



OPEN Endodontic status and oral health in athlete and non-athlete young adults in relation to nutrition and psychological factors

Edanur Maraş¹✉, Özge Başar^{1,2}, Nur Yorgancılar³, Gülce Berberoğlu^{4,5}, Gökhan Çakır⁴ & Oğuz Köse³

This cross-sectional study aimed to compare highly trained athletes and non-athlete individuals in terms of endodontic status and oral health parameters, considering nutritional and psychological factors. Highly trained athletes ($n=50$) and non-athlete individuals ($n=50$) aged 18–30 years were included. Clinical examination evaluated the endodontic and periapical status, decay experience (DMF-T), non-cariou tooth wear and periodontal indexes. The Oral Health Impact Profile-14 (OHIP-14), Perceived Stress Scale and Mental Well-Being Scale were administered. In addition, daily nutrient elements and potential renal acid load (PRAL) were calculated using a one-year food frequency questionnaire. Comparisons between the groups used the independent t-test/Mann-Whitney U test, Fisher's exact test and ANCOVA ($\alpha=0.05$). Athletes showed higher numbers of teeth requiring endodontic treatment, periapical index scores, decayed teeth, and periodontal index scores compared to non-athletes ($p<0.05$). PRAL, organic acid, vitamin D, B vitamins, meal frequency, and mental well-being were also higher in athletes ($p<0.05$). Sucrose, carbohydrate, and vitamin C intake had significant effects on endodontic status ($p<0.05$). The results revealed that athletes had higher numbers of teeth requiring endodontic treatment, decayed teeth, and periodontal symptoms. Education and prevention programs on oral care and nutrition may help improve their oral health.

Keywords Athletes, Diet, food, and nutrition, Endodontics, Oral health, Psychological well-being

The World Health Organization (WHO) defines oral health as a situation without disease or disorder like caries, periodontitis, infection, tumor and trauma, where chewing, talking, smiling and psychosocial well-being are sustainable¹. Inadequate oral health may negatively impact the quality of life, welfare and functional capacity of individuals. Though poor oral health is preventable, the prevalence of oral diseases is high in a variety of population groups. This issue is particularly relevant in athletic populations. Compromised oral conditions among athletes may adversely influence not only general health but also sporting performance². In fact, oral health was defined as an important public health problem at the 2004 Athena Olympics and it was reported that more than 50% of athletes at the 2012 London Olympics had caries, while more than 70% had periodontal disease^{3,4}. More recently, prior to the 2017 Tokyo Olympic Games, it was emphasized that athletes should undergo comprehensive screening with respect to caries, endodontic pathologies, periodontal diseases, pericoronitis, and the use of oral protectors⁵. Consistent with this burden, athletes have also been reported to experience poorer oral health-related quality of life compared with non-athlete individuals^{6,7}.

Several potential risk factors have been debated for oral diseases in competitive sports. Nutritional habits (high carbohydrate [CHO] or protein-specific diets, acidic drinks), psychological stress, changes to saliva and microbiota along with inadequate oral care habits can be listed among these risks⁸. High CHO intake increases caries development, while sports drinks with low pH may cause dental erosion. Fluid loss and dehydration during exercise may cause oral dryness by reducing saliva flow, potentially intensifying the negative effects of cariogenic foods on oral health⁹. Additionally, high micronutrient intake by athletes, regular physical activity

¹Faculty of Dentistry, Department of Endodontics, Recep Tayyip Erdoğan University, Rize, Turkey. ²Present address: Turkuaz Dental Clinics, Izmir, Turkey. ³Department of Periodontology, Faculty of Dentistry, Recep Tayyip Erdoğan University, Rize, Turkey. ⁴Department of Physical Education and Sports, Faculty of Sports Sciences, Recep Tayyip Erdoğan University, Rize, Turkey. ⁵Mapavri Healthy Life Center (Private Dietitian Clinic), Rize, Turkey. ✉email: edanur.maras@erdogan.edu.tr

and behavior focused on healthy life may have a protective effect on oral health. Taken together, these factors suggest that the oral health profile of athletes involves both risk-enhancing and protective components^{9,10}.

In this context, the concept of sports dentistry, which focuses on the prevention, diagnosis, and management of oral health problems that may affect athletes' general health and athletic performance, has gained increasing attention in recent years. Most studies in this field have primarily focused on dental trauma, caries prevalence, periodontal status, and preventive oral health practices. However, endodontic conditions, which may arise as a result of untreated caries, trauma, or advanced dental infections, have received considerably less attention in athletic populations^{4,11}. Nevertheless, endodontic pathologies may cause infection, pain, and functional limitations, thereby potentially compromising athletes' training continuity and competitive performance^{11,12}. In addition to these potential consequences, athlete-specific factors such as nutritional habits and psychological stress may contribute to the cumulative development of dental and endodontic pathologies in this population^{3,8,9}.

Although sports dentistry has increasingly been recognized as a distinct field, evidence regarding the endodontic status of athletes, as well as the potential effects of nutritional and psychological factors on this condition, remains limited¹¹. To the best of current knowledge, no previous study has simultaneously evaluated the endodontic status and overall oral health of athletes in relation to nutritional and psychological factors and compared these findings with those of non-athlete individuals. In light of all this information, the primary aim of this study was to compare endodontic status and oral health parameters between highly trained athletes and non-athlete young adults. The secondary aim was to investigate the possible relationships between endodontic status and oral health parameters with nutritional and psychological factors. The null hypothesis of the study was that there would be no significant difference between athletes and non-athlete individuals in terms of oral health profiles and correlated nutritional and psychological factors.

Methods

This cross-sectional observational study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist¹³. The study protocol was approved by the local ethics committee (no: 2024/275). The required sample size was determined to be 92 cases in total with 46 in each group based on a similar study⁸ (G*Power Ver. 3.1.9.7 Franz Faul, Kiel University, Germany). Considering possible data losses, the sample size per group was increased by 20%, and a total of 110 participants were included in the study. Highly trained athletes (athlete group) and non-athlete individuals (control group) who applied to the Faculty of Dentistry for treatment and met the eligibility criteria constituted the study population. The aim of the study was explained to participants verbally and in writing, and participants provided signed informed consent.

Intraexaminer calibration

Sociodemographic data were recorded, and the scales were administered by an experienced endodontist (EM). Nutritional characteristics were recorded by an experienced dietitian (GB). Clinical measurements were performed blindly. The experienced endodontist (OB) and periodontologist (NY), who would perform the clinical measurements, were trained and calibrated for the measurement of clinical parameters on 15 patients at two different periods (baseline and day 14) before the start of the study. Intra-examiner reliability was evaluated using the intraclass correlation coefficient (ICC) for the Gingival Index (GI), Probing Pocket Depth (PPD), and Decayed, Missing, and Filled Teeth (DMF-T), and the weighted Cohen's kappa for the Periapical Index (PAI). ICC values indicated good reliability for GI (0.867) and PPD (0.884), and excellent reliability for DMF-T (0.998), while the kappa value for PAI (0.898) showed almost perfect agreement^{14,15}.

Eligibility criteria

Eligibility criteria were defined as highly trained athletes and non-athlete individuals who were 18–30 years of age, had no medical history (ASA I), and consented to the use of data for scientific purposes. The athlete group consisted of highly trained athletes (Tier 3; national level) based on the six-tier Classification Framework proposed by McKay et al.¹⁶, which is grounded on training volume and competitive level. Accordingly, the inclusion criteria for athletes were participation in national championships/leagues within the last 2–3 years and regular training on ≥ 5 days per week for ≥ 2 h per day. Pregnant or breastfeeding women, individuals using analgesic drugs 12 h before assessment or using systemic antibiotics within the last 3 months, patients receiving periodontal treatment within the last 6 months, patients with stage II–III–IV periodontitis, patients with history of major chin trauma, and cases with sclerosing osteitis, idiopathic osteosclerosis, cyst, tumor or any other bone pathology were excluded from the study.

Sociodemographic characteristics and oral health behaviors

Age, gender, education and employment status, income level, sports discipline, body mass index (BMI), frequency of smoking and alcohol use, frequency of tooth brushing and frequency of dentist visits (general and in the last 12 months) were recorded.

Endodontic and periapical assessment

In the present study, endodontic status was assessed using the following parameters: the number of teeth requiring endodontic treatment, the number of teeth requiring retreatment (RT), the number of teeth with previous endodontic treatment, PAI scores, and the level of odontogenic pain. The number of teeth requiring endodontic treatment, number of teeth requiring retreatment (RT) and number of teeth with previous endodontic treatment were recorded.

