GRADUATION PROJECT

Degree in Dentistry

SPORTS AND ORAL HEALTH

Madrid, academic year 2022/2023

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Abstract:

Introduction: Oral health is a vital aspect of an individual's overall health and quality of life. A compromised oral health condition can result in a decrease in quality of life, appearance, socialization, and confidence. Conversely, a healthy oral cavity is influenced by multiple factors. One such factor that affects oral health is sports. Sports involve physical exertion and can be pursued for leisure or at an elite professional level.

Objective: Explore the impact of sports, both as a recreational pursuit and at the elite level, on oral health and investigate the role of dentists in optimizing the athletic performance of athletes.

Methodology: Pubmed, Dentistry and Oral science source and Medline Complete have been used to carry out the systematic literature research.

Results: Athletes have a higher susceptibility to oral health problems compared to non-athletes due to various factors, including changes in nutrition, stress, and alterations in oral microbiome and saliva. The most diagnosed oral health problems among athletes are gingivitis and dental caries. Poor oral health can lead to several adverse consequences, including pain, discomfort, and decreased energy levels, which can negatively impact an athlete's performance. Additionally, unhealthy oral conditions can increase the risk of non-traumatic muscular injuries, further compromising an athlete's overall well-being and performance.

Conclusion: It is vital to increase awareness of athletes' unique oral health needs and develop efficient strategies to prevent and treat oral health diseases in this population. By doing so, dental professionals can aid athletes in maintaining optimal overall and oral health.

Keywords: Dentistry; Oral health; Athletes; Sport.

Resumen

Introducción: La salud oral es un aspecto vital de la salud general y la calidad de vida de un individuo. Una condición comprometida de salud oral puede resultar en una disminución en la calidad de vida, apariencia y socialización. Por el contrario, una cavidad oral saludable está influenciada por múltiples factores. Uno de esos factores que afecta la salud oral es el deporte. Los deportes implican una exigencia física y se pueden practicar por diversión o a nivel profesional.

Objetivo: Explorar el impacto del deporte, tanto como actividad recreativa como a nivel de élite, en la salud oral e investigar el papel de los dentistas en la optimización del rendimiento atlético de los deportistas.

Metodología: Se llevó a cabo una búsqueda en las bases de datos de Pubmed, Dentistry and Oral science source y Medline Complete para llevar a cabo la revisión sistemática. **Resultados:** Los deportistas tienen una mayor susceptibilidad a problemas de salud oral en comparación con los no deportistas debido a diversos factores, incluidos los cambios en la nutrición, el estrés y las alteraciones en el microbioma oral y la saliva. Los problemas de salud oral más diagnosticados entre los deportistas son la gingivitis y las caries dentales. Una mala salud oral puede conducir a dolor, molestias y disminución de los niveles de energía, lo que puede afectar negativamente el rendimiento del deportista. Además, las condiciones orales insalubres pueden aumentar el riesgo de lesiones musculares no traumáticas, comprometiendo aún más el bienestar general y el rendimiento del deportista.

Conclusión: Es vital aumentar la conciencia sobre las necesidades únicas de salud oral de los deportistas y desarrollar estrategias eficientes para prevenir y tratar enfermedades de salud oral en esta población. De esta manera, los profesionales dentales pueden ayudar a los deportistas a mantener una salud oral y general óptima.

Palabras clave: Odontología; Salud oral; Deportistas; Deporte.

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1. Introduction

1.1 The concept of Sport

Sports and physical activity have been an integral part of human society for centuries. It is impossible to imagine a life without them (1). The scientifically proven benefits of sports for both the body and mind are numerous, including personal and psychosocial development (2). Moreover, sports bring people together regardless of social class. However, every positive aspect of sports also comes with a negative aspect. Injuries are an unfortunate reality of physical activity, and approximately more than 3.5 million sport-related injuries occur each year (3).

1.2 Definition of sport and oral health

To gain insight into the impact of sports on oral health, it is imperative to delineate the fundamental concepts of sports and oral health.

Sport can be defined as any activity that requires physical prowess, where a team or an individual vies against one or more opponents (4). It is a ubiquitous pursuit that can be undertaken by anyone regardless of age or health status. However, the broad participation in sports also means an increased risk of injuries. Among individual sports, tennis, golf, badminton, table tennis, swimming, and running are the most prevalent. In contrast, football, basketball, ice hockey, handball, and volleyball are the most played team sports in the industrialized world (5).

One's oral health is a critical factor in determining their overall well-being and quality of life. It encompasses various medical issues such as tooth decay, gum disease, oral cancer, dental injuries, and even congenital defects like cleft palate (6). In 2019, it was estimated that oral diseases affected approximately 3.5 billion people, which accounts for 44% of the world's current population (7).

1.3 Definition of physical training, exercise and elite athlete

The terms physical training and sport are closely connected, but they are often confused and used interchangeably. Physical activity is defined as any movement of the body that requires the use of skeletal muscles and results in energy expenditure, including leisure activities, transportation, and work-related movements such as cleaning (8). On the other hand, exercise is defined as the engagement in deliberate and repetitive physical exercise with the aim of conditioning any part of the body. This type of activity is planned and structured to achieve optimal results, such as swimming (1). Sport combines both exercise and physical training but is typically characterized by rules and a competitive mode.

