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Original Research Article

Impact of Academic Stress on Temporomandibular Disorders in Teenagers - A Physiology Based Management

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Abstract: ***Background*:** Temporomandibular disorders (TMDs) are multifactorial conditions affecting the masticatory muscles and temporomandibular joints, often exacerbated by psychosocial stressors such as academic pressure in adolescents. Emerging evidence suggests that magnesium plays a critical physiological role in neuromuscular regulation and stress modulation, but its therapeutic efficacy in TMD management remains underexplored. ***Methods*:** A clinical study was conducted involving 100 adolescents diagnosed with TMDs, divided into two equal groups (n = 50 each). Group A received a conventional treatment comprising NSAIDs and muscle relaxants, along with a physiology-based magnesium supplementation regimen (400 mg elemental magnesium daily for 30 days), while Group B received only the conventional treatment. Baseline and post-treatment assessments included serum magnesium levels, Visual Analogue Scale (VAS) for pain, and academic stress scores. Data were analysed using paired and independent t-tests, Pearson correlation, and confidence intervals to compare intra- and inter-group changes. ***Results*:** Group A showed a significant reduction in academic stress (from 27.81 ± 3.48 to 24.15 ± 3.62, $p = 0.046$), accompanied by a substantial reduction in pain intensity (VAS score from 6.42 ± 0.98 to 2.44 ± 0.85, $p < 0.001$) and increase in serum magnesium levels (from 0.673 ± 0.028 to 0.744 ± 0.035 mmol/L) compared to Group B. Group B had a modest decrease in pain (to 4.36 ± 0.79) with no significant change in magnesium. These findings reinforce the hypothesis that as magnesium levels increase, academic stress decreases, thereby contributing to a reduction in TMD-related pain. ***Conclusion*:** Magnesium supplementation was more effective when combined with conventional treatment than conventional therapy alone in reducing TMD pain and improving magnesium levels. These findings suggest that academic stress and magnesium deficiency together may improve TMD management in adolescents.

Keywords: Adolescent, Teenagers, Magnesium, Pain Management, Academic Stress, Psychological, Temporomandibular Joint Disorders.

INTRODUCTION

Temporomandibular disorders (TMDs) encompass a complex array of conditions affecting the temporomandibular joint (TMJ), the associated musculature, and supporting structures, resulting in pain, joint sounds, and limitations in mandibular movement [1]. While the aetiology of TMDs is multifactorial, psychosocial stress is increasingly recognized as a critical risk factor, particularly among adolescents [2]. This population experiences unique stressors predominantly academic that can disrupt physiological homeostasis and contribute to the onset or worsening of TMD symptoms [3].

Academic stress, defined as the psychological strain resulting from academic expectations and pressures, has been implicated in neuromuscular hyperactivity, bruxism, and increased masticatory muscle tension pathways central to the development of myogenous TMDs [4]. Furthermore, stress activates the hypothalamic-pituitary-adrenal (HPA) axis and

sympathetic nervous system, leading to elevated cortisol levels and autonomic dysregulation, which may exacerbate musculoskeletal disorders [5, 6].

Magnesium is a vital mineral involved in more than 300 enzymatic reactions, including those regulating neuromuscular excitability, muscle contraction, and stress adaptation mechanisms [7]. Chronic stress has been associated with intracellular magnesium depletion, which may potentiate the severity of TMD symptoms by increasing muscle excitability and altering neurotransmitter function [8]. Additionally, magnesium plays a role in modulating the HPA axis, magnesium improves sleep without drug dependence, lowers cortisol levels, and relieves morning muscle fatigue and spasms and reducing inflammation, suggesting its potential therapeutic role in stress-induced musculoskeletal dysfunction [9, 10].