Endodontic treatment need was determined based on a combination of patient history, clinical examination (spontaneous or prolonged pain, percussion and palpation sensitivity, and the presence of swelling or sinus tract), sensibility testing, and radiographic findings. Pulp sensibility was assessed using cold testing, and when necessary, responses were confirmed with an electric pulp test. All periapical radiographs were obtained using a phosphor storage plate system with a parallel radiographic technique (Myray parallel holder, NDental, Imola, Italy) under standardized exposure parameters (70 kV, 8 mA, 0.360 s). The images were subsequently processed and analyzed using TM Vistascan software (Dürr Dental, Stuttgart, Germany). Pulpal and periapical diagnoses were established according to the diagnostic terminology of the American Association of Endodontists (AAE)¹⁷.

The presence of periapical lesions with endodontic origin was evaluated using the Ørstavik¹⁸ PAI. In the presence of several apical lesions in teeth with multiple roots, the root with worst PAI score among all roots was used to represent the score for the relevant tooth. The PAI assessment criteria are as follows; score 1 for normal periapical area; score 2 for mild/suspicious changes in the periapical region; score 3 for an accompanying amount of mineral loss; score 4 for periapical lesion characterized by clear radiolucency at the margins; and score 5 for severe apical periodontitis with flare-up features.

Odontogenic pain levels were recorded using the numerical rating scale (NRS). The NRS has proven validity in a variety of patient groups and is an 11-stage pain scale between 0 and 10. Patients rate their pain from 0 (no pain) to 10 (most severe pain)¹⁹. Periapical radiographs were obtained using a phosphor plate (70 kV, 8 mA, 0.10 s) and processed with TM Vistascan software (Dürr Dental, Stuttgart, Germany).

Oral health assessment

Dental caries was assessed by combined visual–tactile clinical examination using a dental mirror and explorer under adequate illumination and radiographic evaluation. The total (DMF-T) for decayed (D), missing (M) and filled (F) teeth was recorded and each subcomponent (DT, MT, FT) was separately investigated⁸. Erosion, abrasion and attrition were recorded as present or absent. Periodontal assessments were completed with the Löe-Silness GI, Silness-Löe Plaque Index (PI), Ainamo & Bay Bleeding on Probing Index (BOP) and PPD measurements^{20,21}. PPD was measured at six different sites per tooth (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual) as the distance between the deepest point of the sulcus and the gingival margin. The other index scores were taken from four different points (mesial, distal, vestibular and palatal). Measurements were taken by a periodontist (NY) using a Williams probe (Hu-Friedy, Chicago, IL, USA).

Self-reported chin, facial and temporomandibular joint (TMJ) symptoms were evaluated with the following questions: ‘have you experienced pain or ache in the facial region in the last 12 months?’, ‘has there been pain or ache in the jaw region in the last 12 months?’ and ‘have you observed one or more of the following complaints in the jaw joint region in the last 12 months; pain at rest, pain with movement, clicking sounds or difficulty opening your mouth?’ Answer choices were no, occasionally, frequently and very frequently/continuously. Then responses were dichotomized by gathering no and occasionally responses in the no category and frequently and very frequently/continuously in the yes category²².

Nutritional assessment

A one-year food frequency questionnaire was administered to the participants to calculate their average daily nutrient intake²³. Based on the obtained data, a computer-based nutritional database software (Ebispro, Stuttgart, Germany; BeBiS [Nutrition Information System], Vers. 9.0) was used to determine some daily nutritional element intakes of individuals (vitamins B1, B2, B6, B12, C, A, D, E, K, calcium, folate, CHO, sucrose, starch, organic acid, antioxidant). Potential renal acid load (PRAL) calculation was used for dietary acid load calculation because of its strength in reflecting long-term dietary intake, including more nutrients than other formulas used in dietary acid load calculations, and including the intestinal absorption rate of nutrients²⁴. Additionally, the number of daily main meals, snacks and total number of meals were recorded for individuals.

Psychological and OHQoL assessments (PSS-10, SWEMWBS-7, OHIP-14)

Stress

Stress was measured using the 10-item version of the Perceived Stress Scale (PSS-10). The PSS-10 is a 10-item scale measuring the frequency of thoughts and feelings related to stress in a person within the previous month²⁵. Participants completed a Likert-type scale varying from 0 (never) to 4 (very often). A higher total score on the PSS-10 indicates a higher level of perceived stress²⁶. In studies comparing athlete and non-athlete young individuals, stress levels have been determined using the PSS-10^{25,27}. The PSS-10 was used in this study to determine the effects of the stress factor on oral health and whether stress levels differed between the athlete group and control group. In the present study, the Cronbach alpha value for the PSS-10 was 0.72.

Mental well-being

Mental well-being was evaluated using the Warwick-Edinburgh Mental Well-Being Scale-7 (SWEMWBS-7). The SWEMWBS-7 is a 7-item 5-point Likert-type scale measuring positive mood and mental welfare dimensions. High total scores reflect better mental well-being²⁸. The SWEMWBS-7 is frequently used with the aim of assessing the mental well-being of athletes^{29,30}. In this study, the SWEMWBS-7 was used with the aim of investigating differences between the groups in terms of mental well-being and to evaluate possible effects of positive psychological status on oral health indicators. In the present study, the Cronbach alpha value for the SWEMWBS-7 was 0.82.

Oral health–related quality of life (OHQoL)

Evaluation of the OHQoL used the short form of the Oral Health Impact Profile (OHIP-14) based on self-reports by patients³¹. The OHIP-14 comprises 14 items evaluating disease–impairment–disability–handicap in relation to oral health³². Responses are rated on a 5-point Likert scale varying from never (0 points) to very frequently (4 points). High OHIP-14 scores indicate lower OHQoL³³. In the present study, the Cronbach alpha value for the OHIP-14 was 0.87.

Statistical analysis

In this study, descriptive statistics were presented as number, percentage, mean, standard deviation, median, and 25th and 75th percentiles. The reliability of the scales used in the study was tested. In evaluating the internal consistency reliability of the scales, coefficients of 0.70 and above were considered indicative of acceptable reliability. Demographic characteristics were presented according to the study groups, and the relationships between categorical variables were examined using the Pearson chi-square test. In cases where the expected cell frequencies were insufficient, Fisher's exact test was applied. In order to examine the differences between the groups, preliminary analyses were conducted prior to the main statistical tests. The assumption of normal distribution was checked using the Shapiro–Wilk test, and the homogeneity of variances was assessed using the Levene test ($p < 0.05$). When the normality assumption was met, the independent samples t-test was used to compare the athlete and control groups in terms of mental well-being, OHIP-14, perceived stress levels, nutritional intake amounts, and clinical measurements. When the normality assumption was not satisfied, the Mann–Whitney U test, a non-parametric alternative, was used for comparisons between the two independent groups. Analysis of covariance (ANCOVA) was conducted to examine covariance-adjusted differences between independent groups in terms of the number of decayed teeth, joint pain, other clinical parameters, and the effect of gender on endodontic status and oral health parameters, while statistically controlling for potential nutritional and psychological covariates. Prior to the ANCOVA analysis, the assumptions were tested; the measurement reliability of the covariates, the possibility of high correlations among covariates ($r \leq 0.80$), and the linearity assumption were evaluated, and all assumptions were satisfied. In order to control the risk of Type I error in multiple comparisons, post hoc Bonferroni analysis was applied for variables showing statistical significance. All analyses were performed using IBM SPSS 27, and the statistical significance level was set at $p \leq 0.05$.

Results

Demographic characteristics

After applying the exclusion criteria, five patients were excluded from the study due to recent use of antibiotics or analgesics. One patient diagnosed with Stage III periodontitis and two patients who had recently undergone non-surgical periodontal therapy were excluded. Two patients declined to participate in the study. Consequently, 100 individuals were included in the study. No participants were lost to analysis. There were no protocol deviations or changes in participant recruitment or study duration. A total of 50 highly trained athletes and 50 non-athlete individuals were included in the study.

Mean age was 21.50 (± 4.38) years in the athlete group and 24.10 (± 3.67) years in the control group. In the athlete group, the proportion of male individuals (68%) was higher, while in the control group the proportion of female individuals (68%) was higher. The distribution of athletes by sports discipline was as follows: football ($n = 16$; 32%), volleyball ($n = 11$; 22%), and handball ($n = 23$; 46%). When the duration of being a licensed athlete is investigated according to discipline, values were $\bar{x} = 9.12$ (± 2.06) years for football, $\bar{x} = 9.72$ (± 3.28) years for volleyball and $\bar{x} = 12.00$ (± 4.97) years for handball.

In the group categories (athlete and control), statistically significant associations were identified between gender, marital status, frequency of tooth brushing, frequency of dental visits, smoking, and alcohol use ($p < 0.05$). In the athlete group, the rate of going to the dentist only when they had a complaint was higher, while the rate of attending regular dentist visits was higher in the control group (Table 1).