Elite athletes, on the other hand, are individuals who are presently or have previously participated in professional, national, or international-level competitions (9). The Olympic Games, which are held every four years, provide a platform for world-renowned elite athletes to compete against each other. The Olympic Games have a fascinating and long history, dating back to ancient Greece. The games gained popularity in the late 19th century and have been held every four years since then. The ancient Olympic Games included 32 different sports, many of which are still included in the modern-day summer Olympic Games (10). The winter games were approved in 1924. Prior to 1970, only amateur athletes were allowed to participate in the Olympic Games. However, in the 1980s, the rules changed, and the participation of professional athletes was allowed (10). This change allowed some of the world's most

famous and top athletes to compete in the games. Today, the Olympic Games continue to be a showcase for elite athletes from around the world. By allowing both amateurs and professionals to compete, the games have become a true test of ability and athletic skill (10).

1.4 Parameters of physical training

To gain a more comprehensive understanding of how sports impact oral health, it is crucial to investigate the factors that cause the oral cavity to respond differently during physical exercise. During sports, the body requires more energy than during periods of inactivity. As a result, the body uses stored nutrients to convert chemical energy into mechanical energy. However, the extent of this conversion and nutrient expenditure varies depending on the duration and intensity of the exercise (11).

Explosive sports, such as bodybuilding or sprinting, require a rapid availability of energy sources. In these cases, muscle reserves creatine phosphate as an energy source, which lasts for a maximum of 10 seconds. After this period, glucose and muscle glycogen are used for high-intensity exercise lasting up to 3 minutes (1).

1.5 Energy Requirement

The energy requirement for performing a particular sport varies among individuals due to a combination of intrinsic and extrinsic factors. Extrinsic factors include weather conditions, whereas intrinsic factors comprise age, sex, and weight. Regardless of the type of physical activity, the body's caloric need increases during exercise (11). Ainsworth developed a method to estimate energy expenditure for different activities using a unit called metabolic equivalent, where 1 Metabolic equivalent = 1 kcal/kg/h (12). The difference in energy requirement between two activities can be substantial. For instance, an 80 kg female playing badminton in a competitive mode for two hours requires

approximately 1,120 kcal (Figure 1), whereas sitting quietly for two hours demands only 208 kcal (Figure 2).

Metabolic equivalent	Sports
7.0	Badminton, competitive
7.8	Boxing, sparing
9.3	Basketball, general

Figure 1: METs of Sport (15)

Metabolic equivalent	Inactivity Quiet/light
1.3	Sitting quietly
1.0	Lying quietly and watching television
0.95	Sleeping

Figure 2: METs of Inactivity Quiet/Light (15)

1.6 Carbohydrates and oral health

To meet the high energy demands of sports, it is recommended to increase carbohydrate intake. During physical activity, the body primarily uses muscle glycogen and blood glucose as sources of energy (13). Insufficient carbohydrate intake can limit an individual's performance, whereas consuming adequate carbohydrates before and during sports can maintain blood glucose levels and increase hepatic glycogen, enabling the body to perform at a higher level (14). Thus, it is essential for athletes to tailor their diets to their individual needs. Although the optimal amount of carbohydrate intake may vary from person to person, it is recommended that triathletes eat foods rich in carbohydrates and drinks four hours before, during, and six hours after the event (16).

Although insufficient carbohydrate intake can limit an individual's performance, prolonged and increased consumption of carbohydrates has a negative effect on the oral cavity. This effect includes an increased risk of caries due to the acidic plaque environment it creates, as well as diminished

remineralization and buffering potential, ultimately contributing to enamel demineralization and caries development (17).

The negative effect of increased carbohydrate consumption on the oral cavity is not only related to the amount consumed, but also to the timing of carbohydrate intake. Gustafson's 1954 theory emphasizes the role of sugar intake frequency in increasing the risk of caries, underscoring the importance of carefully considering the timing of carbohydrate consumption (18).

1.7 Sport drinks and oral health

Not only does carbohydrate intake increase the risk of dental caries, but the popularity of acidic drinks further compounds the problem. Sports drinks contain high levels of citric acid, which promotes enamel and dentin erosion (19). Moreover, frequent sipping during sports exacerbates this risk by reducing the buffering capacity of the mouth, leading to increased erosion (19).

1.8 Amount of training effect on oral health

The intake of beverages and carbohydrates can greatly impact dental health. However, it is essential to consider the intensity and weekly training time when evaluating the impact on oral health. Research has indicated that athletes who train more often exhibit a higher incidence of dental lesions. A positive association between the total amount of weekly training time and the prevalence of tooth decay was demonstrated by Frese in 2014 (1). This phenomenon can be attributed to a decrease in saliva production and an increase in carbohydrate consumption, which favors demineralization (1). There is not only a positive correlation between caries prevalence and weekly training time, but also fatigued athletes are more prone to opportunistic infections. This is commonly due to a lowered number of IgA levels in the saliva. IgA is one of the major antibodies in the saliva, as it is responsible for safeguarding the buccal cavity by preventing the attachment of microbes to the

oral epithelium and, consequently, the teeth. If this is not controlled, there is a greater risk for opportunistic infections to occur. Competitive swimmers are an example of such athletes. It has been reported that they experience a lowering of immunoglobulin levels, making them more susceptible to opportunistic infections. (20)

1.9 Hyposalivation during sport and its effect on oral health

Saliva serves a multifunctional role, and any quantitative or qualitative modification can pose a significant risk to oral health. Saliva is composed of 1% inorganic and organic molecules and 99% water (21). Each of its components plays a specific role in maintaining a healthy oral cavity, as shown in Figure 3. The major salivary glands are responsible for secreting approximately 93% of the volume, with the minor glands contributing to the remaining 7%. These glands are located throughout the mouth, except for the anterior part of the hard palate and gums, where salivary glands are not present (21).

