Universidad Europea VALENCIA

Grado en ODONTOLOGÍA

Trabajo Fin de Grado

Curso 2021-22

INTERRELATION BETWEEN ELITE ATHLETES' PERFORMANCE AND ORAL HEALTH: A SYSTEMATIC REVIEW.

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ACKNOWLEDGEMENTS

First and foremost, I am extremely grateful to my thesis supervisors, Dr. Juan Antonio Blaya Tárraga, who consistently allowed this paper to be my own work but steered me in the right direction whenever he thought I needed it. He has been an ideal mentor, offering advice and encouragement with a perfect blend of insight and humor. I would also like to thank him for his kindness, support and understanding. I am proud of, and grateful for, my time working with Juancho.

I would also like to thank Dr. Maria Gracia Sarrion Perez, who generously provided knowledge and expertise throughout the year, answering my questions and doubts.

Most importantly, none of this could have happened without my family. My parents, Jamal and Rachida and my older sister, Yasmine, who providing me with unfailing love, support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. Despite the distance, their belief in me has kept my spirits and motivation high during this process. I am forever grateful.

A special thanks to my closest friends, Anaïs and Emma with whom we became inseparable since the first year we met in Valencia. Thank you for the cherished time we spent together during these past 5 years and for being the ones I can always rely on.

To Kathia, my best friend for the past 14 years and my greatest confidante who have always been there to listened to me and advised me, I am happy that you are part of my life.

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ABBREVIATIONS

- World Health Organization: WHO
- World Dental Federation: FDI
- Oral health: OH
- Oral health-related quality of life: OHRQOL
- Temporomandibular disorders: TMD
- National Institutes of Health: NIH
- Decayed Missing Filled Teeth: DMFT
- Decayed, Missing, Filled: DMF
- Decayed and filled teeth: DFT
- International Caries Detection and Assessment system ICDAS
- Caries intensity index: CPI
- Papillary Marginal Attachment index: PMA
- Periodontal Index: PI
- Basic Periodontal Examination: BPE
- Gingival Index: GI
- Probing Pocket Depth / Periodontal Probing Depth: PPD
- Dutch Periodontal Screening Index: DPSI
- International Classification of Diseases: ICD
- Basic Erosive Wear Examination: BEWE
- Erosive Tooth Wear: ETW
- Temporomandibular Joint: TMJ
- Open Pulp, Ulceration, Fistula, Abscess: PUFA
- Creatine Kinase: CK
- Bleeding On Probing: BOP
- Repeated exercise-associated muscle cramps: REAMC
- Muscle or tendon reinjury: MTR
- Multiple types of reinjury: MR

ABSTRACT

Objective: Oral health is as essential to the success of an athlete's athletic performance as regular exercise and proper diet. The objective of this study was to evaluate the oral health of athletes to determine its relationship to athletic performance, as well as to describe the most common oral diseases affecting the oral cavity of athletes.

Methods: A systematic search of multiple databases was conducted using PRISMA guidelines to identify studies that reported the association between oral health and the physical performance of athletes. Papers were included if they evaluated the oral health of professional athletes. The methodological quality of papers was evaluated using a modification of the Newcastle-Ottawa scale for longitudinal observational studies and NIH quality assessment tool for descriptive cross-sectional studies.

Results: A total of 585 articles were initially retrieved from the systematic search of the literature. Of these, a final total of 12 articles following the inclusion criteria were included in the systematic review. The impact on sports performance due to poor oral hygiene in professional athletes was described between 6.9% and 38.5% (mean 22.7%). The prevalence of caries and periodontal diseases were recorded between 20% to 84% (mean 52%) and between 11.2% and 81% (mean 35.6%) respectively. Other orofacial affectations were trauma to the TJM from 7.2% to 53.1% (mean 35.4%) and dental erosions between 10.8% and 40% (mean 35.4%).

Conclusion: This study observed an association between poor oral health and a decrease in performance of elite athletes. Professional athletes' oral health was shown to be strongly affected with a high degree of dental status disorders in which the most common were caries followed by periodontal diseases, erosion and trauma.

KEYWORDS

‘elite athlete’, ‘professional athlete’, ‘performance’, ‘caries’, ‘periodontal diseases’, ‘gingivitis’, ‘periodontitis’, ‘erosion’.

1. INTRODUCTION

Sport is nowadays a regular habit that delivers several health advantages to our bodies as well as a highly appreciated form of social interaction. It may be done recreationally as a pastime or competitively, which requires a significant amount of training and commitment. Despite the health advantages of sports, regular participation has a variety of detrimental impacts on overall health, including an increased risk of dental disease due to the frequent consumption of carbohydrates and sports drinks with a high erosive and cariogenic potential.

For professional athletes, sport success is determined by a number of elements that must work in tandem to reach peak performance. Neglecting any component of the training process may result in sport failure. Maintaining appropriate dental hygiene is seen as a key factor in overall health maintenance.

Nowadays, oral health monitoring is becoming increasingly important in elite sports, according to research undertaken at top-level international championships. During the Olympic Games, oral health care and maintenance have grown more important: in Athens 2004, dental care was the second most requested health service (1), while close to 1600 dental procedures were performed during the Olympic Games in Beijing 2008 (2). Furthermore, oral illnesses caused 30% of all medical crises presented by athletes at the London 2012 Olympic Games, and were second only to musculoskeletal reasons for attendance (3).

Due to the high prevalence of oral problems among athletes, there has been a surge in interest in oral health in sports, resulting in a more preventative approach. As a result, oral screenings and oral health status are considered in athletes qualified to compete, with the goal of raising dental awareness and minimizing potential difficulties during competition (4).

1.1. Oral health

Oral health is an integral part of general health and well-being and a basic human right. According to the third sustainable development goal of the World Health Organization (WHO), good health and well-being, health is defined as a condition of total physical, mental, and social well-being, not only the absence of disease and disability. On the other hand, recent advancements in the definition of health and the measurement of health status, have had minimal impact on dentistry. Oral health is defined by WHO as being free of chronic mouth and facial pain, oral and throat cancer, oral sores, birth defects such as cleft lip and palate, periodontal disease, tooth decay and tooth loss, and other diseases and disorders that affect the mouth and oral cavity (5). In its approach to oral health, the dentistry profession has remained purely clinical, equating health with disease. It is the reason why dentistry has remained unaffected by the expanding concept of health (6).

1.1.1. Oral health-related quality of life (OHRQOL)

As per the literature, the concept of oral health-related quality of life (OHRQOL) did not arise until the early 1980s, in contrast to the broader health-related quality of life (HRQOL) concept that began to emerge in the late 1960s. Poor perception of the impact of oral illnesses on quality of life (QOL) might be one reason for the delay in the development of OHRQOL. Only 40 years ago, researchers dismissed the suggestion that oral disorders may be linked to overall health. Others have claimed that oral disease was one of the common symptoms, along with headaches, rashes, and burns, that were dismissed as minor issues that only seldom contributed to the characteristic ill role. As additional evidence of the influence of oral health became available in the late 1970s, the OHRQOL idea began to emerge (6).

The concept of OHRQOL is defined as a multidimensional construct that represents people's comfort when eating, sleeping, and participating in social activity, their self-esteem and their satisfaction with regard to their oral health. Functional, psychological and social factors, as well as experience of pain or discomfort are all linked to it. Oral

illness can interfere with key functions including breathing, eating, swallowing, and speaking, as well as daily activities like work, school, and family interactions (6).

Oral health issues can have a negative impact on one's well-being and diminish one's quality of life. Local inflammation induced by poor dental health can trigger a systemic inflammatory response and have an impact on physical fitness. Systemic changes caused by dental or oral health problems, such as changes in serum levels of inflammatory biomarkers like C-Reactive Protein (CRP) and interleukin (IL), appear in muscle injury and may thus influence physical fitness, specifically muscle mass, muscle strength, and muscle function (7).

1.2. Sport dentistry

Sports dentistry is one of the most recent and upcoming field in dentistry. The advancement of sports medicine in recent years has resulted in healthier players and greater results. Sports medicine has also grown into a multidisciplinary profession, with sports dentistry likely to play a significant role (8). Sports dentistry is the branch of sports medicine dealing with prevention, diagnosis and management of dental injuries and oral diseases associated with sports and exercise (9).

The integration of dentistry into sports medicine should focus on the most prevalent illnesses observed in athletes, such as dental caries, dental erosion, periodontal disease, malocclusion, temporomandibular disorders (TMD), orofacial injuries, and their prevention. This integration should result in a multidisciplinary follow-up of athletes, including oral screening and necessary oral health treatments (8,9).

Some dental disorders, such as non-carious cervical lesions or caries, might be caused by many factors as overtraining, an unfavorable diet, a parafunctional load or a lack of oral hygiene instruction. Swimmers are especially vulnerable to teeth erosion owing to the possibly acidic water environment (9).

In fact, due to the high quantity of free sugars and acidic components, sports drinks and comparable products eaten in the form of liquids or food supplements can create challenges in the oral environment, including dental hard tissues and dental materials. It should be mentioned that sugar-free sports and energy beverages are frequently still very acidic and might cause teeth erosion. All facets of an athlete's oral and overall health can have an impact on performance and should be addressed (8).

There is also a need to raise awareness about the possible indirect 'doping' effects of dental prescriptions (opioid medications), since some pharmaceuticals often prescribed in dentistry can be converted into prohibited doping substances. The World Anti-Doping Agency, for example, does not restrict codeine-containing medications. However, once in the body, these medications are converted into morphine, which is illegal. There are additional chemicals in the body that, when decompensated owing to functional degeneration, might induce responses and, as a result, have an indirect impact on the athlete's oral health (9).

World Dental Federation (FDI) (9) recommends to:

- Emphasize the significance of personalized mouthguards, shock-absorbing materials, and appropriate use times.
- Encourage preventative actions for the preservation of healthy oral tissues.
- Include a symbol for bespoke face masks and shields manufactured by dentists or under the direction of a dental practitioner.
- Inform the dental staff about the metabolism of prescription medications that may be in violation of WADA laws.
- Explain the significance of an athlete's oral health state to their performance, as well as the appearance of mouth lesions caused by systemic responses caused by sporting conditions.
- Emphasize the significance of the link between an athlete's oral and overall health.
- Emphasize the importance of eating a well-balanced diet for optimal dental health.

Prior to the evaluation, diagnosis, and restoration of oral health within a strict framework set by the athletes' demanding physical exercise, training sessions, games, return to play, and sports medicine principles, sports dentists should be part of the sports medical team and work alongside other medical specialties (8).

1.3. Athlete and oral health

In contrast with the common perception that athletes have an overall excellent health, it is striking to find that the oral health of athletes is poor (10). Oral health is not simply defined as absence of disease. It should positively contribute to the well-being and functioning of individuals including performance of elite athletes (11).

Since the first report from the 1968 Olympic Games, many studies have consistently reported poor oral health in elite athletes (12). Dental consultations accounted for 30% of all medical visits at the London 2012 Summer Olympic Games and were only second to musculoskeletal injury (3). Poor dental health is a major concern since it has a direct influence on one's quality of life, confidence, appearance and socialization. It may generate a systemic inflammatory response (13) which potentially has an effect on athletic performance and training, resulting in poor competition preparation.

Therefore, several studies conducted by sports dentists over the years have improved information about the elements that affect the oral ecology, such as salivary pH and flow, microbial load, and S-IgA levels. To begin with, food, weekly frequency and training hours, climatic circumstances, and psychophysical stress factors can all cause major changes in the oral ecology (14).

The athletes should be more aware of the risks related with participating in sports and pay more attention to their oral health, since changes in the oral cavity have a detrimental impact on the athlete's health, well-being, and physical performance (14).

Overall, oral health that can be affected in athletes such as dental caries, dental erosion, periodontal disease and pericoronitis or impacted third molar are the main

causes of poor oral health. Indeed, Athletes are a population that is especially prone to various oral health diseases, which are worsened by sports-related oral health risk factors due to the physical demands of exercise and training on the human body (15). These risks include his lifestyle, such as his fractionated diet during physical training, and method of hydration, hyposalivation, dental traumatology, high-intensity exercise, self-medication, a neglect of prioritization of oral health as well as the stress caused by high-level athletics, promote the development of mouth illnesses. On the other hand, his schedule owing to the training load, the frequency of tournaments, and the requirements of his job life, scheduling an appointment with a dentist might be difficult and unimportant. Finally, the intensity of sports practice, the hits and shocks absorbed, and the athlete's passion and determination to his sport all encourage oral trauma (15).