Clinical measurements

Individuals in the athlete group were found to have significantly higher numbers of teeth requiring endodontic treatment, numbers of decayed teeth, PAI, PI, GI and BOP scores compared to the control group ($p < 0.05$). Individuals in the control group had higher jaw pain and joint pain levels compared to the athlete group ($p < 0.05$).

No statistically significant differences were identified between the two groups in terms of number of teeth requiring RT, number of teeth with previous endodontic treatment, numbers of missing and filled teeth, BMI, PPD, NRS, DMF-T and facial pain levels ($p > 0.05$) (Table 2).

In the athlete group 0 erosion (0%), 9 abrasion (18%) and 3 attrition (6%) cases were identified, while in the control group 2 erosion (4%), 5 abrasion (10%) and 3 attrition (6%) cases were identified.

Nutritional parameters and number of meals

The PRAL, organic acid, vitamin D, vitamin B12, vitamin B2, vitamin B6, folate and calcium levels were significantly higher in the athlete group compared with the control group ($p < 0.05$). Additionally, there were no significant differences observed between the two groups in terms of sucrose, starch, CHO, antioxidants, vitamin A, vitamin E and vitamin C levels ($p > 0.05$).

In the athlete group, the total number of meals, number of snacks and number of main meals were significantly higher compared to the control group ($p < 0.05$) (Table 3).

		Athlete group		Control group		Test statistic	p
		n	%	n	%		
Gender	Male	34	68.0	16	32.0	12.960 ^a	<0.001*
	Female	16	32.0	34	68.0		
Marital status	Married	2	4.0	9	18.0	5.005 ^a	0.025*
	Single	48	96.0	41	82.0		
Educational level	Primary school	0	0.0	1	2.0	4.770 ^b	0.059
	High school	37	74.0	27	54.0		
	University	13	26.0	22	44.0		
Employment status	Unemployed	27	54.0	31	62.0	0.657 ^a	0.418
	Employed	23	46.0	19	38.0		
Income level	No income	27	54.0	29	58.0	4.253 ^b	0.234
	17,000 TL or lower	1	2.0	4	8.0		
	17,001–39,999 TL	8	16.0	10	20.0		
	40,000 TL or more	14	28.0	7	14.0		
Discipline	Football	16	32.0	0	0.0	–	–
	Volleyball	11	22.0	0	0.0		
	Handball	23	46.0	0	0.0		
Frequency of dentist visits	Never been	2	4.0	0	0.0	5.754 ^b	<0.001*
	If I have a problem	41	82.0	34	68.0		
	Attend regularly	7	14.0	16	32.0		
Attendance at dentist within the last 12 months	0	18	36.0	7	14.0	10.858 ^b	0.055
	1	14	28.0	19	38.0		
	2	13	26.0	16	32.0		
	3	3	6.0	5	10.0		
	4	2	4.0	0	0.0		
Frequency of toothbrushing	Never	0	0.0	2	4.0	8.287 ^b	0.010*
	1 per day	0	0.0	1	2.0		
	2 or more per day	3	6.0	1	2.0		
Smoking	Never	23	46.0	11	22.0	7.550 ^b	0.022*
	Occasionally	24	48.0	38	76.0		
	Regularly	28	56.0	38	76.0		
Alcohol	Never	3	6.0	5	10.0	14.918 ^a	<0.001*
	Occasionally	19	38.0	7	14.0		

Table 1. Distribution of demographic characteristics in athlete and control groups. * $p < 0.05$; ^aPearson chi-square test; ^bFisher's exact test; %: Column percentage.

PSS-10, SWEMWBS-7 and OHIP-14 scores

The mental well-being scores of the athlete group were found to be significantly higher compared to the control group ($p < 0.05$). However, there were no statistically significant differences identified between the groups in terms of OHIP-14 and perceived stress levels ($p > 0.05$) (Table 4).

Number of decayed teeth (ANCOVA; covariate-adjusted)

The ANCOVA test was used to compare the number of decayed teeth according to the study groups in relation to the effects of nutritional and psychological parameters. The results of the analysis determined that OHIP-14 ($p = 0.001$), antioxidant ($p = 0.015$) and vitamin E ($p = 0.032$) intake had statistically significant effects on the number of caries. Contrary to this, other nutritional and psychological factors were not found to have statistically significant effect on the number of caries ($p > 0.05$).

When all these variables were controlled, a statistically significant difference was found between the athlete and control groups in terms of the number of decayed teeth ($p < 0.05$) (Table 5).

Joint pain (ANCOVA; covariate-adjusted)

ANCOVA testing was applied to compare joint pain according to working groups with the effect of nutritional and psychological parameters. The results of the analysis determined that OHIP-14 scores had statistically significant effect on joint pain ($p = 0.012$). The other nutritional and psychological factors were not found to have statistically significant effect on joint pain ($p > 0.05$).

Between the athlete and control groups, when all these variables are controlled, no statistically significant differences were found in terms of the presence of joint pain ($p > 0.05$) (Table 6).

	Athlete group		Control group		Test statistic	p
	Mean ± S.D. (M.)	25%Q.-75%Q.	Mean ± S.D. (M.)	25%Q.-75%Q.		
BMI	23.64 ± 2.93(23.15)	22.04–25.77	23.73 ± 4.29(22.86)	20.96–25	−0.827 ^a	0.408
Number of teeth requiring endodontic treatment	1.56 ± 1.80(1)	0–2	0.70 ± 0.76(1)	0–1	−2.436 ^a	0.015*
PAI	2.16 ± 1.84(2)	0–4	1.02 ± 1.00(1.5)	0–2	−3.233 ^a	0.001*
Number of teeth requiring RT	0.56 ± 1.01(0)	0–1	0.48 ± 0.74(0)	0–1	−0.069 ^a	0.945
Number of teeth with previous endodontic treatment	1.58 ± 2.14(1)	0–2	1.42 ± 1.80(1)	0–2	−0.206 ^a	0.837
NRS	1.86 ± 1.95(2)	0–3	1.70 ± 2.08(0)	0–3	−0.532 ^a	0.595
D-T	3.76 ± 2.06(3)	3–5	1.98 ± 2.10(1)	0–3	−4.199 ^a	<0.001*
M-T	0.38 ± 0.85(0)	0–0	0.56 ± 1.18(0)	0–1	−0.852 ^a	0.394
F-T	3.50 ± 3.48(3)	0–6	4.02 ± 3.35(3)	1–6	−0.953 ^a	0.341
DMFT	7.64 ± 4.86(6)	3–11	6.56 ± 4.08(6.5)	3–9	−0.841 ^a	0.401
Facial pain	0.30 ± 0.46(0)	0–1	0.36 ± 0.66(0)	0–1	−0.110 ^a	0.912
Jaw pain	0.30 ± 0.46(0)	0–1	0.68 ± 0.87(0)	0–1	−2.076 ^a	0.038*
Joint pain	0.42 ± 0.86(0)	0–1	0.72 ± 0.95(0)	0–1	−2.022 ^a	0.043*
PI	1.17 ± 0.58(1.11)	0.75–1.5	0.96 ± 0.4(0.95)	0.66–1.19	2.050 ^b	0.043*
GI	0.57 ± 0.49(0.54)	0.75–1.5	0.37 ± 0.29(0.32)	0.16–0.5	−2.063 ^a	0.039*
BOP	0.16 ± 0.15(0.14)	0.03–0.26	0.09 ± 0.08(0.07)	0.03–0.14	−2.578 ^a	0.010*
PPD	2.61 ± 0.43(2.54)	2.24–2.85	2.7 ± 0.38(2.7)	2.39–2.91	−1.496 ^a	0.135

Table 2. Distribution and comparison of clinical measurements between athlete and control groups. Abbreviations: BMI, body mass index; BOP, bleeding on probing; DMF-T, decayed-, missing- and filled-teeth index; D-T, decayed teeth; F-T, filled teeth; GI, gingival index; M-T, missing teeth; PAI, periapical index; PI, plaque index; PPD, probing pocket depth; RT, retreatment; * $p < 0.05$; ^a Mann-Whitney U test; ^b Independent samples t-test.

