Original paper

Occurrence of dental caries, the prevalence of hygiene and dietary habits, and the influence of the workout session on the selected parameters of saliva in youth swimmers

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Conflict of interest
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Abstract

Background. Poor oral health can affect the overall health of the body, which may result in suboptimal performance in sports.

Objectives. The aim of the present study was to evaluate the occurrence of tooth decay, the prevalence of hygiene and dietary habits, and the influence of the workout session on the selected salivary parameters in youth swimmers.

Material and methods. The study involved 40 adolescents, aged 12–15 years (mean age: 13 ±0.5 years), including 30 competitive swimmers and 10 controls. The decayed, missing and filled teeth index (DMFT) was assessed. Data on oral hygiene and dietary habits was collected through a questionnaire created by the authors. Salivary samples were collected from all subjects in the morning and in the afternoon, and from swimmers before and after training. The salivary flow rate (V), pH, buffering capacity, and calcium (Ca) level were measured.

Results. The DMFT in the group of swimmers was 4.5 ±3.54, which was significantly higher than in the control group (1.6 ±2.59) ($p = 0.0007$). There were no statistically significant differences in oral hygiene habits between the 2 groups. However, swimmers significantly more often consumed chocolate bars ($p = 0.004$), energy drinks ($p = 0.017$) and water ($p = 0.002$) as compared to the control group. Among the consumed beverages, significantly more sweet carbonated drinks were consumed by swimmers than controls ($p = 0.026$). After the workout session, both in the morning and in the afternoon, there was a significant decrease in V ($p = 0.006$ and $p = 0.009$, respectively) and a significant increase in the Ca level ($p = 0.001$ and $p = 0.001$, respectively) in swimmers. While comparing swimmers before training with the control group in the morning, significantly higher V ($p = 0.012$) and lower pH ($p = 0.003$) were observed in swimmers. In the afternoon, significantly lower pH was found in swimmers ($p = 0.006$).

Conclusions. Oral health prevention and promotion should be an important aspect of sports participation, through greater awareness of the impact of oral hygiene and diet on overall health, which can influence sports performance.

Keywords: dietary habits, dental caries, saliva, oral hygiene, physical exertion

Highlights

- Athletes' oral health should be prioritized during sports training and competition.
- Swimmers tend to consume carbohydrate-rich foods and drinks more frequently than the general population, which correlates with a higher incidence of dental caries.
- After a swimming training session, swimmers experience a significant decrease in the salivary flow rate and a significant increase in the calcium level.
- Raising awareness about the importance of oral health monitoring is essential to understand its impact on overall health and sports performance.

Introduction

In accordance with the guidelines developed by the World Dental Federation (FDI), a healthy oral cavity is an important factor in helping athletes achieve their best performance, and conversely, poor oral health affects overall well-being and can have a negative impact on sports performance.[1] Achieving good results in sports serves as motivation for further training to improve performance. Sudden, unexpected problems in the oral cavity can result in the interruption of systematically conducted training for sports competitions, and even withdrawal from them. This is confirmed in a study by Needleman et al., in which athletes emphasized long periods of inability to train and the lack of exercise at the desired level due to oral health problems.[2] Therefore, the oral health of athletes should be considered a priority during sports activities.[3] Athletes themselves often have a dismissive attitude toward oral health.[4] From the few published works, it is evident that poor oral health can have a negative impact on sports performance and training.[2,5–7] Among individuals engaged in regular sports training, the most common oral health issues are tooth decay and gum inflammation, affecting over 50% of athletes.[2,5–7] Other common conditions among athletes include tooth injuries and erosion.

The decayed, missing and filled teeth index (DMFT) is a valuable indicator used for determining and monitoring the oral health status in a community. Moreover, it is the most important index used in epidemiological studies.[8] It determines the number of decayed teeth (DT), the number of teeth missing due to decay (MT) and the number of treated teeth (FT). The DMFT is used to evaluate and monitor oral health interventions in a community by developing policies and programs related to this area.[9–12]

Caries is a multifactorial dental disease and is one of the most common global health problems.[13] Bacteria in the plaque metabolize carbohydrates from the diet into acids, leading to a decrease in pH in the oral cavity, and thus causing the demineralization of the enamel and root cementum.[14]

The main causes of poor oral health among athletes include negligence related to oral hygiene, a poor diet, an unhealthy lifestyle, and lowered immunity.

Poor oral hygiene is the primary factor in the development of dental caries.