During the London 2012 Olympic Games, over half of the athletes did not have a check-up or hygiene visit within a year after the Games, and 8.7% did not receive such treatment at all. This suggests that dental care and oral health have a low priority among professional athletes, and that they did not emphasize oral health in their performance and competition preparation (15).

Prior to Rio 2016, a study of professional athletes revealed that over half of the sample required dental care (15). Furthermore, the prevalence of illness did not appear to be connected to socioeconomic position or continental location, since athletes from both developing and industrialized countries suffered from poor oral health. Finally, poor oral health is widespread among professional athletes and is comparable to that of non-athletes from disadvantaged communities (19).

2. JUSTIFICATION, HYPOTHESIS AND OBJECTIVES

Nowadays, dental health represent a growing interest in sports, especially when dealing with professional and elite sports. Sports dentistry deals with the prevention and treatment of any oral pathology or injury related to the practice of sport. Nowadays, the number of dentists specialized in this field are few, with a limitation in the prevention and management of the oral health of athletes (16). Athletes, in general, have a high frequency of oral disorders due to their lifestyle, frequent use of carbohydrates and acidic sports beverages, dry mouth, and a lack of understanding about oral health (17). Athletes and sports teams in certain countries continue to lack access to specialized and systematic dental treatment under the supervision of specialists, but dentists are increasingly being seen as crucial members of the sports medical team.

Therefore, it seems interesting to conduct this systemic review to explain the underlying relevant role that oral health may play in sports performance. Understanding which are the most prevalent oral diseases in elite athletes and how it relates to their athletic performance can help them in their career goals, as well as have a direct impact on the level of quality of their overall systemic health.

The **hypothesis** of this work is that athletes poor oral health have an impact on their performance. The improvement of oral health behavior, together with the incorporation oral health promotion and disease prevention will raise awareness about athlete's oral health. This would lead to a certain increase in their sports performance.

The **main objective** is to determine, in which manner poor oral health may impact athlete's performances.

The **specific** objective is to establish the most prevalent oral diseases affecting the athletes' oral cavity.

3. MATERIAL & METHODS

3.1. Protocol and registration

This study was conducted following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (18) (Appendix 2). This study was registered in PROSPERO (ID:330001).

3.2. Eligibility criteria

3.2.1. Pico investigation

This systematic review was conducted using the available literature to answer the focused question: Which are the most prevalent oral diseases in elite athletes and how does it impact on their athletic performance?

The electronic search strategy has been based on the following PICO categories that stands for 'population, intervention, comparator and outcomes':

- Population (P): athletes
- Intervention (I): poor oral health
- Control (C): good oral health
- Outcomes (O): changes in the sports performance

3.2.2. Inclusion and exclusion criteria

To be included in the review, the studies had to meet all the following criteria: published between 2010 and 2021, in order to concentrate on latest data, gain more reliability, and provide conclusions that match the current situation; Scientific papers in English language; Exclusively human studies; With the following study designs: Randomized controlled trials, Cohort studies, Case-control studies, Descriptive studies; Only athletes; Age above 16. No restriction was applied regarding the gender. Have been

excluded studies were sample weren´t professional athlete, or less than 16 years-old and papers without significant results.

3.3. Information sources and search strategy

The search was performed through the ESBCO CRAI Jose Planas library online interface, using the following databases: MEDLINE complete, Scopus, Cochrane Library; Dentistry and Oral sciences source, and Sport discuss.

When using Scopus on the 4th of March, the search strategy used the following terms through the advanced search interface: (Title-abstract-keywords (oral AND health) OR Title-abstract-keywords (oral AND hygiene) OR Title-abstract-keywords (dental AND health) OR Title-abstract-keywords (dental AND care) OR Title-abstract-keywords (oral AND care) AND Title-abstract-keywords (athletes) AND Title-abstract-keywords (athletics) OR Title-abstract-keywords (sport) AND Title-abstract-keywords (performance) OR Title-abstract-keywords (saliva) OR Title-abstract-keywords (periodontal)).

The data extraction continued with four other search strategies conducted in MEDLINE Complete, Cochrane Library, Dentistry and Oral Sciences Source and Sport Discuss, using the following terms: (oral health or oral hygiene or dental health or dental care or oral care) AND (athletes or sports or athletics) AND (saliva or periodontal or performance). The searches strategies conducted was reported in **Table 1**.

Table 1. *The table displays for each database consulted its name, the interface through which the database was searched, the date of search, the keywords used, the filters applied and records after the filters appliance.*

Date of the search	Keywords	Data base	Interface of research	Filters	Records after filters
1st march, 2022	(oral health or oral hygiene or dental health or dental care or oral care) AND (athletes or sports or	Cochrane	ESBCO Crai Jose Planas online library	Publication Year from 2010 to 2021 Cochrane Library publication date	(n = 78)

	athletics) AND (saliva or periodontal or performance) (n=96)		catalog, Valencia, SPAIN	Between Jan 2010 and Dec 2021 Search word variations	
1st march, 2022	(oral health or oral hygiene or dental health or dental care or oral care) AND (athletes or sports or athletics) AND (saliva or periodontal or performance) (n=97)	Dentistry and Oral Sciences Source	ESBCO Crai Jose Planas online library catalog, Valencia, SPAIN	Limit from 2010-2021 publication date Limit to English language Only academics publications	(n = 71)
1st march, 2022	(oral health or oral hygiene or dental health or dental care or oral care) AND (athletes or sports or athletics) AND (saliva or periodontal or performance) (n=163)	MEDLINE	ESBCO Crai Jose Planas online library catalog, Valencia, SPAIN	Publication date: 2010-2021 Academics publications Language: English	(n = 129)
1st march, 2022	(oral health or oral hygiene or dental health or dental care or oral care) AND (athletes or sports or athletics) AND (saliva or periodontal or performance) (n=70)	Sport Discuss	ESBCO Crai Jose Planas online library catalog, Valencia, SPAIN	Publication date: 2010-2021 Academics publications Language: English	(n=32)
4th march, 2022	(oral health or oral hygiene or dental health or dental care or oral care) AND (athletes or sports or athletics) AND (saliva or periodontal or performance) (n=159)	Scopus	ESBCO Crai Jose Planas online library catalog, Valencia, SPAIN	Limit from 2001-2021 publication date Limit to English language Limit to DENTISTRY subject area Exclude reviews	(n=22)

3.4. Selection process

Citations identified from the literature searches and reference list checking, were imported to Microsoft® Excel for Macintosh (v 16.61.1) and the duplicates were removed. The selection of the papers, to be include in this systematic review, has been realized in three phases by two independent reviewers (HH,JB). Firstly, titles derived from the online search based were independently screened for the inclusion of the studies as per the eligibility criteria. Subsequently, the abstracts obtained from the selected titles were screened for meeting the inclusion criteria. Thereafter, full-text articles of the selected abstracts that satisfied the eligibility criteria were obtained and included through a full-text assessment. Moreover, Full-texts not available were requested through Research Gate interface. Any disagreements or disambiguates were then resolved through a discussion between the authors.

3.5. Data collection process

Using Mendeley software (Elsevier Inc, NY, USA), the author retrieves titles and abstracts from the five search databases, along with inserts and manages references. Data were extracted, tabulated, and presented by the author. Study design, number of subjects, age, type of sport, data source, oral diseases and performance were displayed. In order to facilitate the critical appraisal conclusion, the measurement of all variables, specified confounding factors, and approaches to deal with were extracted in detail.

3.6. Data item

In this study, the eligible outcomes were established as ‘presence of poor oral health’ and ‘decrease of performance’ among athletes.

The following information on the features of the included studies was extracted and summarized in a tabular format:

- The report: Author, year and source of publication.
- The study: Study design.
- The participants: Type of sport, age and number of participants.

- The research design and features: Caries, periodontal diseases, dental erosion, trauma, malocclusion, other oral diseases and impact on performance.

With the variable data obtained, descriptive statistics were performed. Minimum, maximum mean were described and calculated. The articles that presented omission of data in the tables, but were specified in the text, were extracted and taken into account for the results.

3.7. Risk of bias

Risk of bias assessment of the cross-sectional surveys included in this systematic review was performed by the author using the NIH quality assessment tool for descriptive cross-sectional studies (19). According to the applicability of the included cross-sectional surveys, fourteen domains were evaluated to determine the risk of bias and level of concern: The clear statement of the objective or research question; The clear specification and definition of the study population; If the participation rate of eligible persons was at least 50%; The selection or recruitment of the subjects from the same or similar populations including the same time period; The justification of the sample size and power description; The measure of exposure(s) of interest prior to the outcome(s) measured; If the timeframe was sufficient to see an association between exposure and outcome; The examination of different levels of the exposure as related to the outcome; The definition, validity, reliability and implementation of exposure measures; The assessment of more than one time of the exposure(s); The definition, validity, reliability and implementation of outcome measures; If the outcome assessor was blinded to the exposure status of the participants; The loss of follow-up; The measurement and adjustment of the key confounding variables.
This evaluation was reported in a table and quality was rated as 0 for poor (0–4 out of 14 questions), ‘i’ for fair (5–10 out of 14 questions), or ‘ii’ for good (11–14 out of 14 questions); NA: not applicable, NR: not reported.

Risk of bias assessment of the Longitudinal observational study was achieved by the author with the Newcastle-Ottawa scale where nine domains were evaluated to

determine the risk of bias and level of concern: The representativeness of the exposed cohort; The selection of the non-exposed cohort; The ascertainment of exposure; The demonstration of outcome of interest absence at start of study; The comparability for the most important factor; The comparability for additional factors; The assessment of outcome; The sufficient follow-up; The adequacy of follow-up.

This evaluation was also reported in two adequate tables and studies were considered 'low risk of bias' for a star rating > 6 and 'high risk of bias' for a rating ≤ 6.

4. RESULTS

4.1. Study selection

The searches were carried out in March 2022. The electronic search retrieved a total of 585 potentially relevant articles: 163 in MEDLINE Complete; 159 in Scopus; 96 in Cochrane; 97 in Dentistry and Oral Sciences Sources; and 70 in Sport Discuss. From these records, 253 were excluded due to using a language other than English; the date limitation (only from 2010 to 2021); and study type exclusion (reviews). After removing 66 duplicates, the remaining 270 articles were retrieved for assessment.

