother and child. Additionally, the findings serve as a foundational reference for future research to investigate further sleep biomechanics and their impact on maternal health during pregnancy.

LIMITATIONS

This study has some limitations that may affect the generalizability of the findings. The analysis was restricted to a limited number of muscles due to the availability of EMG sensors, which may have limited the scope of muscle activation patterns studied. Additionally, the absence of standardized non-invasive EMG placement references for pregnant women could have introduced variability in sensor positioning. Furthermore, the cross-sectional design prevents establishing pregnant women between mental strain and sleep quality, and recall bias may have influenced PSQI self-reported data, particularly among participants without notable sleep issues (Neau et al., 2009; Sharma et al., 2016).

CONCLUSION AND RECOMMENDATION

This study highlights the high prevalence of poor sleep quality among pregnant women, particularly during the first and second trimesters. Factors such as muscle strain, lower back pain, abdominal stress, antenatal depression, and elevated perceived stress were found to affect sleep quality significantly. Based on the findings, it is recommended that pregnant women undergo screening and intervention using surface electromyography (sEMG) to identify and mitigate muscle strain through the adoption of optimal sleep positions. The side-lying position with pillow support (SLPS) was identified as the most effective position for reducing muscle activation and improving sleep quality. Educating pregnant women about the benefits of SLPS can contribute to alleviating discomfort, enhancing sleep quality, and promoting overall well-being during the gestational period. Future research should explore the long-term effects of sleep position adjustments on maternal and fetal health to validate these findings further.

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