Component	Function in the oral cavity
Water, mucin & proline-rich glycoproteins	Lubrication
Lactoferrin, IgA, immunoglobins, proline-rich glycoproteins, Lysozyme	Antimicrobial action
Remineralization and buffer capacity	Fluoride, bicarbonate, calcium, phosphate
Digestion	Lipase, amylase, mucin
Taste	Gustin, water
Phonation	Mucin, water

Figure 3: Summary of salivary components and functions (25)

Hyposalivation is a medical condition that refers to a decrease in the normal quantity of saliva produced by the salivary glands. The symptoms associated with hyposalivation include a persistent sensation of dryness in the mouth, difficulty in speaking and swallowing, and increased thirst or polydipsia. Moreover, patients with hyposalivation may develop dental caries in

unexpected surfaces of the tooth and have a heightened susceptibility to Candida infections (22). These symptoms can significantly affect an individual's daily activities and overall quality of life.

During sports activities, hyposalivation is a common occurrence that typically arises during prolonged exercise, as the body tries to conserve water by reducing its saliva production (23). Figure 4 illustrates the three processes that contribute to hyposalivation.

	What causes hyposalivation?	Effect?
First Process	Stress due to rivalry stimulates sympathetic nervous system.	Decrease of saliva secretion into via major and minor glands.
Second Process	Buccal cavity is exposed to climatic elements	Evaporation of oral elements
Third Process	Heat production causes to fail to restore homeostasis.	Saliva secretion is decreased

Figure 4: Hyposalivation effect on oral health (23)

While exercising for 60 minutes may not result in immediate dental caries, prolonged periods of hyposalivation due to longer and more intense workouts can lead to dental problems (1). Therefore, it is important to recognize the potential impact of hyposalivation on oral health, particularly in athletes who engage in prolonged and intense physical activities.

Regardless of the duration and intensity of exercise, saliva becomes more viscous after physical activity due to an elevated secretion of a protein called MUC5B. This increased viscosity can also contribute to the sensation of dryness in the mouth following exercise (23).

1.9 Hypersalivation during sport and its effect on oral health

Hypersalivation or sialorrhea, may be pathological or physiological, and occurs when there is an increase in the salivary secretion. Symptoms of

hypersalivation include halitosis, sialorrhea and an increased risk of secondary infection (22).
The autonomic nervous system is responsible for regulating salivary secretion. Typically, salivary levels increase 10 minutes after exercise as the body compensates for the drying effect caused by mouth breathing (24).

Several physiological processes occur that make the oral cavity more vulnerable to diseases. Therefore, this scientific paper aims to analyze how sports impact the oral cavity and suggest ways in which dental professionals can not only treat athletes effectively but also assist them in achieving their full potential.

2. Objectives

The oral cavity undergoes a series of physiological changes during sports, consequently impacting the oral health of an individual. Furthermore, an unhealthy oral cavity can negatively impact an athlete's performance. Therefore, it is important for dentists to be knowledgeable about this potential risk and formulate effective strategies for the prevention and treatment of oral health diseases in this population.

The purpose of this scientific literature review is to assess how performing sports can affect the oral cavity and subsequently the performance of athletes.

Main objective:

- Establish how does performing sport affect the oral health of athletes.

Secondary objective:

- To examine the correlation between oral health and the performance and well-being of elite athletes
- To investigate whether there is a correlation between periodontitis and the incidence of sports injuries among athletes

3. Materials and methods

To conduct the systematic literature review concerning the topic "Sports and Oral health", the databases PubMed, Dentistry and Oral science source and Medline Complete have been used. The search has been done between the 25th of September 2022 until 20th February 2023.

3.1 Selection criteria:

The inclusion criteria for this review were chosen based on multiple factors, which have been summarized in Figure 5. Firstly, only full-text articles published in the last 15 years (2013-2023) were considered to ensure an up-to-date review. The last research for this review was conducted on December 15th, 2022. Additionally, only full-text articles written in English, Spanish, German, or Czech were reviewed, while books and documents were excluded. Reviews, systematic reviews, meta-analyses, clinical trials and randomized controlled trials were included in the selection criteria.

Inclusion criteria	**Exclusion criteria**
Published in the last 10 years (from January 2023)	Published more than 10 years (From January 2023)
Language: English, Spanish, German or Czech	Other languages
Article type: Review, Systematic Review, clinical trials, meta-analysis, randomized controlled trials	Books and documents
Mean age of athletes ≥18	Mean age of athletes <18
Participation in Olympics	Participation in Para-Olympics

Figure 5: Inclusion and exclusion criteria

The creation of clear inclusion criteria has allowed for an initial screening, followed by more specific ones. Consequently, only articles that have a direct correlation with either the primary or one of the secondary objectives have been considered once the inclusion criteria have been met.

