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Temporomandibular Disorders (TMD) and Sports: Trauma, Overload, and the Role of Mouthguards

Stanisław Pawlak
ORCID: https://orcid.org/0009-0009-8640-7429
E-mail: s.pawlak@me.com
Warszawska Stomatologia, Warsaw, Poland

Karolina Siatkowska
ORCID: https://orcid.org/0009-0003-0581-0010
E-mail: siatkowskarolina@gmail.com
Warszawska Stomatologia, Warsaw, Poland

Agata Moroz
ORCID: https://orcid.org/0009-0001-2720-6696
E-mail: agata.moroz05@gmail.com
Warszawska Stomatologia, Warsaw, Poland

Corresponding Author:
Stanisław Pawlak, E-mail: s.pawlak@me.com

Abstract

Background: Evidence on the relationship between sports and temporomandibular disorders (TMD) is conflicting. While recent data suggest similar symptom rates between athletes and non-athletes, older reviews claimed higher risks for professionals, largely due to methodological flaws and self-reporting.

Aim: To analyze literature on TMD prevalence in athletes, identify key cofactors (trauma, bruxism, anxiety), and evaluate the biomechanical role of custom versus standard mouthguards.

Material and methods: A qualitative synthesis of 36 sources (2008–2026) from PubMed, Scopus, Web of Science, and Cochrane Library was conducted, focusing on studies utilizing DC/TMD or RDC/TMD diagnostic criteria.

Results: General sports do not inherently raise TMD risk. Strict evaluations show elite athlete prevalence at ~10%, refuting older, unstandardized claims of up to 100%. Macrotrauma and internal strains are confirmed triggers. Custom mouthguards offer superior impact absorption, whereas standard "boil-and-bite" models force continuous clenching, inducing muscle fatigue.

Conclusions: Recreational exercise may lower symptom burdens, while elite sports impose heavy mechanical and psychological loads. Custom mouthguards optimally prevent dental trauma, but their direct efficacy for TMD prevention remains a theoretical hypothesis rather than an established clinical fact.

Keywords: temporomandibular disorders, TMD, sports medicine, mouthguards, bruxism, temporomandibular joint, OPPERA

1. Introduction

Temporomandibular disorders (TMD) encompass a heterogeneous group of musculoskeletal and neuromuscular conditions involving the temporomandibular joints (TMJ), masticatory muscles, and associated anatomical structures. Establishing a definitive relationship between sports participation and TMD has proven challenging due to a persistent conflict in the scientific literature. To contextualize this relationship, it is essential to understand the baseline prevalence of these disorders. Recent large-scale epidemiological data from the German National Cohort (NAKO health study, n = 20,603) established the baseline prevalence of painful TMD in the general population at 3.7%, with a significantly higher risk observed in women (OR = 2.72) [14].

Against this general population baseline, sports medicine has historically debated whether athletic participation inherently elevates the risk of TMD due to intense physical exertion, acute macrotrauma, and chronic microtraumatic overload. A major literature review by Freiwald et al. (2021) concluded that professional athletes suffer from temporomandibular dysfunctions more frequently than non-athletes, demonstrating a highly heterogeneous prevalence ranging from 11.7% to 100% among athletes [11]. However, directly comparing these extreme upper limits to rigorous clinical baselines like NAKO is problematic, as high historical rates often relied on unstandardized self-reporting rather than strict DC/TMD criteria. In contrast, well-controlled recent studies, such as Merle et al. (2025), demonstrate that only ~10% of elite athletes report clinically relevant TMD symptoms, closely mirroring general population norms [22]. Consequently, recent meta-analyses argue that the overall symptom frequency is comparable between athletes and non-exercising individuals [12, 29].

This tension in the literature highlights the necessity of analyzing sports and TMD through a comprehensive biopsychosocial model. Physical training has been hypothesized in cross-sectional data to correlate with improved systemic pain tolerance in recreational practitioners [20]. However, high-performance environments impose direct mechanical risks (impacts, whiplash) and psychological burdens that increase trigeminal nociceptive excitability and clenching behaviors [6, 21, 23].

