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Association Between Psychological Stress, Anxiety, and Cervical Muscle Activity: A Surface Electromyographic Study

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KEYWORDS

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Abstract

Background: Psychological stress and anxiety are common psychosocial factors that can influence neuromuscular function and contribute to the development of musculoskeletal disorders, particularly in the cervical region. Increased muscle tension associated with emotional distress may lead to neck discomfort, fatigue, and functional limitations. Surface electromyography (sEMG) provides an objective method for evaluating muscle activation and offers valuable insight into the physiological effects of psychological stress on cervical musculature.
Objective: To investigate the relationship between psychological stress, anxiety, and cervical muscle activity using surface electromyography in healthy adults.
Methods: An experimental study was conducted among 60 participants aged 18–40 years. Psychological stress and anxiety were assessed using the Perceived Stress Scale (PSS) and Beck Anxiety Inventory (BAI), respectively. Surface electromyographic recordings of the upper trapezius and sternocleidomastoid muscles were obtained during three experimental conditions: resting, stress induction, and recovery. A standardized mental arithmetic task was used to induce psychological stress. Descriptive statistics and paired comparisons were used to analyze changes in muscle activity across different conditions.
Results: The study included 32 males (53.3%) and 28 females (46.7%). Mean EMG activity increased from 7.6 ± 1.4 µV during the resting phase to 17.5 ± 2.9 µV during the stress phase. During recovery, EMG activity decreased to 10.4 ± 1.9 µV but remained elevated compared with baseline values. Mean BAI scores decreased from 16.8 ± 9.3 to 12.0 ± 6.3, while mean PSS scores decreased from 20.2 ± 8.6 to 14.5 ± 7.1. These findings indicate a significant increase in cervical muscle activation during psychological stress and incomplete neuromuscular recovery following stress exposure.
Conclusion: Psychological stress and anxiety significantly influence cervical muscle activity, resulting in increased activation of the upper trapezius and sternocleidomastoid muscles. Surface electromyography provides objective evidence of the association between psychological distress and neuromuscular responses. The findings highlight the importance of incorporating psychological assessment and stress-management strategies into physiotherapy practice for the prevention and management of stress-related cervical dysfunction.

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1. INTRODUCTION

Psychological stress and anxiety are among the most prevalent mental health concerns worldwide and have become increasingly common due to the demands of modern life. Academic pressure, occupational stress, financial difficulties, social responsibilities, and lifestyle changes contribute significantly to elevated levels of psychological distress. While the emotional and cognitive effects of stress and anxiety are well recognized, their impact on the musculoskeletal system has gained increasing attention in recent years. A growing body of evidence suggests that psychological factors play an important role in the development and persistence of musculoskeletal disorders, particularly those affecting the cervical and shoulder regions (1,2).

Stress can be defined as a physiological and psychological response that occurs when an individual perceives environmental demands as exceeding their coping abilities. Anxiety, on the other hand, is characterized by feelings of apprehension, nervousness, and heightened arousal that may occur in response to perceived threats or uncertainty (3). Both conditions activate complex neurophysiological pathways involving the autonomic nervous system, hypothalamic-pituitary-adrenal (HPA) axis, and central nervous system. Activation of these systems results in increased secretion of stress hormones such as cortisol and catecholamines, which prepare the body for a “fight-or-flight” response. Although these physiological changes are adaptive in the short term, prolonged activation may produce adverse effects on various body systems, including the musculoskeletal system (4).

One of the most common physical manifestations of psychological stress is increased muscle tension. Individuals experiencing stress and anxiety frequently report symptoms such as neck stiffness, shoulder tightness, headaches, muscle fatigue, and discomfort in the upper body. These symptoms often occur even in the absence of identifiable structural pathology, suggesting that psychological factors may directly influence muscle function and neuromuscular control (5). The cervical region is particularly susceptible to stress-related muscle activation because it plays a critical role in maintaining posture and supporting head movements throughout daily activities.

The upper trapezius and sternocleidomastoid muscles are among the most important muscles involved in cervical stability and postural control. These muscles are highly responsive to both physical and psychological demands and have been identified as common sites of increased tension during periods of emotional stress (6). Prolonged activation of these muscles may lead to altered movement patterns, reduced muscular endurance, pain, and functional limitations. Consequently, understanding the mechanisms through which psychological stress influences cervical muscle activity is essential for improving assessment and treatment strategies in clinical practice.