3.2 System of searching and keywords

For the main objective, establishing how does performing sport affect the oral health of athletes, the keywords in Pubmed, Dentistry and Oral Science source and Medline used were “Athletes” AND “Oral Health”

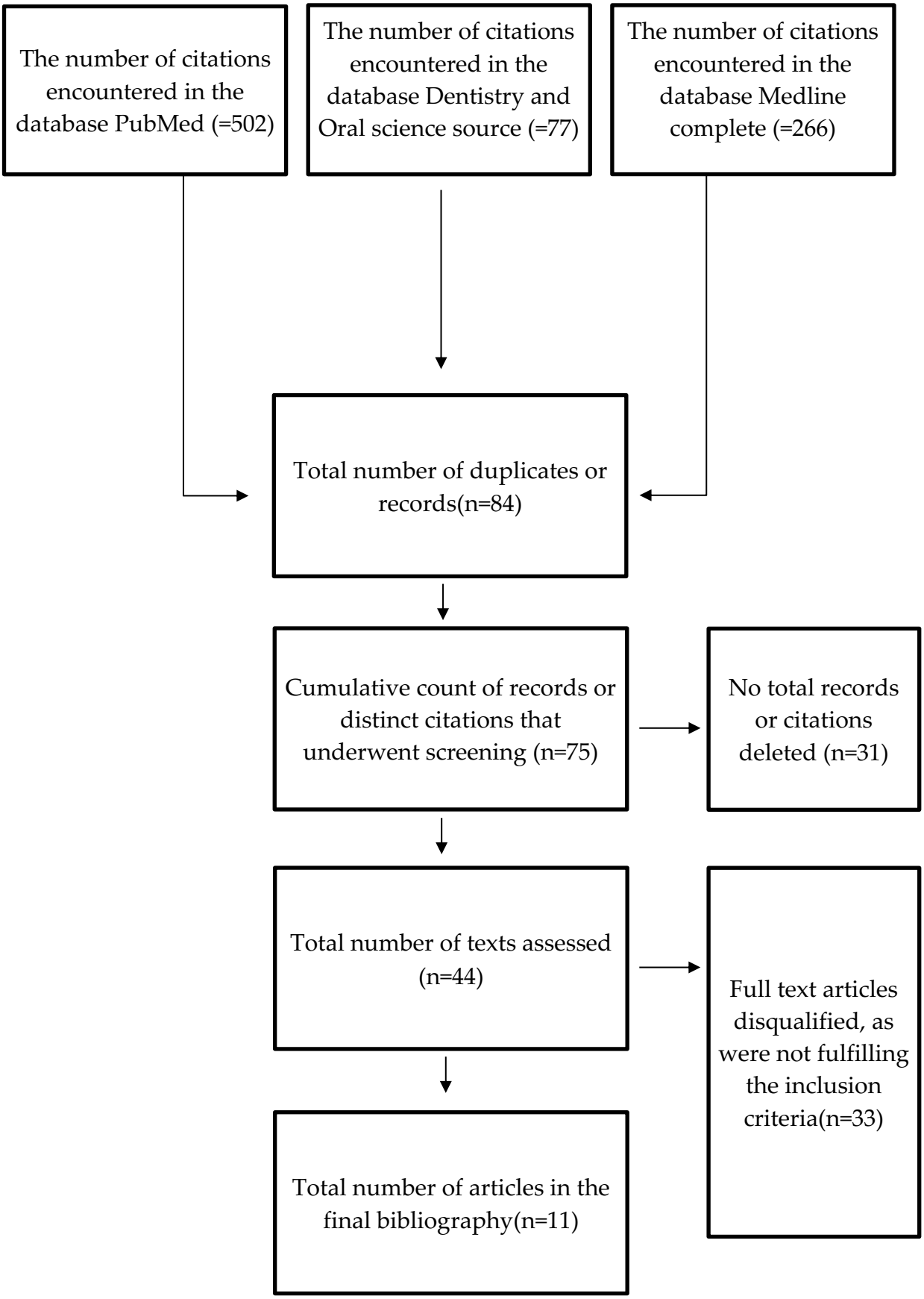
For the secondary objective, to examine the correlation between oral health and the performance and well-being of elite athletes, the keywords in Pubmed, Dentistry and Oral Science source and Medline used were “Performance” AND “oral health”.

For the secondary objective, to investigate whether there is a correlation between periodontitis and the incidence of sports injuries among athletes, the keywords “sport injury” AND “oral health” have been used in Medline, Dentistry and Oral Science source and Pubmed.

4. Results

4.1 Flowchart of the study selection process

Table 1



This sequential flowchart illustrates the process of selecting the relevant articles used in the study.

To conduct the research, the databases PubMed, Medline Complete and Dentistry & Oral Science Source has been used. In total, 44 articles were analysed in detail. Out of these 44 articles, 11 articles met the inclusion criteria and were hence used. The other 33 articles did not meet the inclusion criteria and have therefore not been nominated. The inclusion and exclusion criteria can be reread in Figure 5.

4.2 Summaries of studies regarding the correlation between how does performing sport affect the oral health of athletes

Table 2 summarizes the 11 articles that met the inclusion criteria and studied the correlation between participating in sports and its impact on the oral health of athletes. The table displays the location where the study was conducted, the type of study, the sample size, as well as the mean age of the athletes and the number of sports studied.