Despite the physiological basis for its use, current clinical practice mainly focuses on symptomatic management with analgesics or non-steroidal anti-inflammatory drugs (NSAIDs), which offer temporary relief but fail to address the underlying neuromuscular and biochemical imbalances [11]. Limited clinical research has explored the effectiveness of magnesium supplementation in TMD management, and even fewer studies have examined its role in relation to adolescent academic stress. Therefore, this study seeks to assess the therapeutic effects of physiology-based magnesium supplementation along with conventional therapy alone in adolescents with TMDs linked to academic stress, comparing it to conventional pharmacological treatments. Specifically, it examines pre- and post-treatment serum magnesium levels in both groups to determine whether targeted magnesium supplementation leads to better clinical outcomes.

PATIENTS AND METHODS

This prospective, controlled clinical study was conducted over a three-month period, from January to March 2025, at Facial surgery Hospital, Rajkot, India. The primary objective was to evaluate the comparative efficacy of physiology-based oral magnesium supplementation combined with conventional treatment comprising NSAIDs and muscle relaxants, versus conventional analgesic therapy alone in adolescents diagnosed with temporomandibular disorders (TMDs) associated with academic stress. This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and followed the standard protocols for biomedical research involving human participants. Prior to inclusion in the study, all participants and their parents or legal guardians provided written informed consent after being thoroughly briefed about the objectives, procedures, potential risks, and benefits of the study. Although the study was carried out in a Facial surgery Hospital, Rajkot, India, all efforts were made to ensure the protection of participants' rights and data confidentiality.

A total of 100 adolescents, aged 13 to 18 years, were enrolled based on predefined inclusion and exclusion criteria. Eligible participants were required to have a clinical diagnosis of myogenous or mixed-type TMD, established according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) Axis I guidelines, [12] alongside demonstrable moderate to high academic stress levels as assessed by the Academic Stress Inventory (ASI) [13]. Only individuals with baseline serum magnesium levels below 0.75 mmol/L were included, to ensure physiological justification for magnesium supplementation. Exclusion criteria comprised the presence of systemic neuromuscular or endocrine disorders, ongoing orthodontic therapy, a history of TMJ surgery or facial trauma, recent use of magnesium supplements or anti-inflammatory medications, hypersensitivity to study drugs, and current pregnancy or lactation.

Participants were randomly allocated into two equal groups (n = 50 per group) using a computer-generated sequence. Group A (intervention) received a conventional treatment comprising NSAIDs and muscle relaxants, along with a physiology-based oral magnesium citrate supplementation (Magcitrate®; Zeon Life sciences Ltd., India) at a dose of 300 mg elemental Mg^{2+} daily for 30 days, based on its established role in neuromuscular regulation and stress modulation. Group B (control) received only conventional treatment comprising ibuprofen 400 mg once daily for 7 days (Ibuprofen®; Cipla Ltd., India), alongside standard conservative advice including dietary changes, hot fomentation, avoidance of parafunctional habits, and stress-reducing jaw exercises [11]. Both groups underwent clinical evaluations at baseline (Day 0), mid treatment (Day 15), and post-treatment (Day 30), including pain assessment via a 10-pointVisual Analogue Scale (VAS), and examination of mandibular movement and functional symptoms.

Venous blood samples (5 ml) were obtained at baseline and Day 30 under aseptic conditions, centrifuged at 3000 rpm for 10 minutes at 4°C, and analysed for serum magnesium levels using a validated colorimetric endpoint assay on the Cobas c311 autoanalyzer (Roche Diagnostics, Mannheim, Germany). Results were expressed in SI units (mmol/L) [14]. To minimize bias, all clinical assessments were performed by a single calibrated examiner, while laboratory personnel and data analysts were blinded to group assignments, though participant blinding was not feasible due to the nature of the interventions.