	Athlete group		Control group		Test statistic	p
	Mean ± S.D. (M.)	25%Q.-75%Q.	Mean ± S.D. (M.)	25%Q.-75%Q.		
PRAL	8.14 ± 44.12(5.64)	−16.84–43.13	−8.71 ± 19.51(−11.34)	−21.85–4.71	2.470 ^a	0.016*
Org. ac. (g)	14.27 ± 9.1(12.91)	6.9–17.9	10.28 ± 3.73(10.62)	7.32–12.06	−2.006 ^b	0.045*
Sucrose (g)	63.59 ± 41.51(50.72)	30.24–78.37	50.7 ± 29.65(42.94)	31.52–61.61	−1.468 ^b	0.142
Starch (g)	146.52 ± 110.6(98.17)	70.64–206.28	148.96 ± 80.11(128.31)	95.2–191.66	−1.206 ^b	0.228
CHO (g)	330.4 ± 188.75(284.12)	183.83–414.52	294.79 ± 130.97(270.45)	210.94–348.91	−0.352 ^b	0.725
Antioxidant (mmol)	7.03 ± 4.08(6.51)	4.17–9.49	7.6 ± 4.21(6.77)	5.38–9.19	−0.610 ^b	0.542
A Vit. (µg)	3668.93 ± 3693.01(2868.47)	1564.64–4675.89	3232.08 ± 3554.41(2247.42)	1536.57–3593.64	−1.448 ^b	0.148
D Vit. (µg)	12.45 ± 7.85(12.06)	5.74–16.18	8.08 ± 5.29(6.59)	4.56–10.01	−3.061 ^b	0.002*
E Vit. (mg)	26.88 ± 14.95(24.72)	15.73–34.08	30.32 ± 18.52(24.58)	17.45–39.22	−0.576 ^b	0.565
K Vit. (µg)	205.33 ± 230.3(142.6)	81.74–217.59	230.86 ± 186.89(166.25)	95.4–297.72	−1.241 ^b	0.215
B12 Vit. (µg)	15.96 ± 14.3(11.79)	7.5–20.51	9.19 ± 11.13(5.59)	3.85–10.19	−4.102 ^b	<0.001*
B1 Vit./Thiamin (mg)	1.79 ± 0.99(1.67)	1.19–2.02	1.48 ± 0.61(1.4)	1.1–1.66	−1.510 ^b	0.131
B2 Vit./Ribofl. (mg)	3.59 ± 1.75(3.24)	2.63–4.14	2.23 ± 1.1(1.86)	1.45–2.69	−4.654 ^b	<0.001*
B6 Vit./Pyrid. (mg)	2.90 ± 1.6(2.45)	2.03–3.37	2.09 ± 0.84(1.97)	1.55–2.4	−3.233 ^b	0.001*
Folate tot. (µg)	661.54 ± 369.82(574.09)	419.62–757.89	504.89 ± 246.55(450.64)	363.8–558.38	−2.709 ^b	0.007*
C Vit. (mg)	293.84 ± 189.21(266.35)	128.33–401.33	255.08 ± 111.87(246.43)	185.15–313.36	−0.810 ^b	0.418
Calcium (mg)	1823.67 ± 1034.85(1591.46)	1143.17–2223.48	1124.02 ± 460.74(1008.22)	780.47–1239.26	−4.233 ^b	<0.001*
Total number of meals	3.16 ± 0.91(3)	3–4	2.54 ± 0.73(2)	2–3	−3.739 ^b	<0.001*
Number of snacks	0.84 ± 0.74(1)	0–1	0.44 ± 0.70(0)	0–1	−2.972 ^b	0.003*
Number of main meals	2.34 ± 0.69(2)	2–3	2.10 ± 0.42(2)	2–2	−2.398 ^b	0.017*

Table 3. Distribution and comparison of nutritional amounts between athlete and control groups. Abbreviations: CHO, Carbohydrate; Org. Ac., organic acid; PRAL, potential renal acid load; Pyrid, Pyridoxine; Ribofl, Riboflavin; Tot, total; Vit, vitamin; * $p < 0.05$; ^a Independent samples t-test; ^b Mann-Whitney U test.

	Athlete group		Control group		Test statistic	<i>p</i>
	Mean ± S.D. (M.)	25%Q.–75%Q.	Mean ± S.D. (M.)	25%Q.–75%Q.		
Mental well-being	28.42 ± 3.84(28.5)	26–30	26.72 ± 4.29(27)	24–29	2.087 ^a	0.040*
OHIP-14	8.18 ± 7.18(6)	3–13	9.12 ± 8.09(7)	1–15	−0.454 ^b	0.650
Perceived stress	34.7 ± 5.16(35.5)	31–38	36.74 ± 6.78(37)	32–43	−1.694 ^a	0.093

Table 4. Distribution and comparison of scale scores for athlete and control groups. Abbreviations: OHIP-14, Oral Health Impact Profile-14; * $p < 0.05$; ^aIndependent samples t-test; ^bMann-Whitney U test.

Source	Type 3 total squares	Mean squares	F	<i>p</i>
Corrected model	241.065	10.044	2.873	<0.001*
Fixed	6.709	6.709	1.919	0.170
Total number of means	7.188	7.188	2.056	0.156
Number of snacks	8.245	8.245	2.358	0.129
Number of main meals	5.172	5.172	1.479	0.228
Mental Well-Being	4.086	4.086	1.168	0.283
OHIP-14	42.589	42.589	12.180	0.001*
Perceived stress	1.106	1.106	0.316	0.576
PRAL	0.206	0.206	0.059	0.809
Org. ac. (g)	0.008	0.008	0.002	0.962
Sucrose (g)	8.234	8.234	2.355	0.129
Starch (g)	5.887	5.887	1.684	0.198
CHO (g)	8.480	8.480	2.425	0.124
Antioxidant (mmol)	21.595	21.595	6.176	0.015*
A Vit. (µg)	0.783	0.783	0.224	0.637
D Vit. (µg)	1.652	1.652	0.473	0.494
E Vit. (mg)	16.765	16.765	4.795	0.032*
K Vit. (µg)	5.847	5.847	1.672	0.200
B12 Vit. (µg)	0.578	0.578	0.165	0.686
B1 Vit./Thiamin (mg)	1.391	1.391	0.398	0.530
B2 Vit./Ribofl. (mg)	0.625	0.625	0.179	0.674
B6 Vit./Pyrid. (mg)	4.806	4.806	1.375	0.245
Folate tot. (µg)	1.072	1.072	0.307	0.581
C Vit. (mg)	0.291	0.291	0.083	0.774
Calcium (mg)	5.055	5.055	1.446	0.233
Group	42.325	42.325	12.105	0.001*
Error	262.245	3.497		
Total	1327.000			
Corrected total	503.310			

Table 5. Effect of nutritional and psychological parameters on the number of decayed teeth in athlete and control groups. Abbreviations: CHO, Carbohydrate; OHIP-14, Oral Health Impact Profile-14; Org. Ac., organic acid; PRAL, potential renal acid load; Pyrid, Pyridoxine; Ribofl, Riboflavin; Tot, total; Vit, vitamin; * $p < 0.05$.

Other clinical parameters (ANCOVA; covariate-adjusted)

The ANCOVA test was applied to compare other clinical parameters between the study groups in relation to the effects of nutritional and psychological parameters. The results of the analyses determined that sucrose ($p = 0.001$), starch ($p = 0.015$), CHO ($p = 0.003$) and vitamin C ($p = 0.001$) intake had statistically significant effects on the number of teeth requiring RT. Sucrose ($p = 0.030$), CHO ($p = 0.036$) and vitamin C ($p = 0.017$) intake were identified to have statistically significant effects on the number of teeth with previous endodontic treatment. Vitamin B12 ($p < 0.001$) and vitamin K ($p = 0.041$) levels were observed to have statistically significant effects on NRS scores. Sucrose intake ($p = 0.036$), OHIP-14 ($p = 0.020$) and PSS-10 ($p = 0.027$) scores had statistically significant effects on DMF-T scores. Nutritional and psychological factors did not have statistically significant effects on number of missing teeth, number of filled teeth and PPD scores ($p > 0.05$).

When all these variables are controlled, no statistically significant difference was obtained between the athlete and control groups in terms of number of teeth requiring RT, number of teeth with previous endodontic treatment, number of missing teeth, number of filled teeth, NRS scores, PPD and DMF-T scores ($p > 0.05$) (Supplementary Tables S1–S7).