Table 2

The study, year	Location	Study type	Size of sample	Mean age	Sports studied
Kragt L, 2018	Netherlands	Cohort	116	25.84 years	-
Gallagher et al. 2018	United Kingdom	Cross-sectional	352	25 years	11
Merle et al. 2022	Germany	Cross-sectional	88	20.6 years	5
Needleman et al. 2014	United Kingdom	Cross-sectional	278	25.7 years	25
Morty et al. 2018	France	Case-control	24	27.29 years	1
Botelho et al. 2021	Portugal	Cross-sectional	22	27.7 years	1
Knight et al. 2018	Qatar	Cohort	1079	21.7 years	19
Opazo-Garcia et al. 2021	Peru	Cross-sectional	6680	≥ 18 years	39
Merle, Rott et al.2022	Germany	Cross-sectional	31	25.6 years	2
Solleveld et al.2015	Italy	Cross-sectional	215	19.46 years	1
Minty et al. 2018	France	Case-control	46	27.29 years	1

Table 3 shows the positive correlation between the studied oral conditions and their effects on athletes. However, not all the articles included every oral condition. Nonetheless, all the articles demonstrate at least one positive correlation between the studied oral manifestation and its effect on athletes.

Table 3

The study, year	Gingivitis	Periodontitis	Erosion	Caries	Quality of life/performance impact	Pericoronitis
Kragt et al. 2018	Yes	Yes	Yes	Yes	Yes	Yes
Gallagher et al. 2018	Yes	Yes	Yes	Yes	Yes	Yes
Merle et al. 2022	Yes	Yes	Yes	Yes	-	Yes
Needleman et al. 2014	Yes	Yes	Yes	Yes	Yes	Yes
Morty et al. 2018	Yes	-	-	Yes	-	-
Botelho et al. 2021	Yes	Yes	-	-	Yes	-
Knight et al. 2018	-	-	-	Yes	-	-
Opazo-Garcia et al. 2021	Yes	Yes	-	Yes	Yes	-
Merle, Rott et al. 2022	Yes	Yes	Yes	Yes	-	Yes
Solleveld et al.2015	-	Yes	-	Yes	Yes	-
Minty et al.2018	Yes	-	-	Yes	-	-

5. Discussion

Erosion

Erosion can be characterized as the loss of hard dental tissue resulting from non-microbial factors, namely acid-related dissolution. This condition can occur through extrinsic causes, which stem from the acidity of consumed food and drinks, or intrinsic causes, which result from endogenous acid production. The severity of erosions is dependent on several factors, including saliva composition, nutritional intake, diseases, and mechanical stress caused by attrition. Athletes are at a heightened risk for dental erosion due to their tendency to repeatedly consume acidic food and drinks, which can gradually wear away the enamel on their teeth (25).

The Basic Erosive Wear Examination (BEWE) is the primary method used to evaluate the extent of erosion. It assesses each sextant based on the most severely affected teeth using a four-level scale. The final BEWE-score is then calculated by summing the scores from each sextant, resulting in a maximum range of 0-18 (26).

According to the latest meta-analysis and systematic review done in 2020 the prevalence of erosion in athletes is at approximately 47%, hence almost affecting every second athlete (27). The studies of Gallagher et al. 2018 and Needleman et al.2014, both prove the high prevalence of erosion amongst athletes. Gallagher et al.2018 and Needleman et al.2014 reported the prevalence of erosion to be 42% and 44.6% of athletes, respectively (28,29). On the other hand, the study done by Kragt et al.2018 reported an even higher prevalence, as 59% of the 116 Dutch athletes were diagnosed with erosion prior to the 2016 Olympic games in Rio (26). Additionally, this was almost twice of the occurrence of erosion in a comparable group of non-athletes (26). The higher prevalence could be potentially explained due to the kind of sport performed

by the athlete, as according to Gallagher et al.2018, erosion was twice times greater in mixed/team sport than in endurance sport (28), where constant sipping of drinks is more frequent.

Even tough the prevalence of erosion is higher in athletes compared to non-athletes, a low severity amongst young athletes (mean age 25.5) is identified. In the study of Merle, Rott et al.2022, studying the oral health status of German cross-country skiers and biathletes, the erosive tooth wear in biathletes was at BEWE sum of 5.6 and for the cross-country skiers at 5.3(30). Similarly, the young German athletes, with a mean age of 20.6 years, in competitive sports examined by Merle et al. 2022 reported a BEWE score of about 3.5(31). Additionally, in the study of the dutch athletes by Kragt et al. 2018, the BEWE score was at about 2.0(26). However, as the age increases so does the severity of erosion, as endurance athletes with a mean age of about 37 years, had a BEWE score of 9.6, indicating medium severity (32).

Overall, these studies demonstrate the high prevalence of tooth erosion in athletes, as well as the variability in erosion severity across different age groups. Nevertheless, athletes have higher levels of erosion than non-athletes, indicating a cause for concern. Athletes are more susceptible to tooth erosion due to frequent consumption of acidic sports drinks, which are consumed to replenish lost electrolytes during exercise. The low pH of these drinks, which can be as low as 2.4, can also cause enamel erosion (32). Additionally, physical activity can increase endogenous acid production, further contributing to erosion. Teeth grinding, which occurs in some sports, can also increase the risk of erosion (32).