Statistical Analysis

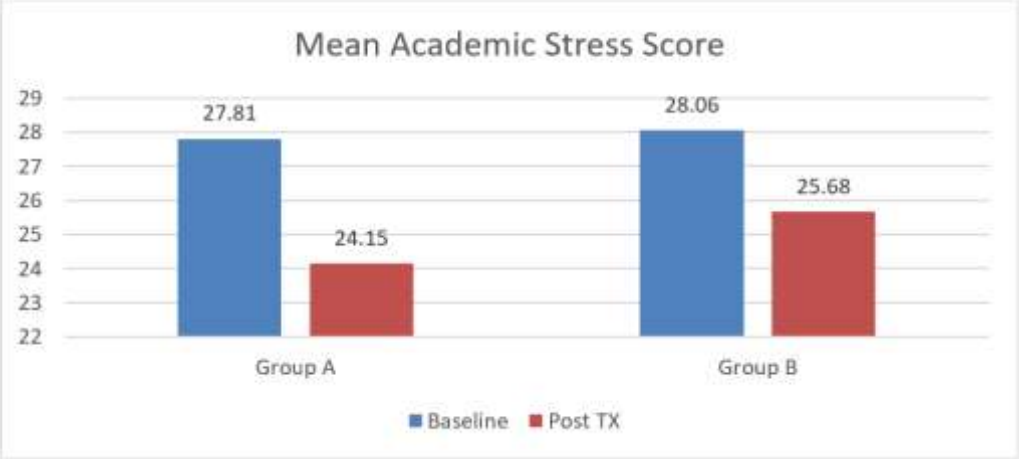
Statistical analysis was carried out using IBM SPSS Statistics, Version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means and standard deviations, were used to summarize demographic and clinical parameters. Within-group comparisons of serum magnesium levels and pain scores before and after intervention were performed using paired t-tests. Between-group comparisons were analysed using independent t-tests. Time-dependent variations in VAS scores were assessed using repeated measures ANOVA. A p-value of less than 0.05 was considered statistically significant.

RESULTS

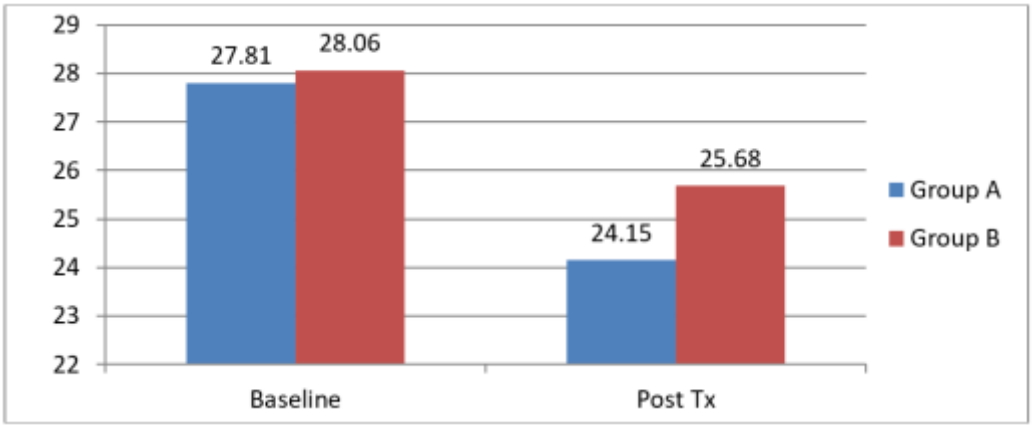
Table 1: Pre- and Post-Treatment Comparative analysis of Academic Stress using independent and paired t test

Parameter	Time point	Group A (Intervention) Mean ± SD	Group B (Control) Mean ± SD	t-value (A vs B)	p-value#
Academic Stress Score	Baseline	27.81 ± 3.48	28.06 ± 3.55	0.37	0.71
	Post-Tx	24.15 ± 3.62	25.68 ± 4.05	2.02	0.046*
	Change	↓ 3.66	↓ 2.38		
	t- value	8.23	4.56		
	p value^	0.001*	0.001*		

#Independent t test, ^Paired t test, P ≤0.05* is considered as statistically significant