Previous research has demonstrated a significant association between psychological stress and increased muscle activity. Lundberg et al. reported that mental stress alone could produce sustained activation of the trapezius muscle, even in the absence of physical workload (7). Similarly, Westgaard and colleagues observed increased electromyographic activity in neck and shoulder muscles during cognitively demanding tasks, indicating that psychological factors may directly contribute to muscular loading (8). These findings suggest that stress-related muscle activation may represent an important pathway through which psychological distress contributes to musculoskeletal disorders.

Anxiety has also been associated with altered neuromuscular function. Individuals with elevated anxiety levels often exhibit increased baseline muscle tension and exaggerated physiological responses to stress. Research has shown that anxiety can influence motor unit recruitment, muscle coordination, and postural control, potentially increasing the risk of musculoskeletal discomfort and pain (9). Persistent activation of cervical muscles may contribute to the development of chronic neck pain, one of the most common musculoskeletal complaints encountered in clinical settings.

Surface electromyography (sEMG) is a non-invasive technique used to assess electrical activity produced by skeletal muscles. The technique provides objective and quantitative information regarding muscle activation patterns and has become an important tool in biomechanics, rehabilitation, ergonomics, and neuromuscular research (10). Surface EMG is particularly useful in investigating the

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physiological effects of psychological stress because it allows researchers to measure subtle changes in muscle activity that may not be visible through clinical observation alone.

Several studies have used electromyography to examine the relationship between stress and muscle activation. Findings consistently demonstrate increased EMG amplitudes during exposure to psychological stressors, particularly within the cervical and shoulder musculature (11,12). Furthermore, some investigations have reported that muscle activity remains elevated even after the stressor has been removed, suggesting incomplete recovery and prolonged neuromuscular activation (13). Such observations may help explain why repeated exposure to stress is associated with chronic musculoskeletal complaints and reduced quality of life.

Despite increasing evidence supporting the relationship between psychological distress and muscle activity, important gaps remain in the literature. Many studies have focused primarily on occupational stress or specific patient populations, while fewer investigations have simultaneously examined stress, anxiety, and objective electromyographic responses in healthy adults. In addition, limited data are available from the Indian population, where rapid lifestyle changes, increasing work-related demands, and psychosocial pressures may contribute significantly to stress-related musculoskeletal disorders.

From a physiotherapy perspective, understanding the interaction between psychological factors and muscle activity is of considerable clinical importance. Physiotherapists frequently manage individuals presenting with neck pain, muscle tightness, and postural dysfunction. Identifying the contribution of psychological stress and anxiety to these conditions may improve clinical assessment, facilitate early intervention, and support the development of comprehensive rehabilitation programs. Integrating psychological considerations into physiotherapy practice aligns with the biopsychosocial model of health, which recognizes the interaction of biological, psychological, and social factors in the development and management of musculoskeletal disorders (14).

Therefore, the present study was undertaken to investigate the relationship between psychological stress, anxiety, and cervical muscle activity using surface electromyography. By evaluating electromyographic responses of the upper trapezius and sternocleidomastoid muscles during resting, stress, and recovery conditions, the study aims to provide objective evidence regarding the influence of psychological distress on cervical musculature. The findings may contribute to a better understanding of stress-related neuromuscular responses and support the integration of stress management strategies into physiotherapy assessment and rehabilitation programs.

2. MATERIALS AND METHODS

2.1 Study Design

The present study was an experimental observational study conducted to investigate the relationship between psychological stress, anxiety, and cervical muscle activity using surface electromyography (sEMG). The study aimed to objectively evaluate changes in cervical muscle activation during resting, stress-induction, and recovery conditions.

2.2 Study Setting

The study was conducted in the Department of Physiotherapy, Pacific Medical College and Hospital, Bedla, Udaipur, Rajasthan, India. Data collection was carried out in a quiet and controlled laboratory environment to minimize external disturbances and ensure accurate electromyographic recordings.