Gingivitis

Most commonly oral inflammation is presented as the reversible form called Gingivitis. Gingivitis is formed by the accumulation of biofilm below and at the level of the gingival margin. Gingivitis, generally painless, is presented with bleeding, edema, and enlargement of the tissues around the teeth (33).

Athletes are commonly affected by gingivitis, as highlighted in research. In the study conducted by Kragt et al. 2018, 21.6% of 116 Dutch elite athletes were reported to have gingivitis (26). In Gallagher et al.'s 2018 study, signs of gingivitis were observed in UK elite athletes from 11 different sports, with 77% of athletes showing bleeding on probing (28). Additionally, all patients with bleeding on probing had the presence of calculus. Furthermore, Gallagher et al. (2018) supported the claim that athletes are more prone to gingivitis compared to non-athletes, as the study found that only 1.1% of the athletes had excellent periodontal status (28).

Similarly, the study conducted by Merle et al. 2022 indicates that excellent periodontal health was rare among young German athletes (31). Despite having low-severity gingivitis, all examined athletes participating in competitive sports showed signs of inflammation of the gingiva, which is an 18.5% increase compared to the athletes examined by Kragt et al. in 2018 (26, 31). Comparison between amateur and competitive athletes revealed that a higher proportion of competitive athletes (40%) had high probing depths, as opposed to only 12% of amateur athletes (31). Therefore, the need for periodontal treatment was higher for the young German athletes compared to the other studies, as they exhibited an increased probing depth (31). Considering that none of the examined periodontal pockets were more than 5.5mm and the young mean age of 20.6

years, the periodontal status of the athletes could potentially be diagnosed as an indication of gingivitis or initial periodontitis (31).

In the study conducted by Needleman et al. 2014, an adequate oral health status was found to be rare among the participating athletes of the 2012 Olympic games. Specifically, 75% of the athletes had either gum bleeding after probing or calculus present (29). Regarding the range of gingivitis, it was found that at least 50% of the oral cavity showed some indication of gingivitis in 76% of the examined athletes (29). Additionally, it is important to note the differences in gingival health status among athletes of different ethnicities, as observed by Needleman et al. in 2013 and Knight et al. in 2019. The studies revealed that white athletes exhibit superior periodontal health status compared to their black counterparts (29). Similarly, Knight et al. in 2019 concluded that black athletes had more oral health problems than the other examined athletes (34). These findings emphasize the significance of acknowledging ethnicity as a vital factor in evaluating and addressing the oral health requirements of athletes.

It is evident that athletes are more prone to developing periodontal diseases than non-athletes. Evidence from the study conducted by Minty et al. 2018 further supports this claim, revealing a significantly higher prevalence of gingivitis in professional rugby players compared to non-athletes. The study found that 58.33% of rugby players had signs of gingivitis, while only 13.63% of non-athletes showed such symptoms (35). Interestingly, despite the similar mean ages of the two groups, the athletes, 27.29 years were found to be at greater risk of developing gingivitis than non-athletes 25.59 years (35). As age is a well-established risk factor for periodontal disease, this finding has important implications for the oral health of athletes (36).

One explanation for the higher incidence of gingivitis in athletes is the nutritional changes they undergo to maintain their energy levels. Minty et al.

2018 reported that rugby players tend to have a significantly higher frequency of food intake, consuming food on average 4.08 times per day compared to non-athletes, who consume food 2.94 times per day (35). This increase in food intake is necessary for athletes to replace the energy lost during physical activity, but it can also create an environment that is conducive to bacterial growth, leading to gingivitis (35).

Furthermore, the study revealed that athletes are less likely to undergo regular dental checkups than non-athletes. Only 77.27% of athletes received a dental checkup in the last 12 months, compared to 20.83% of non-athletes (35). This lack of attention to oral health is another factor that contributes to the increased risk of periodontal disease in athletes.

Periodontitis

If the biofilm is not removed, gingivitis can lead into the irreversible form known as Periodontitis. Periodontitis is an inflammation of the whole periodontium. Not only does Periodontitis cause an increase in the depth of the gingival pockets and reduction of bone, but it also increases the amount of periodontopathic bacteria within the oral cavity (36).

The results of several studies suggest that periodontitis is a more frequent problem among athletes than non-athletes, although it is not as common as gingivitis. Kragt et al. 2018 reported a periodontitis prevalence rate of 0.9% among Dutch athletes (26). However, Gallagher et al. 2018 and Merle et al. 2022 found even higher rates of periodontitis among their examined athletes (28,31). Gallagher et al. 2018 observed a probing depth of more than 4mm in 21.6% of UK elite athletes, indicating periodontitis (28). Although oral hygiene behavior was similar between athletes and non-athletes, young German athletes participating in competitive sports exhibited a higher frequency of having a

probing depth between 3.5mm-5.5mm. Specifically, 40% of athletes had this range compared to only 12% of non-athletes (31).

Similarly high levels of periodontitis have been observed among professional football players in Liga Portugal 2, with Botelho et al. 2021 reporting a prevalence rate of 40.9% (37). Despite athletes undergoing constant medical tests, it appears that their oral health is being overlooked. A reasoning for the high levels of periodontitis can be the socioeconomic status of the parents and athletes, which can be a contributing risk factor for periodontitis (38). Generally, it is considered that soccer players are coming from a lower socioeconomic status, hence it can be a contributing risk factor.