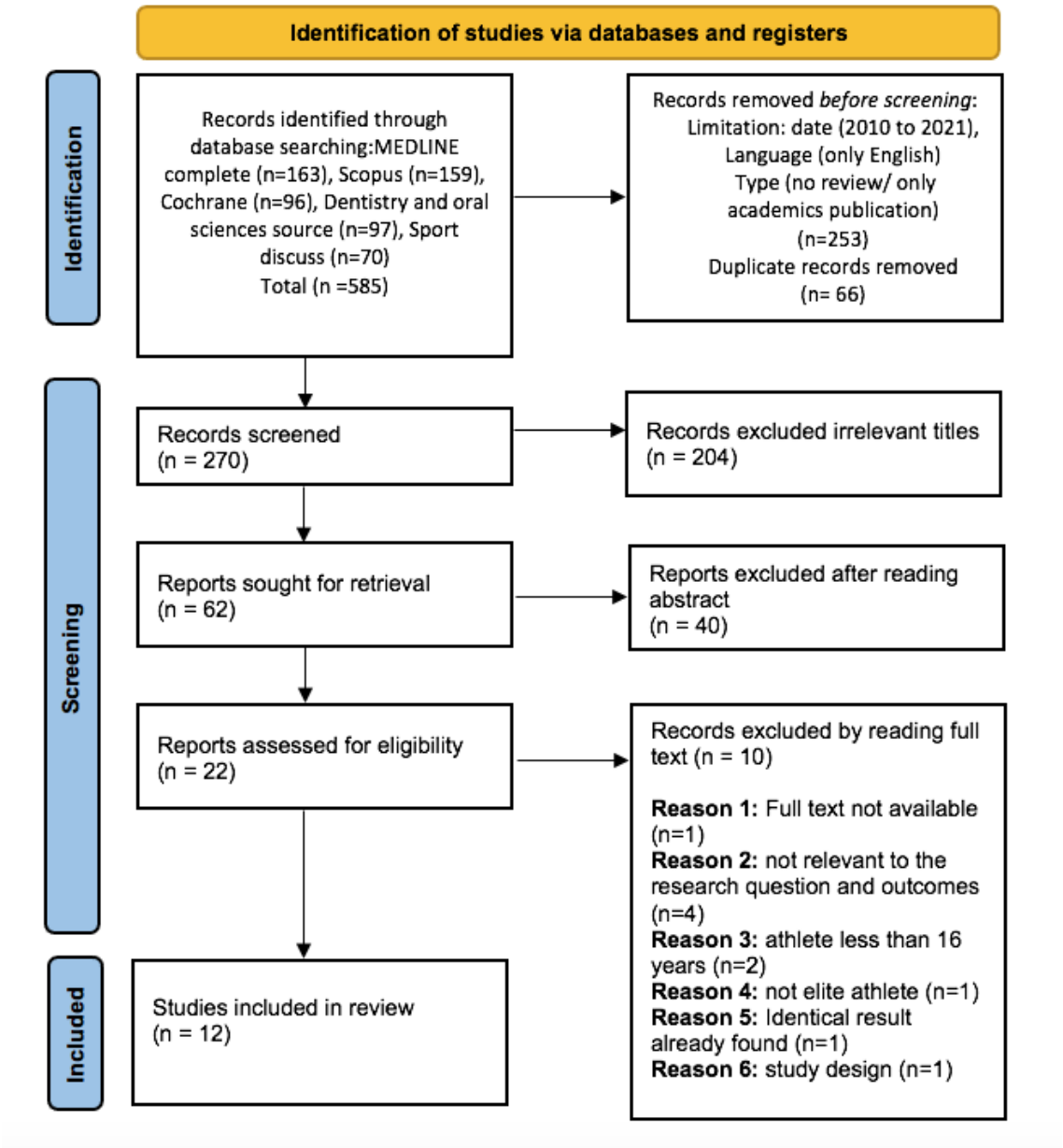
Two hundred and four articles were excluded form titles screening and forty after reading the abstract as they did not meet the inclusion criteria. Of the twenty-two studies retrieved for full text screening, we excluded a further ten after careful review, and twelve papers were included in the final analysis. The article selection process is illustrated in the PRISMA Flow Diagram (**Figure 1**).

Ten articles were excluded due to unavailable full text even after we sent a request, study design, not elite athlete, age range and further the inclusion criteria were optimized: salivary parameters and diet were no longer eligible for inclusion. Finally, twelve studies were eligible for the review. The reasons for their exclusion are reported in **Table 2**.

Table 2. *Characteristics of excluded studies.*

Botelho et al. 2021 (20)	Study design
Bryant et al. 2011 (21)	Focus on diet factor
D'Ercole et al. 2016 (22)	Focus on salivary parameter
Heaney et al. 2018 (23)	Focus on salivary parameter
Azodo et al. 2013 (24)	Not elite athlete
Tamea et al. 2020 (25)	Only talk about non carious cervical lesion
Gallagher et al. 2019 (26)	Result similar to another study by the same author
Márquez-Hidalgo et al. 2020 (27)	Full text unavailable
Cardoso al. 2020 (28)	Sample age range
Von Held et al., 2021 (29)	Sample age range

Figure 1. *PRISMA flowchart.*



4.2. Study characteristics

Twelve studies were included, eleven studies were descriptive cross-sectional studies, and one study was a Longitudinal observational study.

The age range, of the subject among all the studies reviewed, ranged from 16 to 65 years of age (mean 40.5 years). The twelve relevant studies that met the inclusion criteria are presented in **Table 3**.

To summarize all analyzed data, studies have been ranged according to: the age of participants, the type of sport practiced, the data source, the oral disease encountered and their impact on performances.

Out of the twelve studies included, eight studies examined the oral health impact on performances (30–37). Nine out of twelve studies aimed to determine the prevalence of different oral diseases among athletes, including several diseases in each article.

Table 3. *Summary of all included studies.*

Authors	Type of study	Subject	Age	Sport	Data source	Oral disease	Performance
Kazankova et al. 2020 (38)	Descriptive cross-sectional study	n=60	18-30 y	Soccer	Questionnaire and clinical examination	Caries Periodontal	-
Needleman et al. 2013 (31)	Descriptive cross-sectional study	n=278	16-47 y	25 sports	Questionnaire and clinical examination	Caries Periodontal Erosion Trauma Pericoronitis	Impact on performance
Gay-Escoda et al. 2011 (32)	Descriptive cross-sectional study	n=30	21 (± 1.6) y	Soccer	Questionnaire and clinical examination	Caries Periodontal Trauma	Relation with injury
Souzaa et al. 2012 (33)	Longitudinal observational study	n=15	18 ±0.93 y	Soccer	Clinical examination	-	Relation with injury
Needleman et al. 2016 (30)	Descriptive cross-sectional study	n=187	18-39 y	Soccer	Clinical examination	Caries Periodontal Erosion Trauma Pericoronitis	Impact on performance
Kragt et al. 2019 (39)	Descriptive cross-sectional study	n=110	25.84 (±5.82) y	-	Questionnaire and clinical examination	Caries Periodontal Erosion	-
Opazo-García et al. 2021 (40)	Descriptive cross-sectional study	n=6680	≥18 y	All sport	Dental examination	Caries Periodontal Abscess	-
Gallagher et al. 2018 (34)	Descriptive cross-sectional study	n=344	18-39 y	11 sports	Questionnaire and clinical examination	Caries Periodontal Erosion	Impact on performance
De la Parte et al. 2021 (41)	Descriptive cross-sectional study	n=186	24.74 ± 6.96 y	Individual and team sports	Dental examination	Caries Periodontal Erosion	-
Chantaramanee et al. 2016 (35)	Descriptive cross-sectional study	n=25	27.50 ± 4.72 y	Soccer	Questionnaire and clinical examination	Caries Periodontal Attrition	Impact on performance

Solleveld et al. 2015 (36)	Descriptive cross-sectional study	n=215	>16 y	Soccer	Questionnaire and clinical examination	-	Relation with Injury
Nascimento et al. 2015 (37)	Descriptive cross-sectional study	n=254	18-65 y	Triathlon	Questionnaire	-	Impact on performance

4.3. Risk of bias in studies

According to the longitudinal observational study (Souzaa et al. (33)), the overall risk bias was evaluated as low (**Table 3**), as a total of six stars were rated.

In most studies the quality rating in terms of the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was estimated by the author as fair to good (**Table 4**). Among the included descriptive cross-sectional surveys, quality was evaluated as fair for nine studies out of eleven studies (30–32,34,35,37–40) and good for two out of eleven (Solleveld et al.(36) and De la Parte et al. (41)).

	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration of outcome of interest absence at start of study	Comparability (most important factor)	Comparability (others factors)	Assessment of outcome	Sufficient follow-up	Adequacy of follow-up	Total
Souzaa et al, (33)	☆	☆	☆	-	☆	-	☆	-	☆	6

Table 4. *Assessment of the risk of bias of the non-randomized observational cohort study - Newcastle-Ottawa scale.*

	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations?	Was a sample size justification, power description, or variance and effect estimates provided?	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed? Association between exposure and outcome if it existed?	For exposures that can vary in amount or level, did the study examine different levels of the exposure?	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Was the exposure(s) assessed more than once over time?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Were the outcome assessors blinded to the exposure of participants ?	Was loss to follow-up after baseline 20% or less?	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Summary Quality
Needleman et al.(29)	✓	✓	NR	✓	X	✓	✓	✓	✓	CD	✓	NR	✓	X	i
Needleman et al. (28)	✓	✓	✓	✓	X	✓	CD	✓	✓	NR	✓	✓	✓	X	i
Gallagher et al. (32)	✓	✓	✓	✓	X	✓	NR	✓	✓	NR	✓	✓	✓	X	i
Gay-Escoda et al. (30)	✓	X	NR	NR	X	✓	✓	✓	✓	✓	✓	NR	✓	X	i
Chantaramanee et al. (33)	✓	✓	NR	NR	X	✓	✓	✓	✓	NR	✓	NR	✓	X	i
Solleveld et al. (34)	✓	✓	✓	✓	X	✓	✓	✓	✓	NR	✓	✓	✓	X	ii
Nascimento et al. (35)	X	✓	NR	NR	X	✓	X	X	✓	X	✓	✓	✓	X	i
Kragt et al. (37)	✓	✓	✓	✓	X	✓	NR	✓	✓	X	✓	✓	✓	X	i
Opazo-García et al. (38)	✓	✓	✓	✓	NR	✓	✓	✓	X	X	✓	✓	NR	X	i
De la Parte et al. (39)	✓	✓	✓	✓	✓	✓	✓	✓	✓	NR	✓	✓	✓	X	ii
Kazankova et al. (36)	✓	✓	✓	X	NR	✓	✓	✓	✓	NR	✓	✓	✓	NR	i

Table 5. *Quality assessment of the descriptive studies using the NIH quality assessment tool for cross sectional studies.*

4.4. Results of individual studies

4.4.1. Influence of oral health in physical performance

Of the eight articles that relate sports performance to oral health, five of them detailed the percentage of affectation on athletes' performance. The results were obtained through questionnaires by the athletes themselves, where an affectation in performance between 6.9% and 38.5% (mean 22.7%) was specified (**Table 6**).

The longitudinal study of Souzaa et al. (33) showed that for all soccer players, the overall baseline of creatine kinase was 342.4 U/L and augmented CK to 473.7 U/L immediately after training, however, 20 hours later it decreased to 364.3 U/L. There was no statistically significant difference in baseline CK levels between the groups with greater and lower bleeding on probing (377.4164.2 U/L and 311.8187.2 U/L, respectively; p=0.49). The repeated-measures general linear model revealed no

between-group differences (p=0.65), a significant change in CK with time (p=0.001), and no interaction between BOP and time (p=0.13). Overall, CK changed considerably between the first and second examinations (p=0.001) and between the second and third examinations (p=0.02). In all groups, CK alterations after exercise followed the same pattern, rising immediately after training and decreasing after 20 hours. However, only those with higher BOP saw a statistically significant drop in CK immediately after activity for 20 hours. There was a strong connection (r=0.51) between PPD and CK levels shortly following training. The connection between PPD and variations in CK concentration was found to be significant for changes from the immediate measurement to 20h (r =-0.57). Only variations in CK, such as from immediate measurement to 20h (r=-0.51) and baseline to 20h (r=-0.52), showed significant relationships with bleeding on probing.

Moreover, in Gay-Escoda et al. (32) literature, plaque index (PI) demonstrated a statistically significant correlation (p=0.022) (R=0.418) with intrinsic injuries (p=0.022) (R=0.418). Both PI and Ramfjord teeth probing pocket depth (PPD) revealed statistically significant association to muscle injuries (p=0.022 and p=0.032, respectively) (R=0.416 and R=0.392). However, no statistically significant correlations have been found between physical injuries and the DMF index or the other factors.

Solleveld et al. (36) study have demonstrated comparable crude odds ratios in connection to the reinjury factors. When examined as a continuous variable, SumDental exhibited statistically significant associations with all reinjury factors (adjusted odds ratios above 1.5). When compared to players without any of the oral health problems, players with two or all three categories of oral health problems had greater odds of having repeated exercise-associated muscle cramps (REAMC), muscle or tendon reinjury (MTR) and multiple types of reinjury (MR) (adjusted odds ranging from 2.48 to 3.40).

Needelman et al. (31) and Needelman et al. (30) related that oral health has a significant detrimental influence on well-being and performance, according to self-reported data. Respectively the reported that more than 45% (3) and 40% (6) of players were disturbed by their oral health, with 19.6% (3) and 28% (6) expressing an impact on

their quality of life and 6.9% (3) and 18% (6) reporting an impact on training or performance.

Chantaramanee et al. (35) article also showed that more than 40% of athletes were concerned about their dental health. Approximately 28% of all players reported that dental health had an influence on their quality of life. Almost one-fifth (18%) of them experienced oral health issues throughout training and performance. Nonetheless, poor oral health was not shown to be substantially associated to quality of life.

Gallagher et al. (34) study showed that overall, 32% (95% CI 27.3-37.1) reported a nonzero score for one or more sport performance impacts during the previous year with a difficulty participating in normal training and competition for 9% (95% CI 6.4-12.5), reduced training volume for 3.8% (95% CI 2.2-6.4), performance affected for 5.8% (95% CI 3.7-7.9), and oral pain for 29.9% (95% CI 25.3- 25.0).