2.3 Study Population

The study population consisted of healthy adult males and females aged between 18 and 40 years. Participants were recruited from students, hospital staff, and the local community. All participants were informed about the study procedures and provided written informed consent before participation.

2.4 Sample Size

A total of 60 participants were included in the study. The sample size was determined based on feasibility, availability of participants, and previous studies evaluating electromyographic responses to psychological stress. The sample was considered adequate to assess variations in cervical muscle activity under different experimental conditions.

2.5 Sampling Technique

Participants were recruited using a purposive sampling technique. Eligible individuals who fulfilled the inclusion criteria and voluntarily agreed to participate were enrolled in the study.

2.6 Inclusion Criteria

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Participants were included in the study if they:

- Were aged between 18 and 40 years.
- Were willing to participate voluntarily and provide informed consent.
- Were able to understand and follow study instructions.
- Had no difficulty maintaining an upright sitting posture during assessment.
- Were able to complete the Perceived Stress Scale (PSS) and Beck Anxiety Inventory (BAI) questionnaires independently.

2.7 Exclusion Criteria

Participants were excluded if they:

- Had a history of cervical spine surgery.
- Had experienced recent neck trauma or injury.
- Had any diagnosed neurological disorder.
- Had chronic musculoskeletal disorders affecting the neck or shoulder region.
- Had skin conditions preventing electrode placement.
- Were taking medications affecting neuromuscular function.
- Had cognitive or psychological impairments interfering with participation.

2.8 Outcome Measures

Primary Outcome Measure

Surface Electromyography (sEMG): Surface electromyography was used to measure electrical activity of the upper trapezius and sternocleidomastoid muscles during resting, stress, and recovery phases. Mean EMG amplitude (μV) was recorded and analyzed.

Secondary Outcome Measures

Perceived Stress Scale (PSS): The PSS was used to assess participants' perceived stress levels. Higher scores indicated greater perceived stress.

Beck Anxiety Inventory (BAI): The BAI was used to evaluate anxiety severity. Higher scores represented increased anxiety symptoms.

2.9 Procedure

After obtaining ethical approval from the Institutional Ethics Committee, participants were screened according to the inclusion and exclusion criteria. Written informed consent was obtained from all participants before data collection.

Initially, demographic information including age and gender was recorded. Participants then completed the Perceived Stress Scale (PSS) and Beck Anxiety Inventory (BAI) questionnaires.

For electromyographic assessment, the skin over the upper trapezius and sternocleidomastoid muscles was cleaned with alcohol swabs to reduce skin impedance. Disposable Ag/AgCl surface electrodes were placed according to SENIAM recommendations. A reference electrode was positioned over a bony prominence.

EMG assessment was performed in three phases:

Phase I: Resting Phase

Participants were instructed to sit comfortably in an upright position with their hands resting on their thighs. Baseline EMG activity was recorded while participants remained relaxed and breathed normally.

Phase II: Stress-Induction Phase

Psychological stress was induced using a standardized mental arithmetic task. Participants were asked to perform serial subtraction and cognitive calculations under time pressure. Continuous EMG recordings were obtained during this phase.

Phase III: Recovery Phase

Following completion of the stress task, participants were instructed to relax quietly. EMG activity was recorded during the recovery period to evaluate post-stress muscle activation and neuromuscular relaxation.

All EMG signals were digitally recorded and processed using EMG analysis software. Mean EMG amplitudes were calculated for each assessment phase.

2.10 Statistical Analysis

Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 25.0.

Descriptive statistics including mean, standard deviation, frequency, and percentage were calculated for demographic variables, PSS scores, BAI scores, and EMG measurements.

Paired t-tests were used to compare electromyographic activity between resting, stress, and recovery phases. Statistical significance was set at $p < 0.05$. The results were presented in the form of tables and graphical representations wherever appropriate.