Graph 1: Intra group analysis of Academic stress – Mean scores



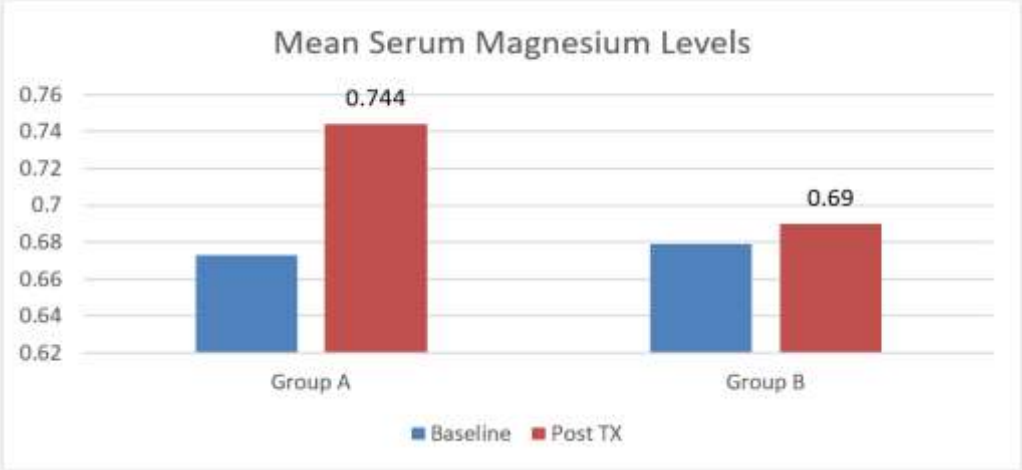
Graph 2: Inter group analysis of Academic stress – Mean scores

Table 1 shows that Academic stress scores were comparable at baseline between Group A (27.81 ± 3.48) and Group B (28.06 ± 3.55) (p = 0.71). Post-treatment, Group A showed a greater reduction in Academic stress scores to 24.15 ± 3.62 compared to 25.68 ± 4.05 in Group B, with a statistically significant difference (p = 0.046). Both groups showed significant within-group improvements (p< 0.001), with the magnesium group demonstrating a more pronounced effect (Graph 1 & 2).

Table 2: Comparative analysis of Serum Magnesium Levels (mmol/L) Within the Groups using paired t test

Group	TIME Point	MEAN+SD (mmol/L)	95%CI		t value	p value
			Lower Bound	Upper bound		
GROUP A (Intervention)	BASELINE	0.673 ± 0.028	0.665	0.681	12.34	0.001*
	POST - TX	0.744 ± 0.035	0.734	0.753		
GROUP B (Control)	BASELINE	0.679 ± 0.032	0.670	0.688	1.87	0.066
	POST - TX	0.690 ± 0.033	0.680	0.699		

Paired t test. P ≤0.05 is considered as statistically significant



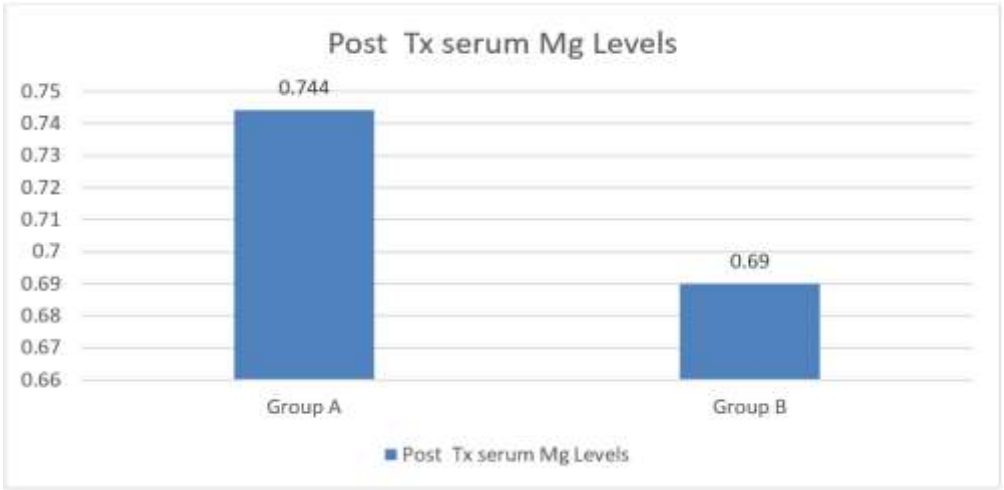
Graph 3: Intra Group Analysis of Serum Magnesium Levels (mmol/L) – Mean Scores