Overall, 49.1% athletes (95% CI 43.9-54.4) reported a nonzero score for one or more psychosocial impacts in the previous year including: difficulty eating or drinking for 34.6 % (95 % CI 29.8- 39.8), difficulty relaxing and sleeping for 15.1% (95% CI 11.7- 19.3), difficulty smiling, laughing, or showing teeth without embarrassment for 17.2% (95% CI 13.5-21.5). The occurrence of dental caries and PUFA was linked to a nonzero difficulty eating score (p =.048) and (p =.027) respectively, relaxing (p =.001), difficulty engaging in regular training or competition (p =.002), mouth discomfort (p =.001), and ‘any sport performance impairment’ (p =.005). Association between dental health and psychological effects were reported such as pain. There were connections between relaxing and athletic performance impacts in terms of overall health condition. Several self-reported oral health problems were linked to athlete-reported impacts on well-being or sports performance due to current tooth pain (p =.001), sensitivity to hot or cold (p =.006), bleeding when cleaning teeth (p =.04), and history of swelling or pericoronitis (p =.001).

Ninety-eight out of 254 athletes related an association between oral health and performance in Nascimento et al. (37) study, which can lead to practice absence due to pain and/or bleeding, as 9 already missed practice due to this reason.

All the data about the impact of oral health on athlete's performances are presented in **Table 6**.

Table 6. *Impact of oral health on athletic performance.*

Author	Study design	Sample	Age	Sport	Data source	Influence of OH on athlete performance
Souzaa et al. 2012 (33)	Longitudinal study	n=15	Mean age 18y	Soccer	Periodontal examination blood samples for CK measurements	Correlation between periodontal disease and serum level of creatine kinase during training that may affect muscle metabolism
Gay-Escoda et al. 2011 (32)	Cross-sectional study	n=30	Mean age 21y	Soccer	Clinical examination and interviews	Correlation between plaque/gingival index and intrinsic/muscle injuries
Solleveld et al. 2015 (36)	Cross-sectional study.	n= 215	>16y	Soccer	Structured questionnaire	Correlation between poor OH and reinjury.
Needleman et al. 2013 (31)	Cross-sectional study	n=278	16-47y	25 sports	Questionnaire and clinical evaluation	18%
Needleman et al. 2016 (30)	Cross-sectional study	n=187	18-39y	Football	Oral health examination	6.9%
Gallagher et al. 2018 (34)	Cross-sectional study	n=344	Mean age 25y	11 sports	Questionnaire Dental screening	32.0%
Chantaramanee et al. 2016 (35)	Study design	n=25	Mean age 27y	Sport	Questionnaire and clinical evaluation	18%
Souzaa et al. 2012 (33)	Longitudinal study	n=15	Mean age 18y	Soccer	Questionnaire	38,5%

4.4.2. Diseases affecting the athletes' oral cavity

4.4.2.1. Prevalence of dental caries

Of the nine articles that relate the prevalence of caries, five of them detail the percentage of affectation on athletes. The results were obtained through dentist clinical examination, where they recorded a prevalence of between 20% to 84% (mean 52%) was specified (**Table 7** in Appendix 1).

Caries were examined in nine studies (71%) and recorded as Decayed Missing Filled Teeth (DMFT) or Decayed and filled teeth (DFT) and using the caries intensity index (CPI)

and International Caries Detection and Assessment system (ICDAS). There was a significant burden of disease in the athlete population.

Kazankova et al. (38) described caries levels in non-contact sports athletes, using the CPI index in three different groups. For the group composed of non-professional athletes, the CPI was 8.5 dominated by filled teeth. For the group of professional athletes the CPI was 9.0, the indicators caries and filled teeth were almost equal. For the control group, the index was 8, dominated by filled teeth.

Moreover, Needelman et al. (31) reported that more than half of athletes presented dental caries (55.1%) with 41% having irreversible dentine caries. In terms of extent, each athlete had an average of two teeth impacted by enamel or dentine caries (range 0–14). There were an average of 3.44 restored teeth per athlete (range 0–24).

Needelman et al. (30) also reported that 36.9% had at least one tooth affected by dental caries and that 84% of all footballers had at least one decayed or restored tooth (DFT=4.6). A correlation between dental caries and the age of the football player was showed; at the age of 16-24 years-old 77.9% had at least one decayed or restored tooth whereas at the age of 25-34 years-old the percentage was 92%.

Opazo-García et al. (40) found in their study that dental caries were often diagnosed with an average of 29% and athletics is the sport with the most prevalence.

Was stated in Gallagher J et al. (34) literature that among 344 athletes, 173 showed an established carious lesion in at least one tooth, and the median of teeth affected of those with caries was estimated as two. No association was shown between caries and age, however prevalence was higher in both rugby and football players.

Gay-Escoda et al. (32), De la Parte et al. (41), Chantaramanee et al.(35) and Kragt et al. (39) reported a great DMFT index (5.7 – 8.12 and 6.1 – 10.08 - 5.28) in their respective athlete population. Indeed, in Gay-Escoda et al. (32) literature, the average DMFT was 5.7. (SD 4.1). The mean active caries was 2.2 (SD 3), the filled component was 2.9 (SD

3.1), and the missing component was 0.6. (SD 1.0). The average PI score was 2.3 (SD 1.1), the average GI score was 1.1 (SD 0.8), and the average PPD score was 1.9. (SD 0.3). Pearson's analysis revealed a positive association between PI and GI. However, no relationship was found between PPD and PI or GI.

On the other hand, in De la Parte et al. (41) paper, they compared individual sports and team sports players. Individual modalities players had had a larger number of decaying teeth, missing teeth, and a higher DMFT index (p 0.05) compared to team player.

Kragt et al. (39) described that 60 out of 111 athletes had a high DMFT (5.28) and it described the relationship between DMFT scores and the frequency added to the duration of practicing sport. In fact, athletes performing more than 20 hours of sport a week tended to have a higher DMFT score than athletes that did less than 20 hours per week.

All the data about the prevalence of caries and their scores are presented in **Table 7** (Appendix 1).

4.4.2.2. Prevalence of periodontal diseases

Ten of the included articles specified the percentages of periodontal involvement suffered by professional athletes. Periodontal disease was described between 11.2% and 81% (mean 35.6%). Gingivitis was described between 21.6% and 80% (mean 56.9%) and periodontitis between 0.9% and 40.9% (mean 20.2%).

Kazankova et al. (38), showed that the most significant alterations in periodontal condition were found in professional athletes, where eleven athletes (55%) had chronic catarrhal gingivitis, eight (40%) had widespread early periodontitis, and one (5%) had intact periodontal disease. The median value of the PMA index was 34.5%, indicating that the majority of the sample had moderate to severe gingivitis. More intense inflammatory events were associated with a greater reduction in capillary resistance

markers. The periodontal index (PI) was 1.95 points, corresponding to the moderate stage of the disease.

This study has also examined the periodontal status of non-professional athletes. The findings indicated chronic catarrhal gingivitis in 12 (60%) participants, moderate generalized periodontitis in 5 (25%) respondents, and complete periodontitis in 3 (15%) subjects. The PMA index had a median value of 20.5% and the periodontal index (PI) indicated a moderate state of illness, 1.6 points.

Finally, the periodontal state of the control group was also analyzed and 10 (50%) exhibited symptoms of chronic generalized gingivitis, 3 (15%) had generalized early periodontitis, and 7 (35%) had good periodontal examination results. Inflammatory phenomena in periodontal tissues were less prominent in this group; the PMA index was 13% at the time of inspection, the bleeding index was 0.95 and the PI was 1.15.

Needelman et al. (31) related an uncommon good periodontal health. Indeed, gingivitis (basic periodontal examination (BPE) codes 1–2) was found in more than three-quarters of athletes, and irreversible periodontitis (BPE codes 3–4) was found in more than 15% of athletes. In terms of extent, gingivitis or periodontitis impacted at least half of the mouth in 76 percent and 8.3 percent of athletes, respectively.

Moreover, Needelman et al. (30) reported that gingivitis (BPE codes 1–2) was found in more than 80% of football players and irreversible periodontitis (BPE codes 3–4) in 5%. In terms of extent, 76.7% of football players had gingivitis in at least half of their mouth.

Excellent periodontal health (BPE code 0 as the poorest result) was identified in 1.1% (95% CI 0.3-3.0) athletes in Gallaghe et al. (34) study. Gingival bleeding on probing and calculus or other plaque retentive variables were found in 77.3% (95% CI 72.6-81.3) of athletes, with a pocket probing depth of 4 mm (BPE code 3 or 4) in a further 21.6 % (95% CI 17.6-26.2). In terms of magnitude, 87.5% of athletes (95 % CI 83.3-90.3) had a BPE score of at least 1 in three or more sextants.

Gay-Escoda et al. (32) The average GI score was 1.1 (SD 0.8), and the average PPD score was 1.9. (SD 0.3). There was no link found between PPD and PI or GI.

The Dutch Periodontal Screening Index was used to measure periodontal health (DPSI) in the study carried by Kragt L et al. (39). The DPSI Index is based on periodontal health and pocket depth, and the mean SD DPSI-score was 2.0±0.73

Chantaramanee A et al. 2016 (35) have found in their study that 30% of athletes had periodontitis.

According to the Opazo-García et al. (40) study, athletes that came from their home nation with pre-existing oral disorders, the most common of which were periodontal diseases (34%). Periodontal affections (ICD: K05, K050, K051, K53, K055, 056) were created to classify various periodontal illnesses based on severity and chronicity.

In the article of De la Parte A et al. (41) they compared Individual sports and team sports players. The presence of periodontal plaque and the sports modality had a significant connection (p=0.05). Individual sports modality athletes had worse oral hygiene and a higher proportion of periodontal plaque. Individual sports comprised 72 athletes, with 39.2% having periodontal pockets, while team sports comprised 112 athletes, with 36.6% having periodontal pockets. On the other hand in the Chantaramanee A et al., 2016 (35) article, around 30% had periodontal pockets.

All the data about the prevalence of periodontal disease and their scores are presented in **Table 8** (Appendix 1).

4.4.2.3. Prevalence of other oral diseases

Five of the articles described the degree and percentage of dental erosions. The most frequent erosion grades were grades 2 and 3, ranging from 7.2 to 53.1% (mean 35.4%) of professional athletes.

About five articles reported dental erosion (30,31,34,39,41). First, Needelman et al. (31) and Needelman et al. (30) related dental erosion in 44.6% of athletes and 53.1% of football players respectively. In fact, Needelman et al. (31) showed that the erosion was comparably distributed in the anterior (37.6%) and posterior areas (48%) with a severity of the most affected tooth between moderate to severe (grade 2–3). Moreover, in the Needelman et al. (30) study the severity of the most affected tooth was also between moderate to severe (grade 2–3) in 20.9% of anterior teeth and 20.6% of posterior teeth.

De la Parte et al. (41) showed in their study, in individual sports (n=74) 68.9% had dental erosion and in team sports the prevalence was of 55.4%.

The basic erosive wear evaluation index was used to measure tooth erosion (BEWE) in Kragt et al., 2016 (39) literature. On a four-level scale, the BEWE notes the most severely eroded teeth in each sextant. The scores of each sextant are added together to get the total BEWE-score, which can vary from 0 to 18. The median BEWE-score was 2.0 (0.0-10.0), and erosion was seen in eight athletes (7.2%).

Gallagher et al., 2019 (34) showed 41.4% of athletes (95% CI 37.0-47.3) have ETW, with a gender difference (48.7% men and 28.4% women) had a BEWE score of 7 (P.001). Forty-one athletes (11.7%; 95% CI 8.7-15.5) had a severity scored between 9 and 13. ETW was most common in football (73.1%; 95% CI 53.7-86.5) and least common in sailing (26.7%; 95% CI 10.5-52.4) and rowing (26.7%; 95% CI 17.0-39.1). ETW varied between mixed sports (51.6%; 95% CI 43.9-59.2) and endurance sports (35%; 95% CI 27.6-43.1).

Four of the articles described some type of trauma with orofacial involvement, between 10.8% and 40% (mean 35.4%). The most frequent were TMJ trauma (40%) followed by dental trauma (23.3%).