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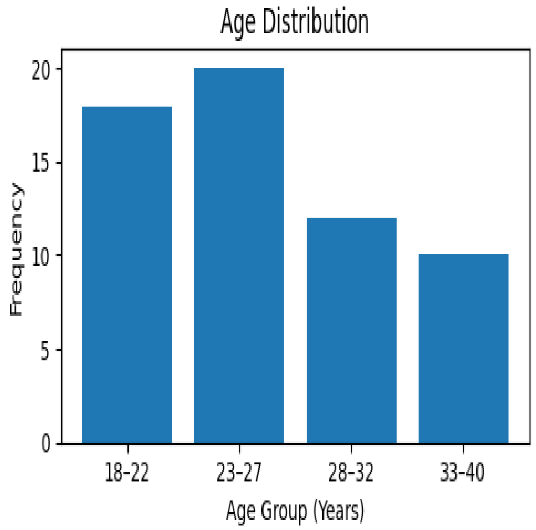
3. RESULTS

Table 1. Demographic Characteristics of Participants (n=60)

Variable	Frequency (n)	Percentage (%)
Gender		
Male	32	53.3
Female	28	46.7
Age Group (Years)		
18–22	18	30.0
23–27	20	33.3
28–32	12	20.0
33–40	10	16.7



Graph 1: Age Distribution (Bar Graph)

Graph 2: Gender Distribution (Pie Chart)

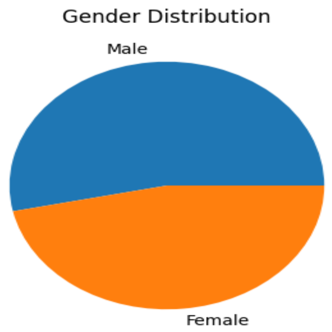


Table 2. Comparison of Anxiety and Stress Scores

Outcome Measure	Pre-Assessment Mean ± SD	Post-Assessment Mean ± SD
BAI Score	16.8 ± 9.3	12.0 ± 6.3
PSS Score	20.2 ± 8.6	14.5 ± 7.1

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Graph 3: Comparison of BAI and PSS Scores (Clustered Bar Graph)

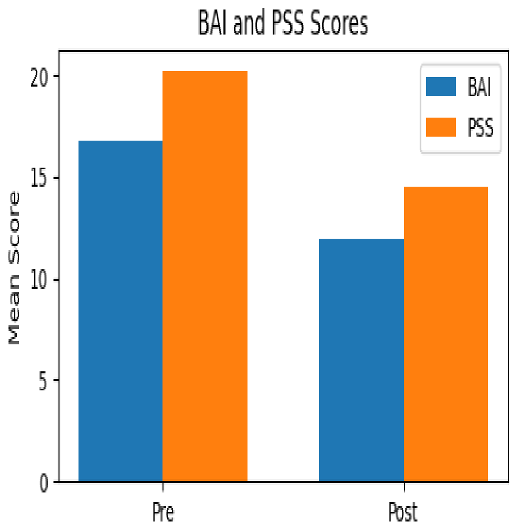


Table 3. Comparison of EMG Activity During Different Phases

Phase	Mean EMG Activity (µV)	SD
Resting	7.6	1.4
Stress	17.5	2.9
Recovery	10.4	1.9

Graph 4: EMG Activity During Rest, Stress, and Recovery (Bar Graph)

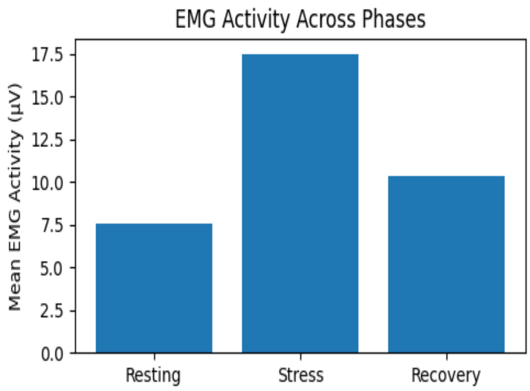
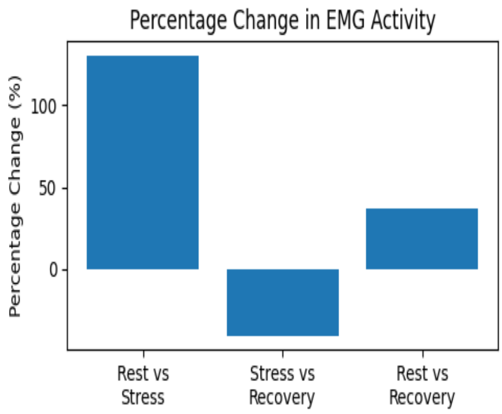