Within this framework, sports mouthguards play a pivotal role. Designed primarily to protect orofacial structures [17], their functional impact on the TMJ depends heavily on appliance construction. Properly fitted custom-made mouthguards distribute shock forces efficiently [2, 35], whereas mass-produced appliances force continuous active intercuspation, serving as a potential iatrogenic driver of muscular fatigue and joint discomfort [8, 13].

Research Objective

To critically review the literature regarding the conflicting epidemiological evidence of TMD in sports, analyze specific traumatic and overload mechanisms (including OPPERA prospective data, combat sports, and scuba diving), and evaluate the biomechanical role of custom versus standard mouthguards.

Research Problems

1. How can the conflicting epidemiological data regarding TMD prevalence in recreational versus professional athletes be reconciled considering methodological heterogeneity?
2. What are the distinct traumatic (internal vs. external) and biomechanical risk factors associated with high-load disciplines?
3. What is the clinical and biomechanical rationale for recommending custom-manufactured over standard boil-and-bite mouthguards?

2. Research materials and methods

2.1. Participants

As this study is a narrative review, the "participants" consist of the populations analyzed in the 36 selected primary sources. These included professional and elite athletes (e.g., martial artists, scuba divers, basketball players), recreational athletes, and sedentary control groups. Data from large prospective and cross-sectional cohorts, specifically the OPPERA (Orofacial Pain: Prospective Evaluation and Risk Assessment) cohort and the NAKO (German National Cohort) health study, were also included to establish general population baselines and trauma risk factors.

2.2. Procedure / Test protocol / Skill test trial / Measure / Instruments

A structured literature search was conducted using PubMed, Scopus, Web of Science, and the Cochrane Library for peer-reviewed literature published between 2008 and 2026. The search strategy utilized combinations of keywords: ("temporomandibular disorders" OR "TMD" OR "bruxism") AND ("sports" OR "athletes" OR "mouthguards" OR "combat sports" OR "scuba diving" OR "OPPERA"). Studies were selected based on relevance to athletic populations and rigorous evaluation of intraoral appliances. The primary diagnostic measures and instruments validated in the included studies were the DC/TMD (Diagnostic Criteria for Temporomandibular Disorders) and RDC/TMD guidelines, as well as validated short-form tools (bDC/TMD).

2.3. Data collection and analysis / Statistical analysis

Data collection involved the critical extraction and qualitative synthesis of epidemiological distributions, etiological cofactors, and biomechanical evaluations from the selected literature.

2.3.1. Statistical Software

As this study is a narrative review based on qualitative synthesis, no primary quantitative statistical software was utilized by the authors to process the data.

2.3.2. AI

Artificial intelligence (AI) tools were utilized for two specific, clearly delimited purposes in this study. First, AI-assisted text analysis was applied to the extracted literature to support the identification of recurring thematic patterns and to help organize the reviewed evidence into coherent conceptual categories (e.g., etiology, pathophysiology, epidemiology, diagnostics, and prevention). Second, AI was used to refine the academic English of the manuscript, ensuring clarity, terminological consistency, and adherence to scientific writing standards.

It is important to emphasize that all AI tools were used strictly as assistive instruments under continuous human supervision. The selection of sources, critical appraisal of the included studies, interpretation of results, and formulation of all conclusions were performed exclusively by the human authors, who are responsible for the scientific content of this review. The AI tools served primarily to enhance efficiency in literature organization, thematic synthesis, and linguistic refinement, and did not replace expert human judgment at any stage of the analytical or interpretive process. The authors have reviewed, verified, and approved all content in its final form and take full responsibility for the integrity and accuracy of the work.

2.3.3. Statistical Methods

No formal statistical hypothesis testing or meta-analysis was conducted by the authors. The methodology relied on a critical qualitative synthesis of descriptive statistics, prevalence rates, Hazard Ratios (HR), Odds Ratios (OR), and Impact Odds Ratios (IOR) as originally reported in the included primary studies and meta-analyses.

3. Research results

3.1. Epidemiological context: the tension in the literature

The current literature presents a stark conflict regarding TMD prevalence in sports. On one side, the systematic review by Freiwald et al. (2021) concluded that professional athletes suffer from TMD more frequently than non-athletes, reporting an athletic prevalence ranging dramatically from 11.7% to 100% [11]. When initially contrasted with the NAKO population baseline (3.7% for painful TMD) [14], this suggests a massive stomatognathic burden. However, directly comparing these figures is methodologically problematic. The extreme upper limits (approaching 100%) largely stem from unstandardized self-reporting and the inclusion of transient, non-painful joint sounds, heavily inflating the perceived clinical burden.