In the studies of Needelman et al. (31) and Needelman et al. (30), 30% and 21.7% of athletes have reported respectively a history of previous orofacial trauma due to sport. The face and lips were the most common sites affected and among the 30%, 17.6%

athletes presented new trauma of which 32.7% were using mouthguards. Whereas, De la Parte et al. (41) study have shown a less percentage, in individual sports composed of 72 athletes 10.8% suffered trauma against 17% for team sport composed of 112 athletes.

40% of athletes had sustained direct TMJ trauma, as was reported by Gay-Escoda et al. (32). It showed that the most prevalent traumatic injury was uncomplicated crown fractures of the maxillary central incisor (23.3%).

The infection around the wisdom teeth, also called pericoronitis were documented at the time of clinical evaluation in 9.9%, 3.2% and 1.1% of athletes population respectively in Needleman I et al. (31), Needleman et al. (30) And Gallagher et al. (34) studies. And during the previous 12 months, 23.3% swelling/infection around wisdom teeth was recorded by Gallagher et al. (34).

PUFA, (open pulp, ulceration, fistula, abscess) have been found at least in one tooth in 7.8% and 3.4% in two article Needleman et al. (30) and Gallagher et al. (34) respectively.

One study by Gay-Escoda et al. (32) have shown that professional soccer players had a prevalence of 30% of bruxism and has shown that 30% of athletes had malocclusion due to uncorrected deviation during vertical jaw opening in 16.7%, and discomfort during TMJ palpation in 6.7%. 60% had class I angle occlusion, 20% had class III angle occlusion, and the same number had Class II occlusion. Chantaramanee et al. (35) also diagnosed its athlete with a prevalence of 10% of malocclusion.

All the data about the prevalence of other oral disease and their scores are presented in **Table 9** (Appendix 1).

5. DISCUSSION

5.1. Impact of oral health on athlete's performance

The main finding was that all the research expressed a clear negative impact of oral health, in training routines and performance. The correlation discovered between poor dental health, well-being and performance might be explained by discomfort and difficulties with eating, drinking, and sleeping caused by caries.

The data source for the impact of poor oral health on performance, from most studies were questionnaires, therefore the results were obtained by self-report answers from the athletes. Another more reliable data source was obtained by the evaluation of oral clinical parameters associated with physical parameters of performance. In fact, Gay-Escoda et al. (32) and Souzaa et al. (33) research, reported that periodontal clinical indicators were correlated to muscle injuries or serum creatin kinase levels. These findings focus on the physiological microlesions caused by physical exercise, implying that the oral health status may have a significant impact on the muscle inflammatory response. Gay-Escoda et al. (32) literature, observed a statistically significant correlation between plaque index and Ramfjord teeth probing pocket depth with intrinsic muscle injuries.

Souza et al. (33) presented preliminary evidence to support the influence of periodontal status on blood levels variations of a muscle damage marker. Serum CK levels can be used to assess the functional status of muscle tissue under various physiological and pathological situations. An increase of this enzyme might be a sign of cellular necrosis or muscle tissue damage. Athletes, for example, have greater CK levels than non-athletes due to increased muscle mass and extensive daily exercise. PPD and BOP were shown to be related to CK alterations after exercise. Furthermore, periodontal inflammation appeared to have a bigger influence on changes in CK after exercise in athletes with higher periodontal inflammation. Moreover, there were strong association between depth of probing and bleeding probing with changes in CK levels throughout training. These findings provided early evidence for a link between oral and muscle

health in young Brazilian soccer players, and they highlighted the need for interventional research to assess the impact of improved periodontal health on muscle injury biomarkers. One disadvantage of this study (33) is the minimal number of participants which may suggest a lack of statistical power in this observed borderline p values.

Supporting our results, Alshail et al. (42) revealed that soccer players with periodontal problem showed higher serum creatin kinase levels than individuals who did not have this condition. Similarly in their study, Botelho et al. (20) compared self-reported muscle and articular injuries based on periodontal health and found that players with periodontitis had a larger percentage of non-traumatic muscle injuries (55.6%) than players without periodontitis (38.4%), albeit this difference in proportion was not determined to be significant ($p = 0.429$). Similarly, players with periodontitis had a larger percentage of articular injuries (22.2%) than players without periodontitis (7.2%), although this difference was not statistically significant ($p = 0.329$).

To achieve a high level of performance, elite athletes must be disease-free. However, providing great dental care to high-level soccer players is a difficult undertaking given to the multiple tournaments that do not allow for sufficient preparation of healthcare decisions. Oral examinations before the start of the season, as well as monthly follow-ups by dentists, are critical for preventing the onset of caries, periodontal disease, and other oral diseases, as well as tooth trauma. As of today, it is not always the case among high-level professional athletes until today (32) .

The results of Solleveld et al. (36) preliminary study uncovered associations between poor dental health and the forms of reinjury investigated in this study, including repeated exercise-related muscular cramps, muscle or tendon reinjury, and numerous types of reinjury. These associations remained after managing for injury anxiety, psychophysical stress, unhealthy eating habits, dissatisfaction with trainer/team, age, and player position. These findings highlight for a more in-depth investigation of the impact of poor oral health on the risk of reinjury while playing elite soccer. Self-report questionnaires were used to assess oral health, which reported that the plaque index

and probing pocket depth were related to muscle damage in professional male soccer players.

Solleveld et al. (36) supports these findings with research demonstrating that poor oral health is related with persistently higher levels of IL-6 and other cytokines, that these chronically higher levels of IL-6 and other cytokines are related with fatigue, and that fatigue is a substantial not only a risk factor but is a requirement for (re)injuries. As a result, repeated exercise-associated muscle cramps (REAMC) were related to both player position and Sum Dental, indicating that both physical activity and poor dental health are linked to the development of muscle tiredness.

The occurrence of muscle and/or articular injuries was self-reported by each athlete up to 6 months previous to oral observation in Botelho et al. (20) paper. They compared self-reported muscle and articular injuries according to periodontal status and it was demonstrated that athletes with periodontitis had a greater rate of non-traumatic muscle and articular injuries than those without periodontitis, however this difference was not proven to be statistically significant ($p = 0.429$ and $p = 0.329$, respectively). The proportion of fat mass, muscle mass, muscle mass index, and total adipose folds all showed a significant moderate connection with clinical attachment loss, periodontal pocket depth, and periodontal epithelial surface area. These findings are intriguing and may be related to the previously demonstrated association of periodontal measurements and indicators of muscle damage. However, the reader should keep in mind that the small sample size and lack of reliable muscle and articular damage measurements restrict the validity of such findings. Future research is needed to determine whether an ongoing state of periodontal inflammation and destruction is a risk factor for muscle injuries or vice versa, whether an injury may cause psychological impairment affecting motivation and self-care, and whether treatment may mitigate such hypothetical risk (20).

Nascimento et al. (37) paper assessed that only 98 out of 254 athletes relate the importance of oral health care to performance. Most of them do not brush their teeth

after the activities, leaving the oral environment more susceptible to the onset of periodontal disease and caries, which can decrease their performance.

Chantaramanee et al. (35), Needleman et al. (31) and Needleman et al. (30) reveled 40-45% of athletes bothered by their oral health, about 20-28% of them reported that oral health impact on quality of life and 7-18% suffered from oral health problems on training and performance. Dental caries, acute pain in the mouth, history of wisdom tooth swelling/infections, and tooth sensitivity were statistically substantially associated with self-reported impacts. The primary restriction of the study was that we utilized six examiners to collect data (30). They discovered a substantially larger influence on training and performance (18%), which might be due to differing techniques or variations in perception of the impact of dental health. However, the method used to measure these effects was a basic three-question form that may lack sensitivity in identifying effects, implying that the real incidence and severity are higher (31).

Gallagher et al. (34) identified a relationship between oral health issues and poor performance. Overall, 32.0% of athletes reported an oral health-related influence on sport performance, mostly related to oral health status and psychological consequences such as dental pain, which causes difficulty participating in regular training and competition, lower performance, and reduced training volume. Other effects included trouble eating, relaxing, sleeping, and smiling. This study offers various advantages. This is one of the largest studies on oral health in sport, with 352 athletes recruited, and is the most methodologically rigorous study to examine oral health and related self-reported performance impacts in elite athletes across diverse sports. We accomplished a 75-100% sample in each team/sport, with track and field being the sole outlier at 26%. All examinations were performed by a single experienced dentist who used clinically specified and reliable self-reported outcome measures.

All these findings were consistent with two prior systematic reviews, Ashley et al. (43) and Souza et al. (44) that found an association between oral health and physical performance in athletes, implying that poor dental health had a detrimental impact on

athletes' self-reported training and performance. There is, however, insufficient information to measure this impact.

5.2. Prevalence of oral diseases in athlete's oral cavity

The present systematic review assessed the prevalence oral diseases and their influence on athlete's performance. There were high levels of oral disease in elite athlete, including dental caries, dental erosion and periodontal disease (30,31,34,39,41). The oral health of athletes appears to be poor across a wide range of sports.

In their systematic review published in 2015, Ashley et al. (43) have stated the same conclusions, as their main finding is that, in contrary to popular belief, sportsmen have poor oral health. There was a considerable disease prevalence in the athletic population. Where caries was documented as a percentage, it varied from 15% to 75% of all athletes which is similar the result of our systematic review that varied from 20% to 84%.
However, the described frequency of caries in the general population is 29.4% (45). Likewise, Needleman et al. (31) recorded that more than half of the athletes had dental caries and a study of soccer players reported that 37% of them had active tooth decay (30). Previous research on the DMFT index found greater levels among competitive soccer players compared to the sedentary population (30,32,43). Other oral issues faced by athletes included periodontal disease, tooth erosion, and dental trauma (43) which appears, similar as in the present review.

Although, in Ashley et al. (43) systematic review only limited data were reported due to the limited study sample sizes (n=18–34), the oral health in these studies was also poor.

In one included study, Gay-Escoda et al. (32), sought to compare the DMF index of professional football players, who have extremely stringent health care, with dentistry and medical students from the University of Barcelona, who all live in the same geographical region, are of comparable age, and are aware of the importance of health care. The DMF index was higher among players (5.9), than compared to dentistry

students and medical students (5.0 and 3.4). Same results were obtained for mean active caries (2.2 in soccer players vs. 1.2 and 0.9 in medical and dental students, respectively). This result can be explained by the fact that dental students are more susceptible to caries treatment.

In addition, a published report concluded that soccer players on an elite level may have a somewhat higher risk of developing caries than non-players (46). Similarly, in their systematic review published in 2020, Azeredo et al. (47) also estimated a high prevalence of dental caries in athletes, and particularly in athletes from developing countries.

Needelman et al. (30) and Gallagher et al. (34) both reported a high prevalence of carious lesion among athletes, however they had a discrepancy with the correlation between dental caries and the age of athlete. Needelman et al. (30) showed a correlation between dental caries and the age of the football player was showed, whereas no association was shown in Gallagher et al. (34) study.

Kragt L et al. (39) has reached a hypothesis that conducting sports increases the risk to poor oral health as they found higher DMFT-score among athletes doing more sports. However, because this comparison has never been done before in the literature, the results are difficult to compare.

According to Ashley et al. (43), the prevalence of mild irreversible periodontal disease was found to be up to 15% and gingivitis was up to 76% in elite athletes. Kragt et al. (39) found that Olympic athletes had a Dutch periodontal screening index score of 1.71 +/- 0.73, which was similar to the presence of tooth plaque. Furthermore, Gay Escoda et al. (32) discovered a relationship between periodontal plaque and gingivitis.

Generally, when periodontitis information was available, the prevalence appeared to be fairly low compared to gingivitis, whose, on the other hand, is quite frequent among professional athletes (30,31,39). However, Kazankova et al. (38) study have shown small

difference in prevalence for gingivitis and periodontitis and Botelho et al. (20) found an alarming prevalence of periodontitis but with the majority at stage I.

Kazankova et al. (38) have compared non-professional athletes, professional athletes and a control group not engaged in sports. For gingivitis the results were relatively similar, although periodontitis showed greatest deviations in professional athletes.

In the literature reviewed by De la Parte et al. (16), there was a strong association between the sports modality and the presence of periodontal plaque. Athletes practicing individual sports modalities presented a worse oral hygiene with a higher proportion of periodontal plaque.