Source	Type 3 total squares	Mean squares	F	<i>p</i>
Corrected model	23.075	0.961	1.213	0.259
Fixed	0.301	0.301	0.380	0.539
Total number of meals	0.080	0.080	0.101	0.752
Number of snacks	0.094	0.094	0.119	0.732
Number of main meals	0.020	0.020	0.025	0.876
Mental well-being	0.411	0.411	0.518	0.474
OHIP-14	5.222	5.222	6.590	0.012*
Perceived stress	0.560	0.560	0.706	0.403
PRAL	0.123	0.123	0.155	0.695
Org. ac. (g)	2.859	2.859	3.608	0.061
Sucrose (g)	0.407	0.407	0.514	0.476
Starch (g)	1.409	1.409	1.778	0.186
CHO (g)	0.968	0.968	1.221	0.273
Antioxidant (mmol)	0.153	0.153	0.193	0.662
A Vit. (µg)	0.390	0.390	0.492	0.485
D Vit. (µg)	0.298	0.298	0.377	0.541
E Vit. (mg)	0.672	0.672	0.848	0.360
K Vit. (µg)	0.694	0.694	0.875	0.353
B12 Vit. (µg)	0.428	0.428	0.540	0.465
B1 Vit./Thiamin (mg)	0.010	0.010	0.013	0.911
B2 Vit./Ribofl. (mg)	1.106	1.106	1.396	0.241
B6 Vit./Pyrid. (mg)	0.406	0.406	0.512	0.476
Folate tot. (µg)	0.287	0.287	0.362	0.549
C Vit. (mg)	2.577	2.577	3.253	0.075
Calcium (mg)	1.443	1.443	1.820	0.181
Group	0.028	0.028	0.035	0.851
Error	59.435	0.792		
Total	115.000			
Corrected total	82.510			

Table 6. Effect of nutrition and psychological parameters on comparison of presence of joint pain in athlete and control groups. Abbreviations: CHO, Carbohydrate; OHIP-14, Oral Health Impact Profile-14; Org. Ac., organic acid; PRAL, potential renal acid load; Pyrid, Pyridoxine; Ribofl, Riboflavin; Tot, total; Vit, vitamin; * $p < 0.05$.

Effect of gender on endodontic status and oral health parameters (ANCOVA; covariate-adjusted)

The ANCOVA test was applied to compare endodontic status and oral health parameters between the study groups, with gender included as a covariate. The main effect of gender was not statistically significant on the number of teeth requiring endodontic treatment and RT, PAI and NRS scores, DT, MT, PI, GI, BOP, facial pain, or jaw pain ($p > 0.05$). However, the main effect of gender was statistically significant on FT, DMFT, PPD, and the number of teeth with previous endodontic treatment ($p < 0.05$).

When gender was controlled for, no statistically significant differences were observed between the athlete and control groups in terms of the number of teeth with previous endodontic treatment, the number of teeth requiring RT, NRS scores, facial pain, joint pain, FT, DMFT, PI, or GI ($p > 0.05$). In contrast, significant differences were observed between the groups with respect to the number of teeth requiring endodontic treatment, PAI scores, DT, MT, BOP, PPD, and jaw pain ($p < 0.05$) (Supplementary Tables S8-S23).

Discussion

The inadequate oral health observed in athletes has critical importance in terms of general health and athletic performance. Nutrition rich in terms of CHO and psychological factors were reported to possibly be related to oral health problems observed in this population^{34,35}. To the best of current knowledge, this is the first study to compare athletes and non-athlete individuals by jointly evaluating endodontic status and oral health in relation to quantitative nutritional intake and psychological factors, including perceived stress and mental well-being.

The findings revealed distinct differences in oral disease profiles between athletes and non-athlete individuals. Athletes exhibited a greater number of teeth requiring endodontic treatment, increased caries experience, and higher PAI, PI, GI, and BOP scores, indicative of more pronounced active endodontic and periodontal disease parameters. In contrast, non-athlete individuals reported higher levels of jaw and TMJ pain. This difference suggests that athletes may be more affected by subclinical and active oral disease parameters. In line with these findings, the null hypothesis that athletes and non-athlete individuals were similar in terms of endodontic status

and oral health was rejected. These findings are consistent with previous evidence indicating a high prevalence of caries burden and periodontal disease among athletes^{8,36–40}. Previous studies have similarly reported a high burden of oral diseases among athletes. For example, professional footballers in Thailand were shown to have very poor oral health, with a high prevalence of dental caries⁴⁰, while elite athletes from various sports disciplines in the United Kingdom exhibited substantial rates of dental caries (49%), erosion (41%), and periodontal findings (77%)³⁹. Moreover, approximately one-third of athletes reported dissatisfaction with their oral health and indicated that it negatively affected their sports performance^{39,40}.

A study evaluating the oral health status of German athletes aged 18–30 years reported most athletes had high findings of gingival inflammation (58–85%). Additionally, the prevalence of caries in competitive athletes (34%) was higher than amateur athletes (19%); while the DMF-T values in both groups were similar. These results are consistent with the present findings. However, unlike the present findings, that study reported a higher prevalence of TMJ symptoms among competitive athletes⁸. The German Society for Craniomandibular Function and Disorders recommends that patients with joint disorders engage in physical activity to compensate for daily stress⁴¹. In this context, the risk of joint disorders observed in athletes may have been compensated through regular physical activity⁴². Additionally, Freiwald et al.⁴² reported that findings related to TMJ disorder in athletes had a broad range in the literature (between 11.7 and 100%). It is difficult to compare these findings due to reasons such as the very small or variable case numbers (ranging from 8 to 347), evaluation of dominantly male athletes and different methodological approaches (such as self-assessment survey, different clinical indexes or clinical examination)^{8,42}. In addition, the available data are mostly based on contact sports⁴², whereas the present study examined contact and limited-contact sports disciplines⁴³. These findings show the need for more research related to the prevalence, determinants and outcomes of TMJ symptoms in the athletic population⁴².

When high-performance athletes seeking dental care during the 2019 Pan American Games were examined, pre-existing oral pathological conditions (most commonly periodontal diseases and dental caries) were observed in 90.8% of the athletes. Additionally, one of the most notable findings of this descriptive study was that the prevalence of trauma (9.2%) was much lower than the prevalence of dental diseases (90.8%)⁴⁴. Because dental emergencies during sports competitions are generally expected to be trauma-related, the focus of sports dentistry research has frequently been on traumatic dental injuries^{32,44–46}. Indeed, to date, endodontic diseases in athletes outside the context of trauma have not been previously investigated^{47,48}. In a study examining trauma-related endodontic sequelae, McCarthy et al.⁴⁸ reported findings consistent with the present study, with the majority of boxers exhibiting gingivitis (88.5%), a small proportion presenting periodontal pocket depths greater than 3 mm (11.5%), and dental caries (11.5%). In addition, dental and endodontic sequelae were more frequently identified in older boxers who had participated in a greater number of competitions. In this study, while the number of teeth requiring endodontic treatment and PAI scores of athletes were higher compared to non-athletes, the number of teeth requiring RT, teeth with previous endodontic treatment and pain with endodontic origin were identified to be similar in both groups. It should be noted that the present study included young adults aged 18–30 years. Considering the cumulative exposure associated with aging, an increase in endodontic treatment needs and other endodontic disease parameters parallel to periapical pathology may be expected in older athletes. Taken together, these findings indicate a dissociation between clinical symptoms and the underlying endodontic disease burden in athletes. Despite higher numbers of teeth requiring endodontic treatment and increased PAI scores, no parallel increase was observed in pain levels, RT needs, or OHQoL. This pattern suggests that a substantial proportion of endodontic lesions in athletes may be chronic, early-stage, or clinically silent. In high-performance populations, this asymptomatic disease burden may be further accentuated by adaptive pain perception, high pain tolerance, and delayed care-seeking behaviors driven by intensive training demands and competition priorities. Indeed, the literature reports that pain perception in athletes may be more adaptive⁴⁹; in populations where care-seeking behavior is largely pain-driven, this may be associated with reduced symptom-based dental attendance and delayed treatment^{4,30,50}. From a clinical perspective, this dissociation underscores the inadequacy of relying solely on symptom-based dental visits in athletes and highlights the importance of regular preventive oral health screening and early radiographic assessment outside of competition periods⁴⁴.

Another parameter frequently investigated in athletes is non-cariious tooth wear, encompassing erosion, abrasion, and attrition. A meta-analysis reported a prevalence of erosion of 47% among athletes⁵⁰. Consistent with the findings of the present study, Merle et al.⁸ identified mild non-cariious tooth wear in athletes aged 18–30 years. Although the present study focused on young adults, abrasion was observed in 18% of athletes, suggesting that non-cariious tooth wear may increase with age and that group differences may become more pronounced over time. Non-cariious tooth wear is a multifactorial condition influenced by dietary habits, oral hygiene practices, and behavioral factors. Therefore, multivariate analyses are required to better elucidate the multiple risk factors associated with tooth wear in athletic populations⁵¹.

Professional athletes are exposed to a specific lifestyle combining special diets, sugar consumption during exercise, mental stress and/or increased orofacial trauma risk. Oral health behaviors may also be adversely affected in parallel with these factors^{8,35,52}. Consistent with the literature, it was observed that problem-oriented dental visits were more common among athletes than regular dental check-ups. This situation may be related to intense training schedules, issues of accessibility or prioritization, and the insufficient integration of preventive care into sports programs^{4,32,53}. One of the differences related to lifestyle is that the incidence of smoking and alcohol consumption is lower among athletes; this tendency is compatible with the literature reporting lower tobacco and alcohol consumption among physically-active individuals³⁵.