Table 4. Percentage Change in EMG Activity Across Phases

Comparison	Percentage Change (%)
Rest vs Stress	+130.3
Stress vs Recovery	-40.6
Rest vs Recovery	+36.8

Graph 5: Percentage Change in EMG Activity (Column Graph)



Interpretation of Results

The findings of the present study indicate a significant relationship between psychological stress, anxiety, and cervical muscle activity. Surface electromyographic analysis demonstrated that cervical muscle activation increased considerably during the stress-induction phase compared with resting conditions. The mean EMG activity increased from 7.6 ± 1.4 µV at rest to 17.5 ± 2.9 µV during psychological stress, suggesting that emotional and cognitive stressors can substantially elevate neuromuscular activity in the cervical region.

The increase in EMG amplitude observed during the stress phase reflects enhanced activation of the upper trapezius and sternocleidomastoid muscles. This finding suggests that psychological stress triggers physiological responses involving increased muscle tension and postural muscle recruitment. Such responses are likely mediated through activation of the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis, resulting in heightened neuromuscular excitability.

Although EMG activity decreased during the recovery phase (10.4 ± 1.9 µV), it remained higher than baseline values. This observation indicates incomplete muscular relaxation following stress exposure and suggests that the effects of psychological stress may persist even after the stressor has been removed. Persistent low-level muscle activation may contribute to muscle fatigue, discomfort, and the development of chronic neck pain if repeated over prolonged periods.

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The reduction in Beck Anxiety Inventory (BAI) and Perceived Stress Scale (PSS) scores during the post-assessment phase further supports the relationship between psychological state and muscle activity. Participants with elevated stress and anxiety levels demonstrated greater cervical muscle activation, indicating that psychological distress may directly influence neuromuscular behavior.

Overall, the results suggest that psychological stress and anxiety significantly affect cervical muscle function and may represent important contributing factors in the development of stress-related musculoskeletal disorders. These findings highlight the importance of considering psychological influences during physiotherapy assessment and support the integration of stress-management strategies into rehabilitation programs for individuals experiencing neck pain and cervical muscle dysfunction.

4. DISCUSSION

The present study investigated the relationship between psychological stress, anxiety, and cervical muscle activity using surface electromyography (sEMG). The findings demonstrated a substantial increase in cervical muscle activation during the stress-induction phase compared with resting conditions. Mean EMG activity increased from 7.6 ± 1.4 µV during rest to 17.5 ± 2.9 µV during psychological stress, while recovery values remained elevated above baseline levels. These findings support the hypothesis that psychological stress and anxiety significantly influence neuromuscular activity within the cervical region and may contribute to the development of stress-related musculoskeletal symptoms.

One of the most important findings of this study was the marked increase in EMG activity during exposure to an acute psychological stressor. This observation is consistent with previous studies that have reported enhanced cervical and shoulder muscle activation during mentally demanding tasks. Psychological stress activates the sympathetic nervous system and stimulates the release of stress hormones such as adrenaline, noradrenaline, and cortisol. These physiological responses prepare the body to respond to perceived threats and are often accompanied by increased muscle tension. As a result, muscles involved in postural control, particularly the upper trapezius and sternocleidomastoid muscles, demonstrate elevated activation even in the absence of physical workload (1,2).

The findings of the present study are in agreement with those reported by Lundberg et al., who observed sustained trapezius muscle activation during mental stress tasks. Their study demonstrated that cognitive stress alone was capable of producing significant muscular activity without any accompanying physical demand (3). Similarly, Westgaard and colleagues reported that psychological workload contributed to increased neck and shoulder muscle activity, suggesting that emotional and cognitive factors play a direct role in musculoskeletal loading (4). The substantial increase in EMG amplitude observed in the present study further supports the concept that psychological stress can significantly alter neuromuscular function.

Another notable finding was that EMG activity remained elevated during the recovery phase despite the removal of the stress stimulus. Although muscle activation decreased from stress levels, recovery values did not return completely to baseline measurements. This suggests that the physiological effects of psychological stress may persist beyond the immediate exposure period. Incomplete muscular relaxation following stress has been reported in previous research and may indicate prolonged sympathetic activation or delayed neuromuscular recovery (5). Repeated exposure to such stress responses over time may contribute to chronic muscle tension, fatigue, and pain within the cervical region.