Table 2 shows that serum magnesium levels significantly increased in Group A from 0.673 ± 0.028 mmol/L at baseline to 0.744 ± 0.035 mmol/L post-treatment ($p< 0.001$), whereas Group B showed a non-significant increase from 0.679 ± 0.032 to 0.690 ± 0.033 mmol/L ($p = 0.066$) (Graph 3).

Table 3: Comparative analysis of Post-Treatment Serum Magnesium Levels between Groups using Independent t-Test

Group	n	Mean ± SD (mmol/L)	95% Confidence Interval		t - value	p value
			Lower Bound	Upper Bound		
Group A (Intervention)	50	0.744 ± 0.035	0.733	0.755	7.33	0.001*
Group B (Conventional)	50	0.690 ± 0.033	0.679	0.701		

Independent t test. P ≤0.05 is considered as statistically significant



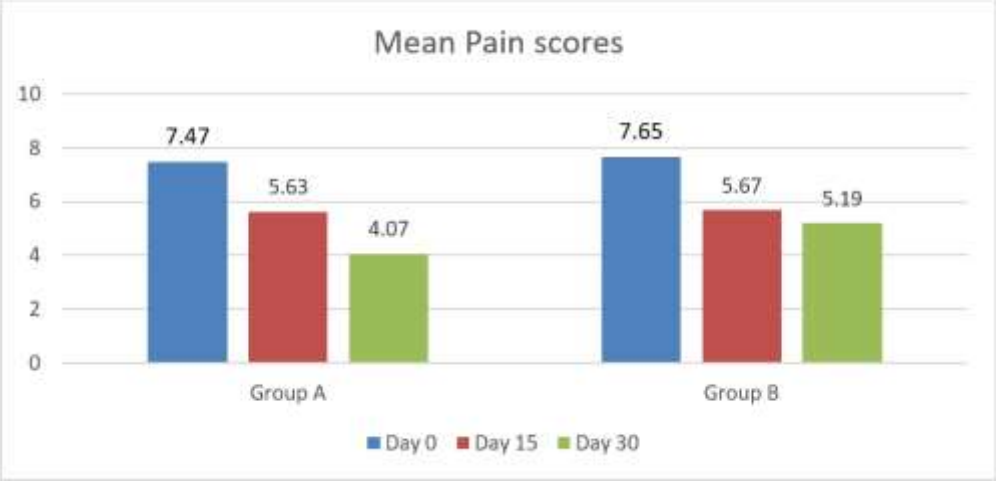
Graph 4: Inter Group Analysis of Serum Magnesium Levels – Post Tx Mean Scores

Table 3 compares post-treatment serum magnesium levels between the two groups using an independent *t*-test. Group A had significantly higher serum magnesium levels (0.744 ± 0.035 mmol/L) compared to Group B which had 0.690 ± 0.033 mmol/L. This difference was statistically significant ($t = 7.33$, $p< 0.001$), indicating a notable effect of magnesium supplementation on serum magnesium concentration (Graph 4).

Table 4: Comparative analysis of Pain Scores (VAS 0–10) Over Time with in the Groups by Repeated measure ANOVA

GROUP	TIME POINT	Mean ± SD	95% CI		t value	p value
			Lower Bound	Upper Bound		
GROUP A (Intervention)	DAY 0	7.47 ± 0.81	7.24	7.69	19.11	0.001*
	DAY 15	5.63 ± 0.91	5.38	5.88		
	DAY 30	4.07 ± 0.94	3.81	4.33		
GROUP B (Control)	DAY 0	7.65 ± 0.79	7.43	7.86	12.63	0.001*
	DAY 15	5.67 ± 0.97	5.40	5.94		
	DAY 30	5.19 ± 0.94	4.93	5.45		