In the current review, five articles related dental erosion in athletes (30,31,34,39,41) with a high prevalence. In their systematic review published in 2015, Ashley et al. (43) have stated the same conclusions as the proportions of athletes with tooth wear were high, ranging from 36% to 85%. Moreover, the data reported by the Frese et al. (48) study, strengthened the association between sports exercise and dental erosion as endurance training influenced saliva flow rate and pH during exercise. The elite athletes with the highest dental erosion were soccer (73.1%) and less in sailing and weightlifting (26.7%) due to pressure, and swimmers due to the low pH (34,49).

Two studies (30,31) showed a prevalence of 30% and 21.7% of athletes that reported respectively a history of previous orofacial trauma due to sport with the face and lips the most common sites affected with TMJ (40%) and uncomplicated crown fractures of the maxillary central incisor (23.3%) (32). Another study has reported that in individual (10.8%) athlete suffered less trauma than in team sport (17%) (41). Compared to their systematic review, Ashley et al. (43) revealed that Trauma was reported in the majority of studies (82% of all included studies) and as primary outcome in 56% of studies.

The infection around the wisdom teeth, also called pericoronitis was not the most prevalent oral disease in our reached as the records evaluated 9.9% (31), 3.2% (30) and 1.1% (34) of athletes suffering from. Additionally, Ashley et al. (43) review reported

pericoronitis or impacted third molars in five of her articles where athletes were required to remove one or more wisdom teeth (range, 4.6–39%). In the study of Botelho et al. showed that only one athlete from their sample had an implant and he was diagnosed with as peri-implantitis.

Bruxism and malocclusion were also prevalent in athletes with similar relevance.

The International Olympic Committee has declared that athlete's health needs to be prioritized and international sporting organizations encourage a comprehensive approach to ensure athlete wellness and performance (16). Given the importance of oral health in general health and well-being, athletes' performance must be improved via health promotion. Oral examination and periodic follow-up are essential parts of the preventive program since they help to identify caries lesions and reduce the onset of caries, periodontal disease, and other oral diseases that have an impact on sports performance.

Dentists play an essential role for prevention of oral diseases and can enhance a behavioral within different elite sport environments. It can be related to increased athlete oral health knowledge, improved oral health behavior, decreased self-reported performance effects, and high participant retention (4). There is an urgent need for effective integration of sports dentistry into sports medicine, research on the impact of the stomatognathic system on body exercise and raising awareness of the importance of oral health in sports among athletes, health professionals, sports federations, and medical centers (17).

The strength of the present review is that it studied for the first time the prevalence of oral disease, together with their direct impact on elite athlete performance.

5.3. Limitations

The limitations of this study should be explained in order to accurately understand the results. The majority of the review's shortcomings are directly connected to the

constraints of the included research. The limitation was due to the rate of heterogenicity in the included studies, for the interpretation thereof should be considerate. Mainly in the data collection variables (self-reported questionnaire and clinical data) and the measurement of the impact of these oral pathologies on sports performance.

For future investigation, standardization of protocols is recommendable to increase the quality in the papers about this topic. It is required to conduct epidemiological studies on representative athletes with experienced examiners and validated outcome measures to analyze the scale of the issue of poor oral health and examine the potential influence on performance using objective performance metrics.

6. CONCLUSIONS

To conclude, apart from the limitations,

- This study observed an association between poor oral health and athletics performance of elite athletes.

- The athletes oral health was strongly affected with a high degree of dental status disorders. The most prevalent were caries followed by periodontal diseases, erosion and trauma.

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APPENDIX 1

Table 7. *Prevalence of caries in athletes.*

Authors	Type of study	Subject	Age	Sport	Data source	Caries prevalence (N° cases)	CPI[1]	DMFT[2]	DFT[3]	ICDAS[4]
Kazankova et al. 2020 (38)	Cross-sectional	n=60 Group 2 (n=20) Professional athletes	18-30y	Soccer	Questionnaire Clinical examination	-	9.0 (7.75-10.25)	-	-	-
Needleman et al. 2013 (31)	Cross-sectional	n=278	16-47y	25 sports	Clinical examination and history	55.1%	-	-	-	-
Needleman et al. 2016 (30)	Cross-sectional	n=187	18-39y	Soccer	Questionnaire Clinical examination	36.9%	-	-	4.6	-
Gallagher et al. 2018 (34)	Cross-sectional	n=344	18-39y	11 sports	Questionnaire Dental examination	-	-	-	-	49.1% code ≥3
Gay-Escoda et al. 2011 (32)	Cross-sectional	n=30	Mean age 21y	Soccer	Questionnaire Clinical examination	-	-	5.7 Active caries: 2.2	-	-
Kragt et al. 2016 (39)	Cross-sectional	n=110	Mean age 25.84y	All sport	Questionnaire Dental examination	20%	-	15% of athlete have DMFT >10	-	-
Opazo-García et al., 2021 (40)	Cross-sectional	n=6680	≥18y	All sport	Dental examination	29%	-	-	-	-
De la Parte et al. 2021 (41)	Cross-sectional	n=186	Mean age 24.74y	Individual and team sports	Dental examination	-	-	Individual: 8.12 ± 3.56 Team: 6.10 ± 3.63	-	-
Chantaramanee et al. 2016 (35)	Cross-sectional	n=25	Mean age 27.50y	Soccer	Clinical evaluation and Questionnaire	84%	-	10.08	-	-

[1]caries intensity index
[2]Decayed, missing, or filled teeth.
[3]Decayed and filled teeth.
[4]International Caries Detection and Assessment system.

Table 8. *Prevalence of periodontal diseases in athletes.*

Authors	Type of study	Subject	Age	Sport	Data source	Periodontal disease	Gingivitis	Periodontitis	PMA[1]	GI[2]	PPD[3]	BPE[4]	Periodontal pocket [5]
Kazankova et al. 2020 (38)	Cross-sectional	n=60	18-30y	Soccer	Questionnaire Clinical examination	-	*Group 1: 60% **Group 2: 55% ***Group 3: 50%	Group 1: 25% Group 2: 40% Group 3: 15%	Groupe 1: 20.5% Group 2: 34.5% Group 3: 13%	-	-	-	-
Needleman et al. 2013 (31)	Cross-sectional	n=278	16-47y	25 sports	Clinical examination and history	-	75%	15%	-	-	-	-	-
Needleman et al. 2016 (30)	Cross-sectional	n=187	18-39y	Soccer	Questionnaire Clinical examination	-	80%	5%	-	-	-	-	-
Gallagher et al. 2018 (34)	Cross-sectional	n=344	18-39y	11 sports	Questionnaire Clinical examination	-	-	-	-	-	-	BPE score 1 or 2: 77% BPE score 3 or 4: 21.6%	-
Gay-Escoda et al. 2011 (32)	Cross-sectional	n=30	Mean age 21y	Soccer	Questionnaire Clinical examination	-				1.1	1.9	-	-
Kragt et al. 2016 (39)	Cross-sectional	n=110	Mean age 25.84y	All sport	Questionnaire Clinical examination	-	21.6%	0.9%	-	-	-	-	-
Opazo-García et al. 2021 (40)	Cross sectional	n=6680	≥18y	All sport	Questionnaire Clinical examination	34%	-	-	-	-	-	-	-
De la Parte et al. 2021 (41)	Cross sectional	n=186	Mean age 24.74y	Individual and team sports	Dental examination	-	-	-	-	-	-	-	Individual: 39.2% Team: 36.6%
Chantaramanee et al. 2016 (35)	Cross-sectional	n=25	Mean age 27.50	Soccer	Questionnaire Clinical examination	-	-	-	-	-	-	-	30%

*Group 1:Non-professional athletes.
**Group 2: Professional athletes.
***Group 3: Not engaged in sports.
[1]Papilla, Marginal gingiva and attached gingiva index.
[2]Löe & Silness gingival index.
[3]Ramfjord teeth probing pocket depth.
[4]Basic periodontal examination.
[5]Basic periodontal examination.

Table 9 *Prevalence of other oral diseases in athletes.*

Authors	Type of study	Subject	Age	Sport	Data source	Dental erosion	Trauma	Others
Needleman et al., 2013 (31)	Cross-sectional	n=278	16-47y	25 sports	Clinical examination and history	44.6% grade 2–3	30% history of trauma 17.6% New trauma	9.9% Pericoronitis 11.8% Unhealthy oral mucosa
Gay-Escoda et al., 2011 (32)	Cross-sectional	n=30	Mean age 21y	Soccer	Questionnaire Clinical examination	-	40% TMJ trauma 23.3% uncomplicated fractures of the maxillary central incisor	30% bruxism 30% soft tissue laceration 30% severe malocclusion
Needleman et al., 2016 (30)	Cross-sectional	n=187	18-39y	Soccer	Clinical examination	53.1% (grade 2–3)	21.7% history of orofacial trauma	3.2% pericoronitis 7.8% at least one **PUFA
Kragt et al., 2016 (39)	Cross-sectional	n=110	Mean age 25.84y	All sport	Questionnaire Clinical examination	7.2%	-	21.6% need 3rd molar extraction
Opazo-García et al., 2021 (40)	Cross sectional	n=6680	≥18y	All sport	Questionnaire Clinical examination	-	-	3% chronic periapical abscess 4% salivary gland mucocele
Gallagher et al., 2019 (34)	Cross-sectional	n=344	18-39y	11 sports	Questionnaire Clinical examination	41.4% *ETW	-	23.3% pericoronitis in last 12 months 3.4% at least one PUFA
De la Parte et al., 2021 (41)	Cross-sectional	n=186	Mean age 24.74y	individual and team sports	Dental examination	Indiv:31% Team:44.6%	Individual: 10.8% Team: 17%	-
Chantaramanee et al., 2016 (35)	Cross-sectional	n=25	Mean age 27.50y	Soccer	Questionnaire Clinical examination	-	-	10% with severe malocclusion 60% dental attrition

* erosive tooth wear
** Pulp, Ulceration, Fistula, Abscess index

APPENDIX 2

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Front page
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	13
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	13
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	15-16
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	16
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	16-17
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	18
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	18
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	18-19
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	18-19
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	19-20
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	19
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	X
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	X
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	X
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	X
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	X
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	X
Reporting bias	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	X

Section and Topic	Item #	Checklist item	Location where item is reported
assessment			
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	X
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	21-22
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	21
Study characteristics	17	Cite each included study and present its characteristics.	22-24
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	24-25
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	25-34
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	X
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	X
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	X
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	X
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	X
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	X
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	35-42
	23b	Discuss any limitations of the evidence included in the review.	42-43
	23c	Discuss any limitations of the review processes used.	42-43
	23d	Discuss implications of the results for practice, policy, and future research.	43
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	X
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	X
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	X
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	X
Competing interests	26	Declare any competing interests of review authors.	X
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	X

APPENDIX 3

INTERRELATION BETWEEN ELITE ATHLETES' PERFORMANCE AND ORAL HEALTH: A SYSTEMATIC REVIEW.

RUNNING TITLE: Oral status and athletic performance.

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ABSTRACT

Objective: Oral health is as essential to an athlete's successful sporting performance, as regular exercise and proper diet. The objective of this study was to evaluate the oral health of professional athletes to determine its relationship to athletic performance, as well as to describe the most common oral diseases affecting the oral cavity of athletes.

Methods: A systematic search and review of multiple databases was conducted using PRISMA guidelines to identify studies that reported the association between oral health and the physical performance of athletes. Papers were included if they evaluated the oral health of professional athletes. The methodological quality of papers was evaluated using a modification of the Newcastle-Ottawa scale for longitudinal observational studies and NIH quality assessment tool for descriptive cross-sectional studies.

Results: A total of 585 articles were initially retrieved from the systematic search of the literature. Of these, a total of 12 articles following the inclusion criteria were included in this systematic review. The impact on sport performance due to poor oral hygiene in professional athletes was described between 6.9% and 38.5% (mean 22.7%). The prevalence of caries and periodontal diseases were recorded between 20% to 84% (mean 52%) and between 11.2% and 81% (mean 35.6%) respectively. Other orofacial affectations were trauma to the TJM from 7.2% to 53.1% (mean 35.4%) and dental erosions between 10.8% and 40% (mean 35.4%).

Conclusion: This study observed an association between poor oral health and a decrease in performance of elite athletes. Professional athletes' oral health was shown to be strongly affected with a high degree of dental status disorders in which the most common were caries followed by periodontal diseases, erosion and trauma.

Keywords: 'elite athlete', 'professional athlete', 'performance', 'caries', 'periodontal diseases', 'gingivitis', 'periodontitis', 'erosion'.