When rigorous diagnostic criteria are applied, the gap narrows significantly. A recent cross-sectional study of 337 German elite athletes revealed that only ~10% reported clinically relevant TMD symptoms, establishing a prevalence level very similar to that of the general population [22]. More recent meta-analytic efforts confirm this trend, suggesting that when pooling various sports disciplines, the overall frequency of musculoskeletal symptoms is comparable between athletes and sedentary control groups [29].

Some cross-sectional studies in recreational athletic groups even note lower symptom frequencies; for instance, competitive female athletes reported fewer TMD symptoms (52.2%) compared to recreationally training women (63.0%) or non-exercising individuals (60.9%) [12]. Furthermore, studies comparing CrossFit® practitioners with sedentary groups suggest athletes may exhibit a greater range of mandibular motion and a lower frequency of myalgia [20]. However, because these "protective" findings rely predominantly on cross-sectional data and self-reports, causal claims must be interpreted with high caution. Elite professional sports, nonetheless, still impose distinct biomechanical and psychological demands that warrant clinical attention.

3.2. Traumatic mechanisms and discipline-specific risks

Trauma Dynamics: The OPPERA Findings

Direct and indirect mechanical injuries represent well-established causal factors for TMD. Crucial insights into trauma etiology are provided by the prospective OPPERA study. In the primary cohort of 1,729 individuals free of baseline TMD, Sharma et al. (2019) demonstrated that the annual incidence of TMD was nearly twice as high among those experiencing jaw trauma (5.37%) compared to uninjured controls (3.44%), yielding an adjusted Hazard Ratio (HR) of 3.94 [31]. Notably, risk estimates were almost identical for internal injuries (HR = 3.85) and external macrotrauma (HR = 4.03) [31].

Further precision is offered by the nested case-control analysis by Sharma et al. (2020), which evaluated the specific odds of painful TMD development following different injury types [32]. A single traumatic event increased the odds of painful TMD with an impact odds ratio (IOR) of 6.0, while multiple injuries exerted a cumulative effect (IOR = 9.4) [32]. The highest specific risks were documented for:

- External trauma (IOR = 7.6) [32]
- Prolonged mouth opening (IOR = 5.4) [32]
- Yawning (IOR = 3.4) [32]

This confirms that non-impact internal strains (such as forced jaw extension) are highly pathogenic. Furthermore, indirect acceleration-deceleration forces ("whiplash") are identified as a triggering mechanism for TMD symptoms in a significant subset of affected individuals [3]. Over a decade of OPPERA research syntheses reveals that long-term TMD onset is heavily mediated by systemic comorbidities, somatic symptoms, and sleep disruption, shifting the primary focus from purely local factors to systemic patient vulnerability [34].

Martial Arts & Combat Sports

In high-impact combat sports, direct facial impacts pose obvious risks to the jaw complex. Comparative evaluations using RDC/TMD criteria demonstrate a significantly higher prevalence of TMD signs in elite martial artists (karate, MMA) compared to non-contact controls or recreational practitioners [5]. Elite fighters primarily present with disc displacement and myofascial pain, yet often display chronic, low-intensity pain profiles, which researchers attribute to pain adaptation and habituation resulting from routine sparring exposure [5].

Scuba Diving Biomechanics

Scuba diving introduces specialized mechanical demands on the masticatory system. In a cohort of 485 divers initially free of symptoms, 44.1% developed TMD-related pain [18]. Independent predictors included habitual clenching (OR = 2.47), diving in warm water conditions (OR = 1.69), and excessive mouthpiece biting (OR = 1.60), while a higher subjective rating of mouthpiece quality exerted a protective effect (OR = 0.89) [18].

The primary biomechanical driver is the forced, sustained anterior positioning of the mandible required to retain a standard regulator mouthpiece, resulting in a total loss of posterior molar support [15]. This posture forces prolonged isometric contractions of the orbicularis oris muscles and masseter muscles [15]. Electromyographic studies indicate that modifying mouthpiece design, such as expanding the lip bumper, redistributes muscle activity to the orbicularis oris muscles, thereby reducing masseter overload [15]. Novice divers experience higher symptom rates due to anxiety and increased muscular effort to retain the regulator [27, 36].