It is well known that frequent consumption of carbohydrates leads to a decrease in pH in the oral environment, causing the demineralization of the teeth and the subsequent development of carious lesions.[6] Many athletes choose carbohydrate-rich foods because of their ability to increase energy levels during training. Foods that adhere to the tooth surface further increase the chance of lowering oral pH, causing a shift in the balance toward the demineralization process. Examples of such often chosen foods are candy bars and muesli. Athletes also tend to choose acidic fruits as snacks during exercise, like oranges, which contributes to the loss of minerals from the tooth tissue.[15]

Saliva is responsible for maintaining proper homeostasis in the oral cavity.

The average daily volume of saliva secretion is 0.5–2 L, and depends on the amount of sleep, the frequency and type of meals, and emotional stimuli.[16] The rate of saliva secretion under normal conditions, in the absence of external stimulation, varies from 0.25 mL/min to 0.35 mL/min, which can increase to 1.50–2.30 mL/min under the influence of a food stimulus.[17] In contrast, during sleep, when the process of saliva secretion is slower, it decreases to 0.05 mL/min.[18]

Saliva has the buffering (acid neutralization) capacity and its diluting action regulates pH in the oral environment. The constant flow of saliva removes food debris and microorganisms from the oral cavity. The ability to remineralize hard dental tissues is due in part to the presence of the calcium (Ca), phosphate and fluoride ions in saliva.[19,20]

Along with blood, saliva can be an alternative diagnostic material for monitoring the response of the body to exercise.[21] The advantage of saliva as a diagnostic material over blood is the non-invasive way it is collected. Stress that often occurs during blood collection due to the sight of a needle or pain during insertion can alter the results of the parameters tested. Saliva secretion is regulated by the autonomic nervous system.[22] Physical exercise induces changes in the activity of the autonomic nervous system, which leads to changes in saliva secretion as well as its composition.

Therefore, the intensity, type, course, duration, and time of day of exercise are crucial in altering salivary parameters.[23] Decreased salivary secretion during intense exercise is explained by an increase in sympathetic innervation activity, causing the constriction of the vessels supplying blood to the salivary glands, and consequently lowering the saliva volume, while the activity of the parasympathetic system increases it.[24] Also, physical exercise causes an increase in vasopressin (an antidiuretic hormone), which can decrease the production of saliva. The effect of the dehydration of the body during prolonged exercise and the evaporation of saliva following mouth breathing, as well as hyperventilation, cannot be overlooked either.[25] Saliva as a diagnostic tool, in particular, determining its rate of secretion, buffering capacity, pH value, and the growth of caries-forming bacteria, is applied for assessing the caries risk.[13,16,26]

Although more and more research on the monitoring of effort through the analysis of biochemical changes in saliva is being conducted, unfortunately, little information is available on the relationship between salivary parameters and oral health in adolescents who train in sports.

The objective of the present study was to determine the occurrence of dental caries, the prevalence of hygiene and dietary habits, and the influence of the training session on the selected salivary parameters in youth swimmers.

Material and methods

The study included 40 adolescents, aged 12–15 years (mean age: 13 ±0.5 years), of which 30 were competitive swimmers (the study group) and 10 were sedentary individuals (the control group). Swimmers were recruited from 2 swimming championship clubs operating in the city, and all of them ($n = 30$) participated in the study. The control group ($n = 10$) consisted of clinically healthy participants who were not taking any medications based on their medical history, did not participate in sports competitions, played sports only recreationally, and were age- and gender-matched with swimmers.

The clinical examination was carried out using a standard mirror and a dental probe under artificial lighting. The examination involved the assessment of the condition of the tooth tissue in terms of carious disease.

The condition of the teeth was assessed according to the World Health Organization (WHO) criteria based on the DMFT index.[27] The DMFT was calculated for each subject, as well as the prevalence of caries in both groups.

All subjects completed a questionnaire created by the authors for the purpose of the study. The questions regarded the sports the participants played, the frequency and time of day of tooth brushing, and the type of toothbrush they used, as well as the date of their last dental visit and the reason for it. In addition, the respondents provided information regarding the consumption of sugary snacks, the type of snacks and the amount of liquids consumed during the day. Also, swimmers provided information on the type and amount of drinks consumed after training. The questionnaire did not exclude the normal consumption of high-carbohydrate snacks beyond training in either group, but differentiated the athletes group from the control group during peri-workout time.

Swimmers trained 21 h a week in the morning (6:00–7:45 a.m.) and in the afternoon (4:00–5:45 p.m.). The swimming workout session consisted of swimming a distance of 5,000 meters. All the recruited participants had to provide written informed parental consent, be willing to undergo saliva sampling and answer the questionnaire. Participants who did not meet the inclusion criteria were excluded from the study.