INTRODUCTION

Nowadays, there is a growing interest that dental health is achieving in sports, especially when dealing with professional and elite sports. Since the first report from the 1968 Olympic Games, many studies have consistently reported poor oral health in elite athletes (1). Dental consultations accounted for 30% of all medical visits at the London 2012 Summer Olympic Games and were only second to musculoskeletal injury (2). Poor dental health is a major concern since it has a direct influence on one's quality of life, confidence, appearance, socialization and generate a systemic inflammatory response (3) which potentially, has an effect on athletic performance and training, resulting in poor competition preparation. Overall, oral health that can be affected in athletes such as dental caries, dental erosion, periodontal disease and pericoronitis or impacted third molar are the main causes of poor oral health. Indeed, Athletes are a population that is especially prone to various oral health diseases, which are worsened by sports-related oral health risk factors due to the physical demands of exercise and training on the human body (4). These risks include hyposalivation and eating habits during physical training, dental traumatology, high-intensity exercise, self-medication, and a neglect of prioritization of oral health. The knowledge and identification of these oral health risks factors that can affect high-performance sports performance is important in the management of active patients, to improve oral health, and therefore the systemic health, as well as the results in sporting tests. Hence, it seems interesting to conduct this systemic review to explain the underlying relevant role that oral health may play in sports performance. Understanding which are the most prevalent oral pathologies in elite athletes and how it relates to their athletic performance can help them in their career goals, as well as have a direct impact on the level of quality of their overall systemic health.

MATERIAL AND METHODS

This study was conducted following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (5) and was later registered in PROSPERO (ID:330001).

Focused question

This systematic review was conducted using the available literature to answer the focused question: 'How does oral health impact the sports performance of professional athletes and what are the most common oral diseases in elite athletes?'.

Selection criteria

To be included in the review, the studies had to meet all the following criteria: published between 2010 and 2021 in order to concentrate on latest data, gain more reliability, and provide conclusions that match the current situation; Language restricted to English; Exclusively human studies; With the following study designs: Randomized clinical trials, Cohort studies, Case-control studies, Descriptive studies; Only athletes. Have been excluded studies were sample weren´t professional athlete, or less than 16 years-old.

Search strategy

The search was performed through MEDLINE complete; Scopus; Cochrane Library; Dentistry and Oral Sciences Source; Sport Discuss and ESBCO CRAI José Planas. The following search terms were applied as follows: (oral health or oral hygiene or dental health or dental care or oral care) AND (athletes or sports or athletics or elite athletes or professional athletes) AND (saliva or periodontal or performance).

Screening methods

Citations identified from the literature searches and reference list checking, were imported to Microsoft® Excel for Macintosh (v 16.61.1), the duplicates were removed. The selection of the papers to be included in this systematic review has been realized in three phases by two independent reviewers (HH,JB). Firstly, titles derived from the online search based were independently screened and the abstracts obtained from the selected titles were screened for meeting the inclusion criteria. Thereafter, full-text articles of the selected abstracts that satisfied the eligibility criteria were obtained and included through full-text assessment. Full-texts not available were requested through Research Gate interface. Any disagreements or disambiguates were then resolved through a discussion between the authors.

Data extraction

Using Mendeley software (Elsevier Inc, NY, USA), the author retrieves titles and abstracts from the five search databases, along with inserts and manages references. Data were extracted, tabulated, and presented by the author. Study design, number of subjects, age, type of sport, data source, oral diseases and performance were displayed. To facilitate the critical appraisal conclusion, the measurement of all variables, specified confounding factors, and approaches to deal with were extracted in detail.

Risk of bias in individual studies

Were assessed the quality of included articles using the NIH quality assessment tool for descriptive cross-sectional studies (6) and the Newcastle-Ottawa scale for the longitudinal observational studies.

Data analysis

With the variable data obtained, descriptive statistics were performed. Minimum, maximum mean were described and calculated. The articles that presented omission of data in the tables, but were specified in the text, were extracted and taken into account for the results.

RESULTS

Study selection

The searches were carried out in March 2022. The electronic search retrieved a total of 585 articles: MEDLINE complete (n=163); Scopus (n=159); Cochrane (n=96); Dentistry and Oral Sciences Sources (n=97); and Sport Discuss (n=70). From these records, 253 were excluded due to using a language other than English; the date limitation (2010 -2021); and study type exclusion. After removing 66 duplicates, the remaining 270 articles were retrieved for assessment. Two hundred and four articles were excluded form titles screening and 40 after reading the abstract, as they did not meet the inclusion criteria. Of the twenty-two studies retrieved for full-text screening, we excluded a further 10 after careful review, and eventually, 12 papers were included in this systematic review. The article selection process is illustrated in the PRISMA Flow Diagram (***Fig. 1***).

Characteristics of included studies

Of the twelve included studies, eleven studies were descriptive cross-sectional studies published between 2011 and 2021 and one study was a longitudinal observational study publish in 2012. The age of the athletes among all the studies reviewed, ranged from 16 to 65 years of age (mean 40.5 years-old). As a summary of the several analyzed data, studies have been classified according to the age of participants, the type of sport practiced, the data source, the oral disease encountered and their impact on performance. Out of the twelve studies included, eight studies examined the oral health impact on performance. Nine out of twelve studies aimed to determine the prevalence of different oral diseases among athletes, including several diseases in each article (**Table 1**)**.**

Risk of bias in studies

Concerning the longitudinal observational study (7), the overall risk of bias was rated as low risk (**Fig. 2a**). And in most studies (8–17) the quality rating, in terms of the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies, was estimated by the author as fair to good (**Fig. 2b**).

Synthesis of the results

Influence of oral health in physical performance

Of the eight articles that related sports performance to oral health, five of them detail the percentage of affectation on athletes' performance. The results were obtained through questionnaires by the athletes themselves, where an affectation in performance between 6.9% and 38.5% (mean 22.7%) was specified (**Table 2**). The two most recent articles relating these variables (8,13) found an impact on elite sports performance of 18% and 32%, respectively.

Gallagher et al. (13) study showed that overall, 32% (95% CI 27.3-37.1) reported one or more sport performance impacts during the previous 12 months with a difficulty participating in normal training and competition for 9% (95% CI 6.4-12.5), reduced training volume for 3.8% (95% CI 2.2-6.4), performance affected for 5.8% (95% CI 3.7-7.9), and oral pain for 29.9% (95% CI 25.3- 25.0).

Souzaa et al. (7) showed a significant connection between periodontal pocket depth and

variations in creatine kinase (CK) concentration from the immediate measurement to 20h (r =-0.57) and variations in CK, such as from immediate measurement to 20h (r=-0.51) and baseline to 20h (r=-0.52), showed significant relationships with bleeding on probing.

All the results with information on the effect of oral health on sports performance are available in **Table 2**.

Oral diseases affecting the athletes' oral cavity

Prevalence of dental caries: Of the nine articles (8,10–16,18) that related the prevalence of caries, five (8,11,12,14,15) had detailed the percentage of affectation on athletes. The results were obtained through dentist clinical examination, where they recorded a prevalence of between 20% to 84% (mean 52%) was specified (**Table 3**).

Prevalence of periodontal diseases: Of the nine included articles (8,10–16,18), eight (8,11–16,18) specified the percentages of periodontal involvement suffered by professional athletes. Periodontal disease was described between 11.2% and 81% (mean 35.6%). Gingivitis was described between 21.6 and 80% (mean 56.9%) and periodontitis between 0.9 and 40.9% (mean 20.2%).

Prevalence of other oral diseases: Five of the articles (12–16) described the degree and percentage of dental erosions. The most frequent erosion grades were grades 2 and 3, ranging from 7.2 to 53.1% (mean 35.4%) of professional athletes. The elite sports with the highest wear were soccer (13,14) and less in sailing, weightlifting (13).

Four of the articles described some type of trauma with orofacial involvement, between 10.8% and 40% (mean 35.4%). The most frequent were TMJ trauma followed by dental trauma such as crown fractures of the maxillary central incisor (23.3%) (10). The face and lips were the most affected sites (30%), 17.6% of the athletes presented new trauma, of which 32.7% used mouthguards (15).

Only two studies (8,10) described that 30% and 10% of athletes had malocclusion.

All results with information on oral disorders in elite athletes are shown in **Table 3**.

DISCUSSION

Impact of oral health on athlete's performance

The main finding was that the investigations expressed a clear negative impact of oral health on training routines and elite sports performance.

In their study, Botelho et al. (19) compared self-reported muscle and joint injuries as a function of periodontal health and found that athletes with periodontitis had a higher percentage of non-traumatic muscle and joint injuries (55.6%-22.2%) than players without periodontitis (38.4%-7.2%).

Research by Gay-Escoda et al. (10) and Souzaa et al. (7) reported that periodontal clinical indicators were correlated with muscle injury or serum creatine kinase levels. These findings focus on physiological microinjuries caused by physical exercise, implying that oral health status may have a significant impact on muscle inflammatory response. Likewise, Souza et al. described the influence of periodontal status on variations in blood levels of a marker of muscle damage (7).

Supporting our results, the record of Alshail et al. (20), revealed that soccer players with periodontal problems showed higher serum creatine kinase levels than individuals without this condition.

Prevalence of oral disease in athletes oral cavity

The oral health of athletes appears to be poor in a wide range of sports according to the current literature. High levels of oral disorders were observed in elite athletes, including dental caries, periodontal disease, dental erosion and trauma.

In a systematic review published in 2015 (21) obtained a considerable prevalence of diseases in the athletic population. They described caries levels between 15% to 75% of athletes. Our results were similar to this one, with a result that ranged from 20% to 84%. However, the described frequency of caries in the general population is 29.4% (22). Comparing both frequencies, the great difference is observed, despite the fact that the concepts of health are traditionally related to elite sportsmen and women.

Regarding periodontal diseases, Ashley et al. (21), reported a prevalence of irreversible

periodontal disease up to 15% and gingivitis up to 76% in elite athletes. Kazankova et al. (18) showed that periodontitis was higher in elite athletes compared to the control group, however the prevalence of gingivitis was similar. They described that athletes practicing individual sports modalities presented worse oral hygiene with a higher proportion of periodontal plaque (16). Our results obtained on the frequency of periodontal diseases were similar to previous studies. However, when compared with the proportion of periodontal diseases in the general population, described as 9.8% (22), a very high percentage in athlete population is reflected.

Regarding dental erosion in elite athletes, the studies showed a high frequency. Ashley et al. (21) described that dental wear is high, ranging from 36% to 85%. Our results were consistent with those described. The elite athletes with the highest dental erosion were soccer, sailing and weightlifting due to pressure, and swimmers due to the low pH (23).

Orofacial and dental trauma in the oral cavity of athletes have been described as frequent. Gay-Escoda C et al. (10) described that 40% of athletes suffered direct trauma to the TMJ, with the most frequent oral involvement being fracture of the crown of the maxillary central incisor (23.3%). Similarly, in the studies of Needelman et al. (14,15), 30% and 21.7% of athletes reported, respectively, a history of orofacial trauma due to sport.

The strength of the present review is that is studied for the first time the prevalence of oral disease, together with their direct impact on elite athlete performance.

The limitation was due to the rate of heterogenicity in the included studies, for the interpretation thereof should be considerate. Mainly in the data collection variables (self-reported questionnaire and clinical data) and the measurement of the impact of these oral pathologies on sports performance.

CONCLUSION

This study observed an association between poor oral health and athletics performance of elite athletes. The oral health of the athletes was strongly affected with a high degree of

dental status disorders in which the most significant were caries, periodontal disease, dental erosion, and trauma.

CONFLICT OF INTEREST: The authors declare that they have no conflicts of interest.

ROLE OF THE FUNDING SOURCE: No external funding was available for this study.

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APPENDIX. TABLES AND FIGURES

Table 1. Summary of all included studies.