The persistence of elevated muscle activity during recovery may have important clinical implications. Many individuals experience repeated episodes of psychological stress throughout daily life, particularly in academic, occupational, and social environments. If cervical muscles remain partially activated after each stress episode, cumulative muscular loading may occur over time. This mechanism may contribute to the high prevalence of neck pain and shoulder discomfort observed among individuals exposed to chronic psychological stress. The findings of the present study therefore provide a possible physiological explanation for the association between stress-related disorders and musculoskeletal complaints.

The results also demonstrated elevated levels of perceived stress and anxiety among participants. Individuals with higher stress and anxiety scores tended to exhibit greater muscle activation during the stress condition. This finding is consistent with previous studies suggesting that anxiety influences neuromuscular behavior by increasing physiological arousal and enhancing muscle tension. Anxiety is characterized by heightened vigilance and anticipation of potential threats, which may increase activation of neural pathways involved in postural control and muscle readiness (6). Consequently, individuals with elevated anxiety may experience greater muscular responses to psychological stressors compared with individuals with lower anxiety levels.

From a physiological perspective, several mechanisms may explain the observed relationship between psychological distress and cervical muscle activity. Activation of the hypothalamic-pituitary-adrenal (HPA) axis during stress results in hormonal changes that influence muscle function and autonomic regulation. Simultaneously, increased sympathetic nervous system activity enhances muscle spindle sensitivity and motor neuron excitability, leading to greater muscle activation (7). The upper trapezius and sternocleidomastoid muscles are particularly susceptible to these effects because of their essential role in maintaining head posture and cervical stability. Continuous low-level activation of these muscles may eventually lead to fatigue, altered movement patterns, and pain.

The findings of this study are also consistent with the biopsychosocial model of musculoskeletal disorders. Traditional biomedical approaches often focus primarily on structural abnormalities when assessing neck pain and related conditions. However, increasing evidence suggests that psychological and social factors play a substantial role in symptom development and persistence. The present study provides objective evidence supporting this perspective by demonstrating that psychological stress alone can significantly increase cervical muscle activity. Therefore, assessment of musculoskeletal disorders should not be limited to physical examination alone but should also include evaluation of psychological factors such as stress and anxiety.

From a physiotherapy perspective, these findings highlight the importance of integrating psychological assessment into routine clinical practice. Physiotherapists frequently encounter patients presenting with neck pain, muscle tightness, headaches, and postural dysfunction. In many cases, structural pathology may not fully explain symptom severity. Recognition of stress-related muscle activation may improve clinical reasoning and support the development of more comprehensive treatment plans. Interventions such as relaxation training, diaphragmatic breathing exercises, mindfulness techniques, cognitive-behavioral approaches, and biofeedback may complement traditional physiotherapy interventions and contribute to improved outcomes (8).

Surface electromyography may also serve as a valuable clinical and research tool for identifying stress-related muscle activity. The ability to objectively measure changes in muscle activation provides clinicians with quantifiable evidence regarding the physiological impact of psychological stress. EMG biofeedback has been shown to improve awareness of muscle tension and may assist individuals in learning relaxation strategies that reduce excessive cervical muscle activation (9). Such interventions may be particularly beneficial for individuals with chronic neck pain associated with stress and anxiety.

Despite the important findings of the present study, certain limitations should be acknowledged. The study involved a relatively small sample size and was conducted at a single center, which may limit the generalizability of the results. In addition, only acute responses to psychological stress were evaluated. Future studies should investigate the long-term effects of chronic stress and anxiety on cervical muscle activity using larger and more diverse populations. Longitudinal research may provide further insight into the role of stress-related muscle activation in the development of chronic musculoskeletal disorders.

Overall, the findings of the present study demonstrate a significant association between psychological stress, anxiety, and cervical muscle activity. The increase in EMG amplitude during stress exposure and the persistence of elevated muscle activation during recovery provide objective evidence of the influence of psychological factors on neuromuscular function. These results emphasize the importance of adopting a biopsychosocial approach in physiotherapy practice and support the integration of stress management strategies into the assessment and

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rehabilitation of individuals with cervical musculoskeletal dysfunction.