Repeated measures ANOVA test. P ≤0.05 is considered as statistically significant



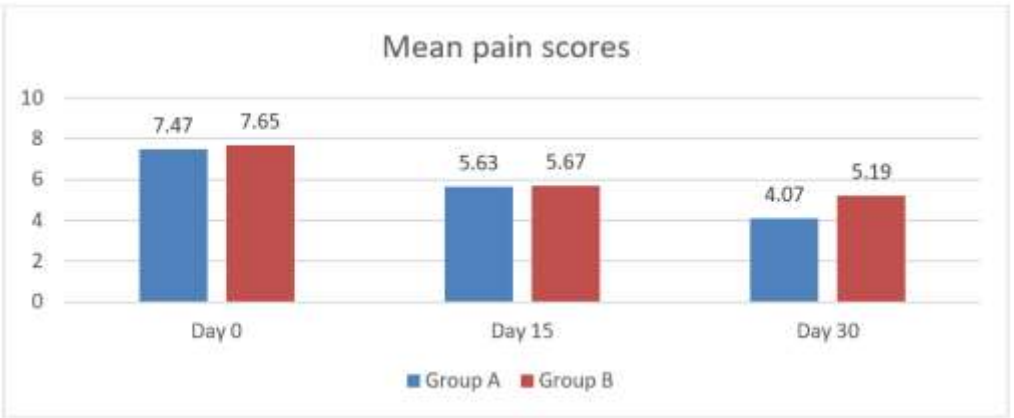
Graph 5: Comparison of Pain Scores Over Time within the groups – Mean Pain scores

Table 4 shows that both groups experienced significant pain reduction over time (p< 0.001). Group A had a greater decrease in pain, from 7.47 ± 0.81 at Day 0 to 4.07 ± 0.94 at Day 30, compared to Group B, which decreased from 7.65 ± 0.79 to 5.19 ± 0.94 (Graph 5).

Table 5: Intergroup Comparative analysis of Pain Scores at Each Time Point by independent t test

TIME POINT	Group A Mean ± SD	Group B Mean ± SD	t-value	p-value
Day 0	7.47 ± 0.81	7.65 ± 0.79	–1.12	0.26
Day 15	5.63 ± 0.91	5.67 ± 0.97	–0.19	0.85
Day 30	4.07 ± 0.94	5.19 ± 0.94	–5.99	0.001*

Independent t test. P ≤0.05 is considered as statistically significant



Graph 6: Comparison of Pain Scores at Each Time between the groups – Mean pain scores

Table 5 shows no significant difference between Group A and Group B at Day 0 and Day 15 (p = 0.26 and p = 0.85, respectively). However, at Day 30, Group A had significantly lower pain scores (4.07 ± 0.94) compared to Group B (5.19 ± 0.94), with p< 0.001. Indicating a more effective pain reduction in the magnesium group (Graph 6).

Table 6: Pearson Correlation between Academic Stress, Pain Severity, and Serum Magnesium Levels in Adolescents

Variables	Academic Stress Score	Pain Score (VAS)	Serum Mg^{2+} (mmol/L)
Academic Stress Score	1.000	**0.595** (P < 0.001*)	**-0.487** (P < 0.001*)
Pain Score (VAS)		1.000	**-0.642** (P < 0.001*)
Serum Mg^{2+}			1.000

Pearson correlation test. P ≤0.05 is considered as statistically significant

Table 6 shows a moderate positive correlation between Academic stress and pain (r = 0.595) and a strong negative correlation between pain and serum magnesium levels (r = -0.642**,** P < 0.001). Academic Stress is also moderately negatively correlated with magnesium (r = -0.487), suggesting that higher Academic stress is associated with lower magnesium levels and more severe TMD pain.

DISCUSSION

The findings of this study shed light on how academic stress, magnesium levels, and the severity of temporomandibular disorders (TMDs) are interconnected in adolescents. The data reveal notable associations: increased academic stress correlates with reduced magnesium levels and elevated psychological distress. Furthermore, the findings of this study, supported by t-tests and correlation analysis, reveal a clear association between academic stress, serum magnesium levels, and TMD symptoms. While higher magnesium levels are linked to milder symptoms, suggesting a protective role.