3.3. Psychosocial cofactors, stress neurobiology, and bruxism

Psychological stressors inherent to competitive sports exert profound neurobiological effects on masticatory muscle tone. Pre-competition anxiety and emotional stress activate the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system, dampening descending central pain inhibition and increasing trigeminal nociceptive excitability [21]. This physiological cascade strongly correlates with habitual tooth clenching and awake bruxism [6, 21, 23].

Systematic reviews establish a strong link between athletic stress, bruxism, and painful TMD [4, 7]. Rather than asserting that psychological states "fully mediate" disease onset—a claim too categorical for cross-sectional data—the literature confirms that awake bruxism serves as a highly significant behavioral correlate connecting psychological anxiety with clinical myofascial dysfunction [6, 23]. Pain catastrophizing further exacerbates symptom intensity, creating a persistent feedback loop of muscular tension and pain perception [21].

While certain malocclusions (e.g., Angle Class II, deep bite) show cross-sectional correlations with myalgia in athletic cohorts [1, 10], long-term prospective 20-year studies demonstrate that static occlusal parameters alone are weak predictors of TMD onset, emphasizing the primacy of behavioral and psychosocial factors in disease pathogenesis [25].

3.4. Biomechanical and clinical impact of mouthguards

Evaluating sports mouthguards requires distinguishing between two distinct therapeutic end-points:

1. **Orofacial Trauma Prevention:** Systematic reviews confirm that the relative risk of orofacial injuries, including dental trauma and lacerations, is approximately 1.6 to 2.3 times higher in athletes who do not wear mouthguards compared to those who utilize them [17].

2. **TMD Symptom Modulation:** Meta-analyses have noted an association between the application of intraoral appliances and a reduction in baseline TMD pain and joint clicking [29]. However, it is vital to exercise caution here. Cochrane reviews evaluating therapeutic occlusal splints report that evidence for pain reduction is of very low certainty [33]. Extrapolating the purported mechanisms of therapeutic splints to sports mouthguards remains a biomechanical hypothesis, not a definitive clinical fact.

Meta-analyses comparing mouthguard construction types consistently demonstrate the absolute superiority of custom-made models over self-adapted boil-and-bite (B&B) appliances [16]. Custom mouthguards offer significantly better fit ($p = 0.0002$), speech clarity ($p < 0.00001$), and uninhibited breathing ($p < 0.00001$) [8, 16].

Conversely, the iatrogenic mechanism of standard boil-and-bite models is well documented. Due to loose anatomical adaptation, athletes must continuously clench their teeth to stabilize the device [8]. In a clinical trial evaluating eight distinct mouthguard designs, standard B&B models induced transient, iatrogenic TMJ symptoms and masseter fatigue precisely because they required active biting for retention; symptoms resolved completely upon switching to custom appliances [13].

Finite element analysis (FEA) models suggest that custom mouthguards can absorb impact energy and lower compressive and shear stresses within the condyle and articular disc [35]. This is often theoretically referred to as "joint decompression." However, this mechanical concept must be reconciled with the physiological reality that *any* intraoral appliance forces the mandibular condyle downwards and forwards [24]. While this displacement physically separates the articular surfaces (thereby theoretically "decompressing" the joint space), excessive material thickness can over-extend the joint capsule and unbalance the masticatory musculature [24]. Modern 3D-printed digital custom mouthguards (e.g., 4 mm EVA) attempt to offer an optimal balance between force absorption and physiological comfort [19, 28].

Table 1. Comparison of the impact of different types of mouthguards on the temporomandibular joints.

Feature / Parameter	**Custom-Made Mouthguards**	**Boil-and-Bite (Standard) Mouthguards**
Fit and Retention	Precise anatomical adaptation, stable retention without active biting [8, 16, 19].	Loose fit, poor retention, easily displaced during movement or speech [8, 16].
Impact on TMJ & Muscles	Absorbs impact energy; forces mild condylar displacement but avoids muscle strain [24, 35].	Induces muscle hypertonia and masseter fatigue due to forced active clenching [13].
Clinical Recommendation	Strongly recommended in sports medicine for total orofacial protection [2].	Not recommended as professional protection in competitive sports [2, 13].