5. CONCLUSION

The present study demonstrated a significant association between psychological stress, anxiety, and cervical muscle activity as measured through surface electromyography. Participants exposed to a standardized psychological stress task exhibited a substantial increase in electromyographic activity of the upper trapezius and sternocleidomastoid muscles compared with resting conditions. Although muscle activity decreased during the recovery phase, EMG values remained elevated above baseline levels, indicating incomplete neuromuscular recovery following stress exposure.

These findings suggest that psychological stress and anxiety contribute to increased cervical muscle tension and may play an important role in the development of neck discomfort, muscular fatigue, and stress-related musculoskeletal dysfunction. The study provides objective evidence supporting the interaction between psychological and physiological processes, highlighting the influence of emotional distress on neuromuscular function.

Surface electromyography proved to be an effective tool for identifying stress-induced changes in cervical muscle activity. The results emphasize the importance of incorporating psychological assessment and stress-management strategies into physiotherapy evaluation and rehabilitation programs. A biopsychosocial approach that addresses both physical and psychological factors may enhance treatment outcomes and support the prevention and management of stress-related cervical disorders.

6. Clinical Implications

The findings of this study have important implications for physiotherapy practice and musculoskeletal rehabilitation. The significant increase in cervical muscle activity during psychological stress suggests that stress and anxiety should be considered potential contributing factors in individuals presenting with neck pain, muscle tightness, and postural dysfunction. Physiotherapists should incorporate psychological screening tools, such as the Perceived Stress Scale and Beck Anxiety Inventory, into routine assessment procedures when appropriate. The use of stress-management interventions, relaxation techniques, breathing exercises, mindfulness training, and EMG biofeedback may help reduce excessive muscle tension and improve treatment outcomes. Adopting a biopsychosocial approach that addresses both physical and psychological factors may enhance rehabilitation effectiveness and contribute to the prevention and long-term management of stress-related cervical musculoskeletal disorders

7. Limitations

The present study has several limitations that should be considered while interpreting the findings. First, the study was conducted on a relatively small sample size, which may limit the generalizability of the results to larger populations. Second, participants were recruited from a single center, potentially reducing population diversity. Third, only acute responses to psychological stress were evaluated, whereas the long-term effects of chronic stress and anxiety on cervical muscle activity were not investigated. Additionally, other factors influencing muscle activation, such as sleep quality, physical activity levels, and occupational demands, were not controlled. Future studies should address these limitations through larger, multicenter, and longitudinal research designs.

8. Recommendations for Future Research

Future research should employ larger sample sizes and include participants from different age groups, occupational backgrounds, and clinical populations to improve the generalizability of findings. Longitudinal studies are recommended to determine the causal relationship between psychological stress, anxiety, and cervical muscle activity over time. Further investigations should explore the influence of varying levels of stress and anxiety on different cervical and shoulder muscles using advanced electromyographic techniques. Future studies may also incorporate physiological biomarkers such as cortisol levels, heart rate variability, and autonomic nervous system responses to provide a more comprehensive understanding of stress-related neuromuscular changes.

Interventional studies evaluating the effectiveness of stress-management programs, cognitive-behavioral therapy, mindfulness-based interventions, relaxation techniques, biofeedback training, and physiotherapy-based exercise programs on cervical muscle activity are warranted. Additionally, researchers should investigate whether reductions in stress and anxiety lead to improvements in muscle activation patterns and musculoskeletal health.

Future studies may also examine the relationship between psychological stress, anxiety, cervical muscle activity, posture, neck pain, sleep quality, and quality of life. Such research could contribute to the development of multidisciplinary approaches for the prevention and management of stress-related cervical musculoskeletal disorders and improve clinical outcomes in both healthy and symptomatic populations.

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Conflict of Interest

The authors declare that there is no conflict of interest related to this study.

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Author Contributions

Dr. Hemant Choubisa contributed to the study conception, methodology, data collection, data analysis, interpretation of results, and manuscript preparation. All authors reviewed and approved the final manuscript.

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