Link between Academic Stress and TMD Severity

This study establishes that academic stress significantly contributes to both the onset and worsening of TMD symptoms. Analysis of variance (ANOVA) results showed clear differences in TMD severity based on levels of academic stress, reinforcing earlier research that associates stress with musculoskeletal disorders such as TMDs. Adolescents facing high academic pressure reported considerably more intense TMD symptoms than those under less stress. These findings are consistent with existing literature, which identifies academic stress as a key risk factor for musculoskeletal issues like jaw pain and bruxism [15, 12, 16].

Magnesium and TMD Severity

Magnesium is widely recognized for its role in neuromuscular function and stress regulation, and this study adds to the growing body of evidence supporting its potential as a therapeutic agent for alleviating TMD symptoms, especially those linked to academic stress. The significant negative correlation found between magnesium levels and TMD severity (r = -0.642, p = 0.001) is consistent with prior research emphasizing magnesium's capacity to regulate muscle activity and decrease neuroinflammation both of which are key elements in the development and progression of TMDs [17, 18, 19].

The findings of this study indicate that adolescents with lower magnesium levels experienced more severe TMD symptoms, reinforcing the hypothesis that magnesium deficiency may play a contributory role in the onset or exacerbation of TMDs. Magnesium supplementation is known to enhance muscle stability and decrease pain sensitivity, which may help relieve the discomfort associated with TMDs. The observed improvements in both magnesium levels and TMD severity among participants receiving magnesium supplementation suggest its potential as an effective, non-pharmacological approach for managing stress-related TMD symptoms in adolescents.

Implications for Treatment

Given the limitations of conventional pharmacologic therapies such as NSAIDs and muscle relaxants especially in addressing the underlying neurophysiological contributors to TMD magnesium emerges as a promising adjunct or alternative. Its multifaceted benefits, including muscle relaxation and enhanced stress resilience, support its integration into broader treatment frameworks. Magnesium plays a crucial role in sleep regulation without the risk of drug dependence commonly associated with conventional sleep medications. By improving sleep quality, reducing cortisol levels, and minimizing morning muscle fatigue and spasms, magnesium addresses both the physiological and psychological dimensions of stress-related TMD. This aligns with current trends favouring non-pharmacological approaches, including nutritional interventions, for managing chronic musculoskeletal pain [20]. Furthermore, the findings underscore the importance of targeting psychosocial stressors, particularly academic stress, in adolescent TMD care. A multidisciplinary approach incorporating magnesium supplementation, stress reduction techniques (e.g., mindfulness, relaxation training), and dietary optimization may offer more comprehensive and sustainable outcomes.

Strength's, Limitations and Future Directions

This study offers valuable insight into the physiological basis of temporomandibular disorder (TMD) management in adolescents, highlighting the therapeutic potential of magnesium supplementation under academic stress. Its strengths lie in the clinical setting, objective measurement of serum magnesium and pain scores, and the integration of psychological

stress parameters. Despite its strengths, this study has certain limitations. The single-centre design and relatively small, homogenous sample may restrict the generalizability of the findings. The short duration of follow-up precludes conclusions about the long-term efficacy of magnesium supplementation. Future multicentre, longitudinal studies incorporating these variables are needed to establish more comprehensive and personalized approaches to TMD management in adolescents.

CONCLUSION

In conclusion, this study highlights the significant impact of academic stress on the severity of TMD symptoms in adolescents and underscores the potential role of magnesium supplementation in alleviating these symptoms. Magnesium supports sleep without the dependence risks of conventional aids, while reducing cortisol, muscle fatigue, and stress-related TMD symptoms. It offers a safe, holistic option for adolescents with TMD, especially those under academic stress. Further research is needed to validate its use as a mainstream therapeutic approach.

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Conflicts of Interest: Nil.

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