Rather than acting as isolated risk factors, nutritional variables in athletes appear to function as modulators of oral and endodontic disease risk within a broader behavioral and physiological context^{54–56}. In addition to behavioral features, both the amount and frequency of carbohydrate intake, as well as sports-specific daily protein consumption, have previously been reported as key contributors to increased caries risk among athletes⁵⁴. In the present study, although total carbohydrate intake did not differ significantly between athletes and non-athletes,

athletes exhibited higher meal frequency, PRAL, and organic acid intake. These findings suggest that not only absolute nutrient amounts, but also the timing and frequency of dietary exposure, may be critical determinants of oral disease risk. Such dietary patterns, when combined with exercise-induced dehydration and reduced salivary flow during training, may create a physiological environment that favors oral demineralization and caries development^{54–56}. Consistent with this interpretation, athletes continued to exhibit a higher number of decayed teeth even after controlling for all evaluated nutritional and psychological factors. This persistent difference may be attributable to dehydration during sports activity, physicochemical alterations in saliva, or differences in oral microbiota composition^{54,57}. At the same time, higher levels of vitamin D, B-group vitamins, and calcium observed in athletes indicate the coexistence of protective nutritional behaviors, underscoring the dual role of nutrition as both a risk-enhancing and protective modulator of oral health^{35,55}. In addition, consistent with the literature, OHIP-14 scores, antioxidant levels, and vitamin E levels were observed to influence the number of decayed teeth^{58,59}. Similarly, Hussein and Hussein⁵⁸ reported that vitamin E and antioxidant levels in salivary samples of children with dental caries were lower compared to those in children without caries. Together, these findings suggest that oral disease risk in athletes is shaped less by single dietary components and more by cumulative exposure patterns, behavioral habits, and sport-specific physiological conditions^{54–56,59}.

Importantly, specific dietary components were also found to influence endodontic status. Intake of sucrose, carbohydrates, and vitamin C showed significant effects on the number of endodontically treated teeth and teeth requiring retreatment, while sucrose and carbohydrate intake may have indirectly increased endodontic treatment needs by elevating caries risk³⁵. Vitamin C supplementation, on the other hand, has been reported to enhance healing processes and reduce periodontal disease risk, suggesting a complex and context-dependent relationship between micronutrient intake and endodontic outcomes^{60,61}. However, the mechanisms linking these nutrients to endodontic status remain unclear, and further clinical studies are required to elucidate these associations.

When the literature is examined, higher levels of physical activity are consistently associated with greater psychological well-being^{62,63}. In the present study, the higher mental well-being observed in the athlete group compared to the control group supports the beneficial role of regular physical activity in promoting psychological health. Importantly, despite this higher mental well-being, perceived stress and OHIP-14 scores were similar between athletes and non-athletes. This apparent dissociation suggests that competitive stressors inherent to athletic life, such as intensive training schedules and performance pressure, may coexist with adaptive psychological mechanisms developed through regular physical activity and sport participation. In support of this interpretation, a meta-analysis has demonstrated that athletes consistently exhibit higher pain tolerance compared to normally active control groups⁶⁴. While pain thresholds are considered relatively stable, pain tolerance is reported to be strongly modulated by psychological and psychosocial factors such as self-efficacy, pain acceptance, and coping skills^{5,46,65}. Regular exposure to intense physical and psychological demands may enable athletes to develop more effective pain-coping strategies over time and to regulate pain perception in a more adaptive manner^{49,64}. Similarly, Gerber et al.⁶⁵ reported that mental resilience may buffer perceived stress and related burnout or depressive symptoms in young elite athletes. Such adaptive psychological mechanisms may have attenuated the impact of clinical or functional problems on subjective OHQoL by regulating stress perception, symptom reporting, and disease appraisal^{49,66–68}. Consistent with this perspective, Kragt et al.² demonstrated generally high OHQoL among Dutch elite athletes despite a substantial oral disease burden. Additionally, in this study, the significant effect of the OHIP-14 scores on DMF-T score and joint pain shows that the subjective evaluation of oral health by individuals may be closely related not just to dental caries but also to functional problems like joint pain. Taken together, these findings indicate that psychological adaptation in athletes may partially explain why clinically meaningful oral health findings do not necessarily translate into worse subjective outcomes.

To the best of the authors' knowledge, this study is the first to evaluate the endodontic status and oral health of athletes together with quantitative nutritional and psychological measures. It is also among the first comparative studies to assess the relationship between nutrition and oral health in athletes at the nutritional-element level rather than by food types. Literature screening observed limited studies included a control group comprising non-athlete individuals⁴². In the present study, a control group within the same age range was established, and the experimental group consisted of athletes with comparable training volume and competition level. Athletes are expected to possess a certain level of physical strength and BMI. Previous studies have shown that periodontitis, missing teeth, and decayed teeth in athletes are significantly associated with higher BMI values^{69,70}. In the present study, similar BMI levels between groups stand out as a strength that enhances the reliability of the comparisons.

The present study has several limitations that should be acknowledged. First, the cross-sectional design precludes causal inferences, and the reliance on self-reported measures may have introduced reporting bias^{2,8}. In addition, the imbalance in gender distribution between the athlete and control groups represents an important limitation, given known sex-related differences in oral health behaviors and disease prevalence. In previous studies involving athletes, it appears more male participants were generally included^{9,71}. Similarly, in this study, there were higher numbers of men in the athlete group with a higher number of women in the control group. Considering the studies reporting that males may have poorer oral health compared to females, it can be assumed that the findings of the present study, as well as previous results, may have been partially influenced by gender differences^{72,73}. To address this potential confounding factor, additional analyses were conducted with gender included as a covariate. When the effect of gender was controlled, the results regarding the number of teeth requiring endodontic treatment, the number of teeth requiring RT, PAI and NRS scores, DT, MT, BOP, facial pain, and jaw pain remained unchanged between the groups, indicating that these findings were not affected by the imbalance in gender distribution. Accordingly, the observed differences in the number of teeth requiring endodontic treatment, PAI scores, DT, BOP, and jaw pain are more likely to be associated with group-specific

behavioral and environmental factors rather than gender differences. In contrast, when gender was controlled for, the group effect for joint pain, PI, and GI—parameters that were initially higher in the athlete group—lost statistical significance, suggesting that the observed group differences for these outcomes may have been influenced by differences in gender distribution. Nevertheless, gender did not independently affect joint pain, PI, or GI levels.

Furthermore, DMFT, FT, and the number of teeth with previous endodontic treatment differed significantly according to gender, whereas no significant differences were observed between the athlete and control groups for these parameters. When the subcomponents of DMFT were evaluated together, the presence of a significant group effect for DT in the absence of group differences in MT and FT may have resulted in a balancing effect on the overall DMFT score. This finding may explain why the DMFT index, which reflects cumulative oral health burden, remained similar between the groups despite differences in active disease indicators. In addition, although DT and the number of teeth requiring endodontic treatment were higher in the athlete group, the lack of a marked difference in FT and the number of teeth with previous endodontic treatment suggests that active disease indicators are more pronounced in athletes, whereas indicators of completed dental treatment remain more limited. Finally, gender was found to have a significant effect on PPD levels, and the group variable also showed a significant association with PPD. This finding suggests that the pronounced influence of gender on PPD may have masked the true group differences in unadjusted comparisons.

Another limitation of the present study is the heterogeneity of sports disciplines represented in the athlete group. Different sports may be associated with distinct physical demands, stress exposure, nutritional habits, and injury profiles, all of which could differentially influence oral and periodontal health^{11,54,74–76}. However, all athletes included in the present study were engaged in team sports, which may have partially limited variability related to individual sport-specific training and competition characteristics. Moreover, heterogeneity across sports disciplines may also reflect the real-world diversity of participation in competitive sports and enhance the external validity of the findings^{77,78}.

Future longitudinal studies with larger and more homogeneous samples, including athletes from different performance levels, sports disciplines, and age groups, are needed to better characterize oral health profiles and related risk factors. Further research may also elucidate the underlying biological mechanisms associated with physical activity, nutrition, and stress physiology. In particular, studies simultaneously assessing local and systemic inflammatory markers, such as salivary and serum cytokine levels, may provide deeper insight into the interaction between oral inflammation and systemic inflammatory burden in athletes. Moreover, future investigations integrating oral health parameters with objective and subjective measures of athletic performance may further clarify the clinical relevance of oral health in competitive sports. In addition to quantitative approaches, qualitative studies employing interview-based methodologies could enable a more in-depth exploration of athletes' perceptions, behaviors, and psychosocial factors related to poor oral health, thereby complementing quantitative findings and supporting the development of more targeted preventive strategies.