When comparing individuals of similar age and gender, it is evident that athletes exhibit more signs of periodontitis than non-athletes. For example, in a study of top-elite cross-country skiers and biathletes, 61.3% of competitive athletes had signs of periodontitis compared to 44.1% of non-competitive athletes (30).

Athletes commonly suffer from periodontitis. One reason for the higher frequency of periodontal problems in athletes compared to non-athletes is their importance towards oral health and nutrition habits (31). In addition, the physical stress that athletes undergo leads to a reduction in immune system activity, creating an opportunistic window for oral infections to occur (45).

Caries

Dental caries is a biofilm-related disease that affects both primary and permanent dentition and is caused by a dynamic process of remineralization and demineralization of the tooth's hard tissues (39). In order to measure dental caries levels, the DMF index is often used, which is the sum of decayed, missing due to caries, and filled due to caries teeth (40).

The diagnosis of caries among athletes varies across studies, reflecting differences in oral hygiene habits and individual priorities. For instance, prior to the Rio 2016 Olympics, only 19.8% of Dutch elite athletes were found to have caries, which is the lowest incidence among the studies (26). Similarly, Knight et al. 2018 reported 1 to 3 decays in 20.1% of the examined athletes competing in the Middle East (34).

Studies have shown a higher incidence of dental caries in elite athletes from the UK, as well as in those who participated in the London 2012 Olympic games and the 2019 Pan American Games in Lima. One study found that 49.1% of UK elite athletes had dental caries (28). Another study conducted on athletes from the London Olympic games reported that 55% of them had dental caries, while a different study found that 29% of athletes who participated in the Pan American games had dental caries (29, 41). A possible explanation for the increased caries levels among athletes might be the increase of the pH of athletes' saliva. This which may cause a dysbiotic microbiota and increase the likelihood of caries (35).

According to Merle et al. 2022 and Minty et al. 2018, competitive sport athletes are at a higher risk of developing dental caries compared to non-competitive athletes. One study found that 34% of young competitive athletes had caries, while only 19% of non-competitive athletes had caries (31). Another study comparing professional rugby players to a control group found that rugby players had a DMF index of 5.52, which was significantly higher than the control group's DMF index of 2.14 (35).

Another potential factor that makes athletes more susceptible to dental caries is a disturbance in their oral microbiota, mainly caused by a decrease in Streptococcus levels. This decrease leads to the formation of a biofilm that plays a crucial role in the development of dental caries (42). Minty et al. 2018 found

that professional rugby players had higher Streptococcus levels than non-athletes, which could be attributed to their higher consumption of carbohydrates and meats (35).

The higher level of DMF index score in athletes can be attributed to various factors, one of which is the increased mental stress experienced by athletes. This was demonstrated in a study by Minty et al. in 2018, where stress scores were determined using a 10-point scale. Professional rugby players had a stress score of 4, which was higher than that of the control group (2.68). The study found a positive correlation between the DMF index and stress score, indicating that higher levels of stress can lead to an increase in dental caries. (35)

In summary, the prevalence of dental caries is generally higher in athletes compared to non-athletes, with a worldwide prevalence estimated at 46% according to the latest meta-analysis (43). The high incidence of caries in athletes can be attributed to factors such as their diet, frequency of dental check-ups, increase in salivary ph and stress levels.

Pericoronitis

Pericoronitis is a form of oral inflammation that occurs around teeth that have only partially erupted. It is commonly observed in athletes, and numerous studies have investigated the prevalence of pericoronitis among them. In the general population, approximately 5% of individuals exhibit symptoms of pericoronitis between the ages of 20-25 years (44).

The prevalence of pericoronitis was found to be 1.1% among elite athletes in the UK (28). In contrast, 23.3% of athletes reported experiencing infections around their wisdom teeth area within the past year, which is significantly higher than the rates observed in the general population (44). Furthermore, during an examination of young German athletes, 15% were diagnosed with partially

erupted wisdom teeth, which may increase the likelihood of symptomatic pericoronitis (31). Notably, any symptoms experienced by athletes during competition can lead to reduced performance due to severe pain and discomfort (26). The third study investigated the prevalence of pericoronitis in athletes who participated in the 2012 London Olympic Games and found that 9.9% of them were diagnosed with the condition, which is higher than the rate observed in the general population (29). Moreover, the study found that 21.6% of Dutch elite athletes were advised to undergo extraction of one or more wisdom teeth, indicating the need for prompt management of Pericoronitis in athletes to prevent potential complications and improve their overall health and performance (26).

The high prevalence of pericoronitis among athletes can be attributed to the increased nutritional intake and subsequent accumulation of food and bacteria, particularly around partially erupted teeth. Poor oral hygiene practices, which may be associated with frequent travel and busy schedules, can further increase athletes' susceptibility to pericoronitis (44).

On the other hand, it is important to note that a study by Merle, Rott et al. in 2022 found similarly high rates of pericoronitis among professional biathletes and cross-country skiers as well as their non-athlete, gender and age-matched control group. The study diagnosed 20% of both athletes and non-athletes with pericoronitis, indicating that the risk of developing pericoronitis is not exclusive to athletes (30). These findings are consistent with previous studies, highlighting the need for effective prevention and treatment measures for pericoronitis in both athletes and non-athletes.