Authors	Type of study	Subject	Age	Sport	Data source	Oral disease	Performance
Kazankova et al. 2020 (18)	Descriptive cross-sectional study	n=60	18-30 y	Soccer	Questionnaire and clinical examination	Caries Periodontal	
Needleman et al. 2013 (15)	Descriptive cross-sectional study	n=278	16-47 y	25 sports	Questionnaire and clinical examination	Caries Periodontal Erosion Trauma Pericoronitis	Impact on performance
Gay-Escoda et al. 2011 (10)	Descriptive cross-sectional study	n=30	21 (± 1.6) y	Soccer	Questionnaire and clinical examination	Caries Periodontal Trauma	Relation with injury
Souzaa et al. 2012 (7)	Longitudinal observational study	n=15	18 ±0.93 y	Soccer	Clinical examination		Relation with injury
Needleman et al. 2016 (14)	Descriptive cross-sectional study	n=187	18-39 y	Soccer	Clinical examination	Caries Periodontal Erosion Trauma Pericoronitis	Impact on performance
Kragt et al. 2019 (12)	Descriptive cross-sectional study	n=110	25.84 (±5.82) y	-	Questionnaire and clinical examination	Caries Periodontal Erosion	
Opazo-García et al. 2021 (11)	Descriptive cross-sectional study	n= 6680	≥18 y	All sport	Dental examination	Caries Periodontal Abscess	
Gallagher et al. 2018 (13)	Descriptive cross-sectional study	n=344	18-39 y	11 sports	Questionnaire and clinical examination	Caries Periodontal Erosion	Impact on performance
De la Parte et al. 2021 (16)	Descriptive cross-sectional study	n=186	24.74 ± 6.96 y	Individual and team sports	dental examination	Caries Periodontal Erosion	
Chantaramanee et al. 2016 (8)	Descriptive cross-sectional study	n=25	27.50 ± 4.72 y	Soccer	Questionnaire and clinical examination	Caries Periodontal Attrition	Impact on performance
Solleveld et al. 2015 (9)	Descriptive cross-sectional study	n=215	>16 y	Soccer	Questionnaire and clinical examination		Relation with Injury
Nascimento et al. 2015 (17)	Descriptive cross sectional study	n=254	18-65 y	Triathlon	questionnaire		Impact on performance

Table 2. Impact of oral health on athletic performance.

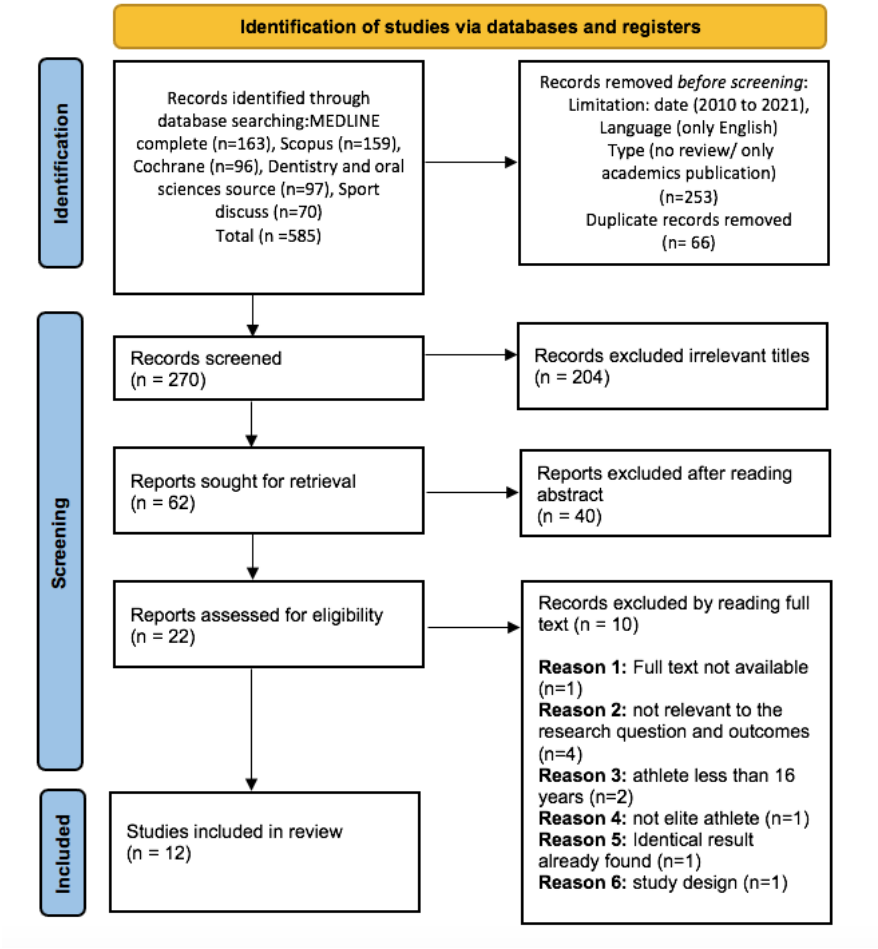
Author	Study design	Sample	Age	Sport	Data source	Influence of OH on athlete's performance
Souzaa et al. 2012 (7)	Longitudinal	n=15	Mean age 18y	Soccer	Periodontal examination Blood samples for CK measurements	Correlation between periodontal disease and serum level of creatine kinase during training that may affect muscle metabolism
Gay-Escoda et al. 2011 (10)	Cross-sectional	n=30	Mean age 21y	Soccer	Clinical examination and interviews	Correlation between plaque/gingival index and intrinsic/muscle injuries
Solleveld et al. 2015 (9)	Cross-sectional.	n=215	>16 y	Soccer	Structured questionnaire	Correlation between poor OH and reinjury.
Needleman et al. 2013 (15)	Cross-sectional	n=278	16-47y	25 sports	Questionnaire and clinical evaluation	18%
Needleman et al. 2016 (14)	Cross-sectional	n=187	18-39y	Soccer	Questionnaire and clinical evaluation	6.9%
Gallagher et al. 2018 (13)	Cross-sectional	n=344	Mean age 25y	UK elite from different sports	Questionnaire and clinical evaluation	32%
Chantaramanee et al. 2016 (8)	Cross-sectional	n=25	Mean age 27y	Soccer	Questionnaire and clinical evaluation	18%
Nascimento et al. 2015 (17)	Cross sectional	n= 254	18-65y	Triathlon	Structured questionnaire	38,6%

Table 3. Prevalence of oral athlete oral disease.

Authors	Type of study	Subject	Age	Sport	Data source	Caries prevalence	Periodontal disease	Dental erosion	Trauma	Others
Kazankova et al. 2020 (18)	Cross sectional study	n=60 Professional athletes (n=20)	18-30y	Soccer	Questionnaire Clinical examination	CPI[1]: 9.0 (7.75-10.25)	Gingivitis: 55% Periodontitis: 40% PMA[5]:34.5%	-	-	-
Needleman et al. 2013 (15)	Cross-sectional study	n=278	16-47y	Olympic games 25 sports	Clinical examination and history	55.1%	Gingivitis:75% Periodontitis:15%	44.6% grade 2-3	30% history of trauma 17.6% New trauma	9.9% Pericoronitis 11.8% Unhealthy oral mucosa
Needleman et al. 2016 (14)	Cross-sectional study	n=187	18-39y	Soccer	Clinical examination and questionnaire	36.9% DFT[2]: 4.6	Gingivitis: 80% Periodontitis: 5%	53.1% grade 2–3	21.7% history of orofacial trauma	3.2% pericoronitis 7.8% at least one PUFA[11]
Gallagher et al. 2018 (13)	Cross-sectional study	n=344	18-39y	11 sports	Questionnaire Dental examination	ICDAS[3]: 49.1% code ≥3	BPE[6] score 1 or 2: 77% BPE score 3 or 4: 21.6%	ETW[10]: 41.4%	-	23.3% pericoronitis in last 12 months 3.4% at least one PUFA
Gay-Escoda et al. 2011 (10)	cross-sectional study	n=30	Mean age 21y	Soccer	clinical examinations and questionnaire	DMFT[4]: 5.7 Active caries: 2.2	GI[7]: 1.1 PPD[8]: 1.9	-	40% TMJ trauma 23.3% uncomplicated fractures of the maxillary central incisor	30% bruxism 30% soft tissue laceration 30% severe malocclusion
Kragt et al. 2019 (12)	Cross-sectional study	n=110	Mean age 25.84 y	Olympic Games	Questionnaire Dental examination	20% DMFT > 10: 15%	Gingivitis: 21.6% Periodontitis: 0.9%	7.2%	-	21.6% need 3rd molar extraction
Opazo-García et al. 2021 (11)	Cross-sectional	n= 6680	≥18y	Pan American games	Dental examination	29%	34%	-	-	3% chronic periapical abscess 4% salivary gland mucocele
De la Parte et al. 2021 (16	Cross-sectional	n=186	Mean age 24.7y	Individual and team sports	dental examination	DMFT: Individual: 8.12 ± 3.56 Team: 6.10 ± 3.63	Periodontitis: Individual: 39.2% Team: 36.6%	Individual: 31% Team: 44.6%	Individual: 10.8% Team: 17%	-
Chantaramanee et al. 2016 (8)	Cross-sectional study	n=25	Mean age 27.5y	soccer	Clinical evaluation and Questionnaire	84% DMFT: 10.08	Periodontitis: 30%	-	-	10% with severe malocclusion 60% dental attrition

[1]caries intensity index
[2]Decayed and filled teeth.
[3]International Caries Detection and Assessment system
[4]Decayed, missing, or filled teeth.
[5]Papilla, Marginal gingiva and attached gingiva index.
[6]Basic periodontal examination.
[7]Löe & Silness gingival index.
[8]Ramfjord teeth probing pocket depth.
[10]erosive tooth wear
[11]Pulp, Ulceration, Fistula, Abscess index

Figure 1. *PRISMA flowchart.*



	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration of outcome of interest absence at start of study	Comparability (most important factor)	Comparability (others factors)	Assessment of outcome	Sufficient follow-up	Adequacy of follow-up	Total
Souzaa BC et al., 2012 (7)	☆	☆	☆	-	☆	-	☆	-	☆	6

Figure 2a. Assessment of the risk of bias of the non-randomized observational cohort study using the Newcastle-Ottawa scale.

	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations?	Was a sample size justification, power description, or variance and effect estimates provided?	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed? Association between exposure and outcome if it existed?	For exposures that can vary in amount or level, did the study examine different levels of the exposure?	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Was the exposure(s) assessed more than once over time?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Were the outcome assessors blinded to the exposure of participants ?	Was loss to follow-up after baseline 20% or less?	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Summary Quality
Needleman et al. (15)	✓	✓	NR	✓	X	✓	✓	✓	✓	CD	✓	NR	✓	X	**i**
Needleman et al. (14)	✓	✓	✓	✓	X	✓	CD	✓	✓	NR	✓	✓	✓	X	**i**
Gallagher et al. (13)	✓	✓	✓	✓	X	✓	NR	✓	✓	NR	✓	✓	✓	X	**i**
Gay-Escoda et al. (10)	✓	X	NR	NR	X	✓	✓	✓	✓	✓	✓	NR	✓	X	**i**
Chantaramanee et al. (8)	✓	✓	NR	NR	X	✓	✓	✓	✓	NR	✓	NR	✓	X	**i**
Solleveld et al. (9)	✓	✓	✓	✓	X	✓	✓	✓	✓	NR	✓	✓	✓	X	**ii**
Nascimento et al. (17)	X	✓	NR	NR	X	✓	X	X	✓	X	✓	✓	✓	X	**i**
Kragt et al. (12)	✓	✓	✓	✓	X	✓	NR	✓	✓	X	✓	✓	✓	X	**i**
Opazo-García et al. (11)	✓	✓	✓	✓	NR	✓	✓	✓	X	X	✓	✓	NR	X	**i**
De la Parte et al. (16)	✓	✓	✓	✓	✓	✓	✓	✓	✓	NR	✓	✓	✓	X	**ii**
Kazankova et al. (18)	✓	✓	✓	X	NR	✓	✓	✓	✓	NR	✓	✓	✓	NR	**i**

Figure 2b. Assessment of the risk of bias of the descriptive studies using the NIH quality assessment tool for cross sectional studies.

PRISMA

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	4
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	4
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	4
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	4
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	5
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	5
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	5
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	5
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	5
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	X
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	X
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	X
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	X
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	X
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	X
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	X
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	X

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	5,15
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	5
Study characteristics	17	Cite each included study and present its characteristics.	6,13
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	6,15,16
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	6,7,13,14
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	X
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	X
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	X
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	X
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	X
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	X
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	8-9
	23b	Discuss any limitations of the evidence included in the review.	9
	23c	Discuss any limitations of the review processes used.	9
	23d	Discuss implications of the results for practice, policy, and future research.	9
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	X
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	X
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	X
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	X
Competing interests	26	Declare any competing interests of review authors.	X
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	X