Conclusion

In the athlete group, the number of teeth requiring endodontic treatment, PAI scores, number of decayed teeth, and periodontal index scores (GI, PI, and BOP) were higher compared to non-athlete individuals. However, athletes exhibited higher levels of mental well-being. In the athlete group, PRAL, organic acid, vitamin D, vitamin B12, vitamin B2, vitamin B6, folate, and calcium levels were higher compared with the control group. Importantly, even after controlling for nutritional and psychological factors, athletes continued to exhibit a higher number of decayed teeth. In addition, sucrose, starch, carbohydrate, and vitamin C, B12, and K intake were identified as key nutritional factors influencing endodontic status. In this context, professional support programs about diet and oral care supporting the oral health of athletes may provide significant benefits.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Received: 10 November 2025; Accepted: 31 March 2026

Published online: 06 April 2026

References

1. Organization, W. H. O. Oral health fact sheet No. 318. *Geneva: WHO* (2012).
2. Kragt, L., Moen, M. H., Van Den Hoogenband, C. R. & Wolvius, E. B. Oral health among Dutch elite athletes prior to Rio 2016. *Phys. Sportsmed.* **47** (2), 182–188 (2019).
3. Vougiouklakis, G. et al. Dental data of the Athens 2004 Olympic and paralympic games. *Int. J. Sports Med.* **29** (11), 927–933 (2008).
4. Needleman, I. et al. Oral health and impact on performance of athletes participating in the London 2012 Olympic Games: A cross-sectional study. *Br. J. Sports Med.* **47** (16), 1054–1058 (2013).
5. Henriques, P. S. & Sukekava, F. The importance of oral health in high performance athletes: A brief review. *J. Dent. Oral Biol.* **2** (4), 1037–2017 (2017).
6. do Ferruzzi, C., Davi, L. P., de Lima, L. R., Tavares, D. C. B. & de Castro, M. Oral health-related quality of life of athletes with disabilities: A cross sectional study. *Biosci. J.* **37** (e37008), 1981–3163 (2021).
7. Rafie, F., Habibi, M., Nekouei, A. H. & Kakoei Oral health-related quality of life and associated factors in athlete and non-athlete students. *Sport Sci. Health.* **19** (4), 1093–1100 (2023).
8. Merle, C. L. et al. Orofacial conditions and oral health behavior of young athletes: A comparison of amateur and competitive sports. *Scand. J. Med. Sci. Sports.* **32** (5), 903–912 (2022).
9. Frese, C. et al. Clinical management and prevention of dental caries in athletes: A four-year randomized controlled clinical trial. *Sci. rep.* **8** (1), 16991 (2018).

10. Chan, C. C. K., Chan, A. K. Y. & Chu, C. H. Tsang, Y. C. Physical activity as a modifiable risk factor for periodontal disease. *Front. Oral Health*. **4**, 1266462 (2023).
11. Ashley, P., Di Iorio, A., Cole, E., Tanday, A. & Needleman, I. Oral health of elite athletes and association with performance: A systematic review. *Br. J. Sports Med.* **49** (1), 14–19 (2015).
12. Sharma, R., Verma, M. & Mehrotra, G. Dental treatment at the Commonwealth Games, 23 September to 16 October 2010, Delhi, India. *Int. Dent. J.* **62** (3), 144–147 (2012).
13. von Elm, E. et al. The strengthening of the reporting of Observational studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J. Clin. Epidemiol.* **61**, 344–349 (2008).
14. Landis, J. R. & Koch, G. G. An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics* **33** (2), 363–374 (1977).
15. Koo, T. K. & Li, M. Y. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J. Chiropr. Med.* **15** (2), 155–163 (2016).
16. McKay, A. K. et al. Defining training and performance caliber: A participant classification framework. *Int. J. Sports Physiol. Perform.* **17** (2), 317–331 (2021).
17. Glickman, G. N. AAE Consensus Conference on Diagnostic Terminology: Background and perspectives. *J. Endod.* **35** (12), 1619–1620 (2009).
18. Ørstavik, D., Kerekes, K. & Eriksen, H. M. The periapical index: A scoring system for radiographic assessment of apical periodontitis. *Dent. Traumatol.* **2** (1), 20–34 (1986).
19. Karcioğlu, O., Topacoglu, H., Dikme, O. & Dikme, O. A systematic review of the pain scales in adults: Which to use? *Am. J. Emerg. Med.* **36** (4), 707–714 (2018).
20. Löe, H. The gingival index, the plaque index and the retention index systems. *J. Periodontol.* **38** (6), 610–616 (1967).
21. Ainamo, J. & Bay, I. Problems and proposals for recording gingivitis and plaque. *Int. Dent. J.* **25** (4), 229–235 (1975).
22. Miettinen, O. et al. Association of temporomandibular disorder symptoms with physical fitness among Finnish conscripts. *Int. J. Environ. Res. Public Health*. **18** (6), 3032 (2021).
23. Gunes, F. E. et al. Development and validation of a semi-quantitative food frequency questionnaire to assess dietary intake in Turkish adults. *J. Pak Med. Assoc.* **65** (7), 756–763 (2015).
24. Ostrowska, J. & Janiszewska, J. Szostak-Węgierek, D. Dietary acid load and cardiometabolic risk factors—A narrative review. *Nutrients* **12** (11), 3419 (2020).
25. Avery, C., Shipherd, A. M., Gomez, S. & Barczarenner, K. Exploring stress mindset and perceived stress between college student-athletes and non-athletes. *Int. J. Exerc. Sci.* **15** (5), 1554–1562 (2022).
26. Contreras, D. W., Granquist, M. D., Martin, L. A. Stress sport anxiety, neuroticism, and coping in student-athletes: Implications for patient mental health. *J. Athl. Train.* **58** (9), 733–739 (2023).
27. Lee, E. H. Review of the psychometric evidence of the perceived stress scale. *Asian Nurs. Res.* **6** (4), 121–127 (2012).
28. Stewart-Brown, S. et al. Internal construct validity of the Warwick-Edinburgh Mental Well-being Scale (WEMWBS): A Rasch analysis using data from the Scottish Health Education Population Survey. *Health Qual. Life Outcomes*. **7**, 15 (2009).
29. Griffin, S. et al. Mental health and well-being in rugby players' (MAUL) study: An online survey of diverse cohorts of rugby union players internationally. *BMJ Open. Sport Exerc. Med.* **10** (4), 2164 (2024).
30. Gray, H. M. et al. Grit, Athlete burnout, and well-being in female collegiate student-athletes. *J. Athl. Train.* **58** (10), 796–802 (2023).
31. Slade, G. D. Derivation and validation of a short-form oral health impact profile. *Community Dent. Oral Epidemiol.* **25** (4), 284–290 (1997).
32. Kragt, L., Moen, M. H., Van Den Hoogenband, C. R. & Wolvius, E. B. Oral health among Dutch elite athletes prior to Rio. *Phys. Sportsmed.* **8**, 2–3 (2018).
33. Liu, P., McGrath, C. & Cheung, G. What are the key endodontic factors associated with oral health-related quality of life? *Int. Endod J.* **47** (3), 238–245 (2014).
34. Gallagher, J. & Fine, P. The value of oral health screening for athletes. *Res. Sports Med.* **15**, 1–10 (2025).
35. Dubois, M., Ortis, M., Doglio, A. & Bougault, V. Microbiote orale et santé bucco-dentaire des sportifs: revue narrative. *Cah Nutr. Diet.* **59** (4), 233–242 (2024).
36. Souza, J. J., Grande, R. S., Bahls, R. & Santos, F. A. Evaluation of the oral health conditions of volleyball athletes. *Rev. Bras. Med. Esporte.* **26** (3), 239–242 (2020).
37. de la Parte, A., Monticelli, F., Toro-Román, V. & Pradas, F. Differences in oral health status in elite athletes according to sport modalities. *Sustainability* **13** (13), 7282 (2021).
38. Medeiros, T. L. M., Mutran, S. C. A. N., Espinosa, D. G., Pinheiro, K. & D'Almeida Couto, H. H. C. do Carmo Freitas Faial, R. S. Prevalence and risk indicators of non-carious cervical lesions in male footballers. *BMC Oral Health*. **20**(1), 215 (2020).
39. Gallagher, J., Ashley, P., Petrie, A. & Needleman, I. Oral health and performance impacts in elite and professional athletes. *Community Dent. Oral Epidemiol.* **46** (6), 563–568 (2018).
40. Champeecharoensuk, T. S. & Samnieng, P. Oral health status of the professional soccer players in Thailand. *J. Dent. Indones.* **23** (1), 1–4 (2016).
41. Lange, M., Ahlers, M. & Ottl, P. The German Society for Craniomandibular Function and Disorders (DGFD) guideline (2013).
42. Freiwald, H. C., Schwarzbach, N. P. & Wolowski, A. Effects of competitive sports on temporomandibular dysfunction: A literature review. *Clin. Oral Investig.* **25** (1), 55–65 (2021).
43. Rice, S. G. Medical conditions affecting sports participation. *Pediatrics* **121** (4), 841–848 (2008).
44. Opazo-García, C., Moya-Salazar, J., Chicoma-Flores, K. & Contreras-Pulache, H. Oral health problems in high-performance athletes at 2019 Pan American Games in Lima: A descriptive study. *BDJ open*. **7** (1), 21 (2021).
45. Yoon, J., Bae, M., Kang, H. & Kim, T. Descriptive epidemiology of sports injury and illness during the Rio 2016 Olympic Games: A prospective cohort study for Korean team. *Int. J. Sports Sci. Coach.* **13** (6), 939–946 (2018).
46. Steffen, K. et al. Sports injuries and illnesses in the Lillehammer 2016 youth Olympic winter games. *Br. J. Sports Med.* **51** (1), 29–35 (2017).
47. Silva-Sousa, A., Oliveira-Aguiar, C., Paula-Silva, J. & Sousa-Neto, F. W. G. Candemil, A. P. Management strategies for sport-related traumatic dental injuries: a systematic review based on case reports. *BMC Sports Sci. Med. Rehabil.* **17** (1), 208 (2025).
48. McCarthy, S., Gulabivala, K., St. George, G., Harvey, S. & Ng, Y. L. Endodontic sequelae associated with repetitive impacts to the dentofacial region during boxing activities. *Int. Endod J.* **57** (10), 1380–1394 (2024).
49. Assa, T., Geva, N., Zarkh, Y. & Defrin, R. The type of sport matters: Pain perception of endurance athletes versus strength athletes. *Eur. J. Pain.* **23** (4), 686–696 (2019).
50. de Queiroz Gonçalves, P. H. P. et al. Dental erosion prevalence and its relation to isotonic drinks in athletes: a systematic review and meta-analysis. *Sport Sci. Health.* **16** (4 Suppl 1), 207–216 (2020).
51. Oudkerk, J. et al. Risk factors of tooth wear in permanent dentition: A scoping review. *J. Oral Rehabil.* **50** (10), 1110–1165 (2023).
52. Gallagher, J., Ashley, P. & Needleman, I. Core oral health outcomes for sports dentistry research. *Int. Dent. J.* **74** (1), 46 (2023).
53. Minty, M. et al. Oral health and microbiota status in professional rugby players: A case-control study. *J. Dent.* **79**, 53–60 (2018).
54. Schulze, A. & Busse, M. Sports diet and oral health in athletes: A comprehensive review. *Medicina* **60** (2), 319 (2024).
55. Tripodi, D. et al. Association between salivary/microbiological parameters, oral health and eating habits in young athletes. *J. Int. Soc. Sports Nutr.* **22** (1), 2443018 (2025).