Comparing these studies suggests that pericoronitis is a prevalent condition among athletes, possibly due to increased nutritional intake and inadequate

oral hygiene practices. If left uncontrolled, pericoronitis can have a negative impact on athletes' performance and quality of life.

Performance

Maintaining good oral health is essential for athletes to ensure optimal performance and overall well-being. Therefore, understanding the significance of oral health in athletes is crucial. While an athlete's performance is influenced by multiple factors, including individual susceptibility to discomfort and pain, the connection between oral health and performance cannot be overlooked.

According to a study, 32% of elite UK athletes reported that their performance was affected by oral health reasons, with oral pain being the most reported issue at 29.9% (28). Poor oral health can have a significant negative impact on an athlete's ability to perform at their best. For instance, 9% of athletes reported that their oral health condition led to complications in participating in competitions or daily training, subsequently affecting their performance negatively (28). This could be due to pain, discomfort, or a lack of energy caused by the oral health problem.

Another negative effect of oral health was reported by 15.1% of the athletes who could not relax due to a present oral health condition. It's essential for athletes to be in a relaxed state of mind to perform at their best, and if they are unable to do so due to oral health problems, it can negatively affect their overall performance (28). This could also lead to sleep problems, which further exacerbate the issue.

Additionally, 34.6% of the examined athletes noted that they could not eat properly due to an oral health problem (34). This can lead to a lack of proper nutrition, which is crucial for athletes to perform at their best. Without proper nutrition, the athlete may feel weak and without energy, further affecting their performance negatively (28).

According to a survey of athletes, around 40% of them reported experiencing oral health problems (29). This high number of reported issues could potentially have a negative impact on their individual performance. In fact, 18% of athletes even reported that their current oral health status was negatively affecting their training or performance (29).
Achieving peak performance requires optimizing every factor, including oral health. However, given that almost half of the examined athletes were bothered by their oral health status, it is questionable whether they will be able to perform at their highest level.

It's important to note that not all studies have reported such drastic negative effects on performance as the previous study. For instance, in a study of Dutch elite athletes, it was found that the athletes had a high oral health-related quality of life and reported that their individual oral health status had a relatively low impact on their performance and training (26).
However, the difference in results between studies could be attributed to the origin and reason for participating in each study. In the Needleman et al.2013 study, the athletes were from developing countries where oral health status may be worse (29). Furthermore, the athletes in that study visited a dental clinic located inside the Olympic Games village, which may have influenced their decision to seek treatment for any oral health issues. In contrast, the Dutch athletes in the study participated voluntarily.

Injury

Several studies have examined the impact of oral health on the rate of injury in athletes and found that poor oral health can increase the risk of injuries unrelated to the oral cavity. In a study of professional football players (37), athletes with periodontitis were found to have a higher incidence of non-traumatic muscular injuries compared to non-athletes with periodontitis. Specifically, 55.6% of athletes experienced non-traumatic muscular injuries and 22.2% experienced articular injuries, while only 38.4% of non-athletes experienced non-traumatic muscular injuries and 7.2% experienced articular injuries (37).

The studies conducted by Solleveld et al. 2015 and Gay-Escoda et al. 2011 support the assertion that inadequate oral health can increase the likelihood of injuries and re-injuries. Solleveld et al. 2015 found in male elite soccer players that an unhealthy oral cavity was associated with muscle cramps and injuries (47). Similarly, Gay-Escoda et al. 2011 observed that players with deeper periodontal pockets experienced more muscle injuries (48). Therefore, maintaining good oral health may help reduce the risk of sports-related injuries.

The increased likelihood of muscle injury among athletes with poor oral health can be attributed to higher levels of serum creatine kinase, which is a marker of muscle damage measured via blood samples. Poor oral health can cause an increase in serum creatine kinase levels by increasing probing depth and bleeding on probing (45). Additionally, poor oral health can increase levels of cytokines, which are involved in the onset of muscle fatigue. Muscle fatigue can cause cramps and make the muscle more susceptible to injury (46).

6. Conclusion

Engaging in sports activities poses a significant risk to oral health. Athletes are more prone to oral health diseases than non-athletes, which is a complex issue that necessitates attention from the dental community. Athletes face the challenge of maintaining their oral health due to a combination of nutritional changes, mental stress, and changes in oral microbiome and saliva, making them more susceptible to oral health diseases. Hence, it is vital to increase awareness of athletes' unique oral health needs and develop efficient strategies to prevent and treat oral health diseases in this population. By doing so, we can assist athletes in maintaining optimal overall and oral health.

Maintaining good oral health is crucial for athletes to ensure optimal performance and overall well-being. The negative impact of poor oral health on an athlete's performance cannot be overlooked. Studies have shown that a significant proportion of athletes experience oral health problems that can affect their ability to perform at their best. Athletes experiencing pain, discomfort, and lack of energy due to oral health problems can face challenges in participating in competitions or daily training, affecting their performance negatively.

Ensuring good oral health is vital for athletes, not only to optimize their performance but also to prevent injuries unrelated to the oral cavity. The findings of several studies indicate that periodontitis can increase the risk of non-traumatic muscular injuries, which can negatively impact an athlete's performance and overall well-being. Therefore, promoting good oral hygiene practices and providing necessary oral health care to athletes can help prevent these injuries and contribute to their optimal performance.

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