The study protocol was approved by the Bioethics Committee at Wroclaw Medical University, Poland (approval No. KB-327/2009). All examinations were conducted in accordance with the relevant guidelines and regulations.

Saliva sampling and the studied parameters

Unstimulated mixed saliva samples were collected from swimmers 4 times – before and after workout, in the morning and in the afternoon. In the control group, the samples were collected twice, at the time of the pre-workout sampling in swimmers. All test subjects were asked to rinse their mouths with water before saliva collection. In total, 140 samples of saliva were collected daily. During sampling, the subjects sat with their heads bowed and their mouths open. Saliva samples were collected from the floor of the mouth, with the use of a plastic pipette, and put into a graded test tube stored on crushed ice. Based on the measurement of the volume of the collected saliva sample and the time needed for its collection, the salivary flow rate (V) was calculated and expressed in mL/min.

The samples were centrifuged for 10 min at a speed of 3,500 rpm before chemical assays. The pH and the buffering capacity in mmol/L (the potentiometric method), and the Ca level (the method based on the formation of a chromogenic complex between the Ca ions and o-cresolphthaelin, using a commercial kit (Alpha Diagnostics, Warsaw, Poland)) were assessed.

Statistical analysis

Depending on variable distribution, Student's t test or the Mann–Whitney U test were used for the analysis of independent variables. For dependent variables, repeated measures Student's t test or non-parametric repeated measures Wilcoxon's test were employed. Moreover, Fisher's test was used if the data was categorical (answers to questions). To study the monotonic component of the relationship between the variables, Spearman's coefficient of correlation (ρ) between the DMFT scores and the difference in salivary parameters before and after training, as well as with hygiene and dietary habits, was calculated. In addition, the correlation between dietary habits and salivary parameters was checked.

The level of significance was set at $p < 0.05$. All analyses were performed with the use of the Statistica 13.3 software package (StatSoft, Inc., Tulsa, USA) and the R package (https://www.r-project.org).

In the statistical analysis, we employed an exploratory approach, without including a correction for the families of hypotheses, which leads to an increased risk of type I error. Thus, the results must be interpreted with caution. The study might serve as a starting point for further research in the field.

Results

DMFT ratio and caries prevalence

Caries prevalence in swimmers was 56.7%, and it was 40.0% in the control group (Fig. 1).

In the studied athletes, the DMFT values were as follows: DT = 1.2; MT = 0.0; and FT = 3.3. In contrast, in the control group, the mean values of the components of DMFT were DT = 0.8, MT = 0.0 and FT = 0.8. Overall, DMFT in the studied athletes was 4.5, while in the control group it was 1.6. In the group of swimmers, the FT value, as well as the total DMFT value, were significantly higher as compared to the control group ($p = 0.0005$ and $p = 0.0007$, respectively). The mean and median values for the DT, MT, FT, and DMFT variables are shown in Table 1.

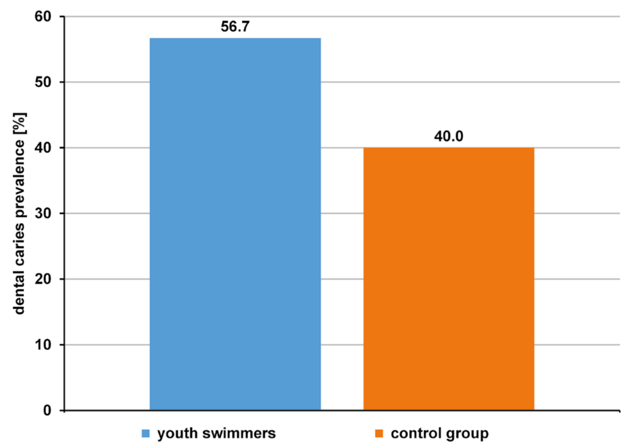

Fig. 1. Dental caries prevalence in youth swimmers and the control group

Frequency and time of tooth cleaning, and the type of toothbrush used

No statistically significant differences in oral hygiene habits were observed between the 2 groups. Most of the subjects, both swimmers and controls, brushed their teeth twice a day (66.7% vs. 80.0%); 16.7% of swimmers reported brushing their teeth more often than twice a day, while 13.3% brushed only once a day. In the morning, 60.0% of the surveyed swimmers cleaned their teeth before breakfast, while 70% of controls cleaned their teeth after breakfast. Both swimmers (93.3%) and control group subjects (100.0%) cleaned their teeth in the evening. Both groups (86.7% vs. 100.0%, respectively) used a manual toothbrush (Table 2).