56. Júdeice, A. et al. Sports dentistry intricacies with season-related challenges and the role of athlete-centered outcomes. *Front. Oral Health*. **6**, 1531653 (2025).
57. Stamos, A. et al. A suggested universal protocol for dental examination in sports. *Dent. Traumatol.* **39** (6), 521–530 (2023).
58. Hussein, P. M. & Hussein, V. M. Assessment of vitamin E and glutathione peroxidase levels in salivary samples of children with and without dental caries in Erbil City, Iraq. *Cureus* **16** (11), e74872 (2024).
59. Gurupriya, M. M. et al. Effect of dental caries management on the *Candida Albicans* carriage and oral health-related quality of life in children living with perinatal HIV/AIDS under antiretroviral therapy-A pre- and post-experimental study. *J. Pharm. Bioallied Sci.* **16** (5), S4445–s7 (2024).
60. Li, X., Tang, L., Lin, Y. F. & Xie, G. F. Role of vitamin C in wound healing after dental implant surgery in patients treated with bone grafts and patients with chronic periodontitis. *Clin. Implant Dent. Relat. Res.* **20** (5), 793–798 (2018).
61. Buzatu, R., Luca, M. M. & Bumbu, B. A. Does Vitamin C supplementation provide a protective effect in periodontal health? A systematic review and meta-analysis. *Int. J. Mol. Sci.* **7** (16), 8598 (2024).
62. Granero-Jiménez, J., López-Rodríguez, M. M., Dobarrio-Sanz, I. & Cortés-Rodríguez, A. E. Influence of physical exercise on psychological well-being of young adults: A quantitative study. *Int. J. Environ. Res. Public Health*. **19** (7), 4282 (2022).
63. Casimiro-Andújar, A. J., Martín-Moya, R., Maravé-Vivas, M. & Ruiz-Montero, P. J. Effects of a personalised physical exercise program on university workers overall well-being: UAL-Activa Program. *Int. J. Environ. Res. Public Health*. **9** (18), 11331 (2022).
64. Tesarz, J., Schuster, A. K., Hartmann, M., Gerhardt, A. & Eich, W. Pain perception in athletes compared to normally active controls: A systematic review with meta-analysis. *Pain* **153** (6), 1253–1262 (2012).
65. Gerber, M. et al. Effects of stress and mental toughness on burnout and depressive symptoms: A prospective study with young elite athletes. *J. Sci. Med. Sport*. **21** (12), 1200–1205 (2018).
66. Svensson, M. et al. Physical activity is associated with lower long-term incidence of anxiety in a population-based, large-scale study. *Front. Psychiatry*. **10**, 12:714014 (2021).
67. Anshel, M. H. & Sutarso, T. Relationships between sources of acute stress and athletes' coping style in competitive sport as a function of gender. *Psychol. Sport Exerc.* **8** (1), 1–24 (2007).
68. Eather, N., Wade, L., Pankowiak, A. & Eime, R. The impact of sports participation on mental health and social outcomes in adults: a systematic review and the 'Mental Health through Sport' conceptual model. *Syst. Rev.* **12** (1), 102 (2023).
69. Pradhan, A. Targeting dental caries and body mass index among special olympics athletes in Australia. *J. Policy Pract. Intellect. Disabil.* **15** (4), 314–318 (2018).
70. Miralles-Amorós, L. et al. Study of different personalised dietary plans on eating behaviour, body image and mood in young female professional handball players: a randomised controlled trial. *Children* **10** (2), 259 (2023).
71. Júdeice, A. et al. Elite athletes' overall oral health, values and related quality of life: a cross-sectional study. *Sci. Rep.* **15** (1), 25564 (2025).
72. Skośkiewicz-Malinowska, K., Kaczmarek, U. & Malicka, B. Gender-wise comparison of oral health quality of life and its relationship with oral health parameters among elderly from Wrocław, south-west Poland. *PLoS one*. **3** (11), e0259286 (2021).
73. Klarić Puđa, I. et al. A cohort study on the impact of oral health on the quality of life of adolescents and young adults. *Clin. Pract.* **7** (4), 76 (2025).
74. Margo, M., Jorunn Kaiander, S. B., Louise, M. B., Kathryn, E. A. & Cheri, B. Naama, C. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *Br. J. Sports Med.* **52** (11), 687 (2018).
75. Needleman, I. et al. Oral health and elite sport performance: consensus statement. *Br. J. Sports Med.* **28** (1), 3–6 (2014).
76. Ranalli, D. N. Dental injuries in sports. *Curr. Sports Med. Rep.* **4** (1), 12–17 (2005).
77. Robertson, M., Hague, C., Evans, M. B. & Martin, L. J. Do participant reporting practices in youth sport research adequately represent the diversity of sport contexts? *Psychol. Sport Exerc.* **38** (1), 31 (2019).
78. Dongoran, M. F., Setyawati, H., Kristiyanto, A., Raharjo, H. P. & Setiawan, C. Understanding significant experiences of adolescent athletes' participation in competitive sports life: a systematic review. *Front. Sports Act. Living*. **24** (7), 1515200 (2025).

Acknowledgements

We thank all study participants.

Author contributions

EM: Conceptualization, Supervision, Writing—review & editing, Recording of sociodemographic data and administration of questionnaires; OB: Endodontic clinical measurements and data collection; NY: Periodontal clinical measurements and data collection; GB: Conceptualization, Recording of nutritional characteristics; GC: Conceptualization, Critical review and editing; OK: Conceptualization, Supervision, Critical review and editing.

Funding

This study has been supported by the Recep Tayyip Erdoğan University Development Foundation (Grant number: 02026001008017).

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

The study protocol was approved by the local ethics committee (no: 2024/275). Informed consent was obtained from all individual participants included in the study. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Additional information

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1038/s41598-026-47464-z>.

Correspondence and requests for materials should be addressed to E.M.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

© The Author(s) 2026