3.5. Diagnostic standardized frameworks

Discrepancies across TMD literature heavily stem from the heterogeneity of applied diagnostic methodologies [11]. The DC/TMD (Diagnostic Criteria for Temporomandibular Disorders) represents the international gold standard, incorporating physical Axis I evaluations (myofascial pain, arthralgia, disc displacements) and Axis II psychosocial assessments (anxiety, depression, somatization) [30]. For epidemiological field studies involving athletic populations, validated short-form tools—such as the brief DC/TMD (bDC/TMD) [26] and adolescent adaptations [9]—provide reliable diagnostic screening without requiring complex laboratory setups.

4. Discussion

This narrative review highlights a fundamental duality regarding the impact of sports on the stomatognathic system. The literature contains a persistent tension: while historical reviews reported massive TMD burdens (up to 100%) in athletes [11], recent rigorously standardized data demonstrate that elite athletes report TMD symptom prevalences (~10%) much closer to the general population [22]. The apparent "epidemic" of TMD in sports is largely an artifact of methodological heterogeneity, over-reliance on self-reporting, and differing diagnostic criteria [11, 29].

For recreational practitioners, cross-sectional studies have hypothesized that structured physical activity might correlate with potential protective musculoskeletal benefits and stress mitigation [12, 20]. However, these interpretations must be approached with caution, as cross-sectional associations do not establish causality. Unquestionably, high-performance environments—characterized by rigorous physical loads, competitive anxiety, and discipline-specific mechanics—impose substantial demands that warrant clinical monitoring [7, 11, 22].

Findings from the prospective OPPERA studies [31, 32] profoundly refine our understanding of trauma. The evidence that internal microtrauma (such as prolonged jaw extension) carries risk estimates comparable to severe external macrotrauma highlights the TMJ's vulnerability to non-impact strains [31, 32]. Furthermore, the strong correlation between anxiety-driven awake bruxism and symptom severity confirms that sports-related TMD management must employ a holistic biopsychosocial approach [21, 23, 34].

From a preventive perspective, the data unequivocally support the use of custom-manufactured mouthguards over mass-produced boil-and-bite devices for orofacial protection [2, 16]. Boil-and-bite models clearly introduce iatrogenic muscular fatigue by forcing continuous isometric clenching [8, 13]. However, the assumption that custom mouthguards actively "treat" or prevent TMD through joint decompression remains a biomechanical hypothesis requiring further robust clinical validation, especially given the low certainty of evidence supporting even therapeutic occlusal splints [33].

Research Limitations & Future Directions

There remains a critical need for multi-year prospective cohort studies tracking young athletes from baseline through their competitive careers using validated DC/TMD protocols [30].

Additionally, the precise biomechanical trade-off between impact absorption and condylar displacement caused by thick (>4 mm) mouthguards requires further MRI evaluation in athletes with pre-existing internal derangements [24].

5. Conclusions

1. The relationship between sports and TMD is highly dependent on participation intensity and study methodology. While cross-sectional data suggest recreational exercise might correlate with lower symptom reporting (though causal protective claims remain inconclusive), recent robust evidence places elite athletic TMD prevalence closer to general population norms, debunking claims of an absolute athletic "epidemic" [11, 22, 29].

2. Direct macrotrauma and internal joint strains (e.g., prolonged jaw extension) are major confirmed mechanical triggers for incident TMD, carrying nearly identical risk magnitudes [31, 32].

3. Specific biomechanical loads—such as direct facial impacts in combat sports or prolonged isometric mouthpiece retention in scuba diving—drive discipline-specific pathologies [5, 15, 18].

4. Psychological stress and pre-competition anxiety are strongly correlated with awake bruxism and masticatory muscle hypertonia, serving as highly significant behavioral factors in the onset of painful TMD rather than fully causal mediators [6, 21, 23].

5. Custom-made mouthguards provide superior fit and shock absorption for trauma prevention [16, 35], whereas boil-and-bite models force continuous clenching, inducing iatrogenic muscular overload and fatigue [8, 13]. Claims regarding their direct therapeutic efficacy for joint decompression remain theoretical [24, 33].

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