Eating habits

Almost all swimmers declared that they did not follow a special diet for athletes (96.6%), and only one person (3.4%) followed such a diet. In the control group, 100.0% of the respondents followed a regular diet.

Swimmers consumed carbohydrate-containing products more often as compared to the control group. Most of them (63.3%) consumed sweet rolls, doughnuts or cookies every day or almost every day. In contrast, chips were not very popular in either group and were consumed occasionally (43.4% in the swimmer group vs. 30.0% in the control group). Most swimmers consumed chocolate bars daily or nearly daily (80.0%). In the control group, only 30.0% consumed this snack on a daily basis. The difference

Table 1. The DMFT (decayed (DT), missing (MT) and filled (FT) teeth) values for swimmers and the control group

Dental status	Swimmers (*n* = 30)						Control group (*n* = 10)						*p*-value
	M ±*SD*	*Me*	min	max	lower quartile	upper quartile	*M* ±*SD*	*Me*	min	max	lower quartile	upper quartile	
DT	1.2 ±1.27	1.00	0.00	4.00	0.00	2.00	0.8 ±1.55	0.00	0.00	5.00	0.00	1.00	0.935
MT	0.0 ±0.00	0.00	0.00	0.00	0.00	0.00	0.0 ±0.00	0.00	0.00	0.00	0.00	0.00	–
FT	3.3 ±3.19	3.00	0.00	12.00	1.00	4.00	0.8 ±1.13	0.00	0.00	3.00	0.00	2.00	0.0005*
DMFT	4.5 ±3.54	4.00	0.00	15.00	2.00	6.00	1.6 ±2.59	0.00	0.00	8.00	0.00	3.00	0.0007*

M – mean; *SD* – standard deviation; *Me* – median; min – minimum; max –maximum; * statistically significant.
DMFT = (DT + MT + FT) / number of examined people

Table 2. Oral hygiene habits of swimmers and the control group

Oral habit		Swimmers (*n* = 30)	Control group (*n* = 10)
When do you clean your mouth?	before breakfast	18 (60.0)	4 (40.0)
	after breakfast	16 (53.3)	7 (70.0)
	before supper	2 (6.7)	0 (0.0)
	before sleep	28 (93.3)	10 (100.0)
How often do you clean your mouth?	once a day	4 (13.3)	1 (10.0)
	twice a day	20 (66.7)	8 (80.0)
	more than twice a day	5 (16.7)	0 (0.0)
	after eating	0 (0.0)	1 (10.0)
	every second day	0 (0.0)	0 (0.0)
	once for a few days	0 (0.0)	0 (0.0)
	as I recall	1 (3.3)	0 (0.0)
What kind of toothbrush do you use?	always manual	26 (86.7)	10 (100.0)
	always electric	1 (3.3)	0 (0.0)
	manual and electric toothbrush	3 (10.0)	0 (0.0)
When was the last time you went to the dentist?	a month ago	14 (46.7)	2 (20.0)
	3 months ago	2 (6.7)	2 (20.0)
	half a year ago	7 (23.3)	5 (50.0)
	a year ago	4 (13.3)	1 (10.0)
	I don't remember	3 (10.0)	0 (0.0)
What was the reason for the visit?	noticed carious lesion	6 (20.0)	2 (20.0)
	dental pain	1 (3.3)	0 (0.0)
	prevention	0 (0.0)	2 (20.0)
	check-up	23 (76.7)	6 (60.0)

Data presented as number (percentage) (*n* (%)).

between the groups proved to be statistically significant in this regard ($p = 0.004$). Also, candies were consumed very often by swimmers, while in the control group, daily consumption was recorded in only one person (26.7% vs. 10.0%, respectively). Among control group subjects, 70.0% consumed this snack occasionally. The situation was similar with the consumption of chocolate, which was eaten daily or nearly daily by most swimmers as compared to the control group (93.3% vs. 40.0%) (Fig. 2).

In addition to sweet snacks, the diet of both groups contained sweet drinks. Swimmers consumed energy drinks significantly more often ($p = 0.017$) (Fig. 3) and drank more sweet carbonated drinks per day ($p = 0.026$) (Fig. 4) than the control group. Both groups reported daily water consumption (100.0% of swimmers vs. 60.0% of control subjects), with swimmers consuming this beverage significantly more often ($p = 0.002$) (Fig. 3).

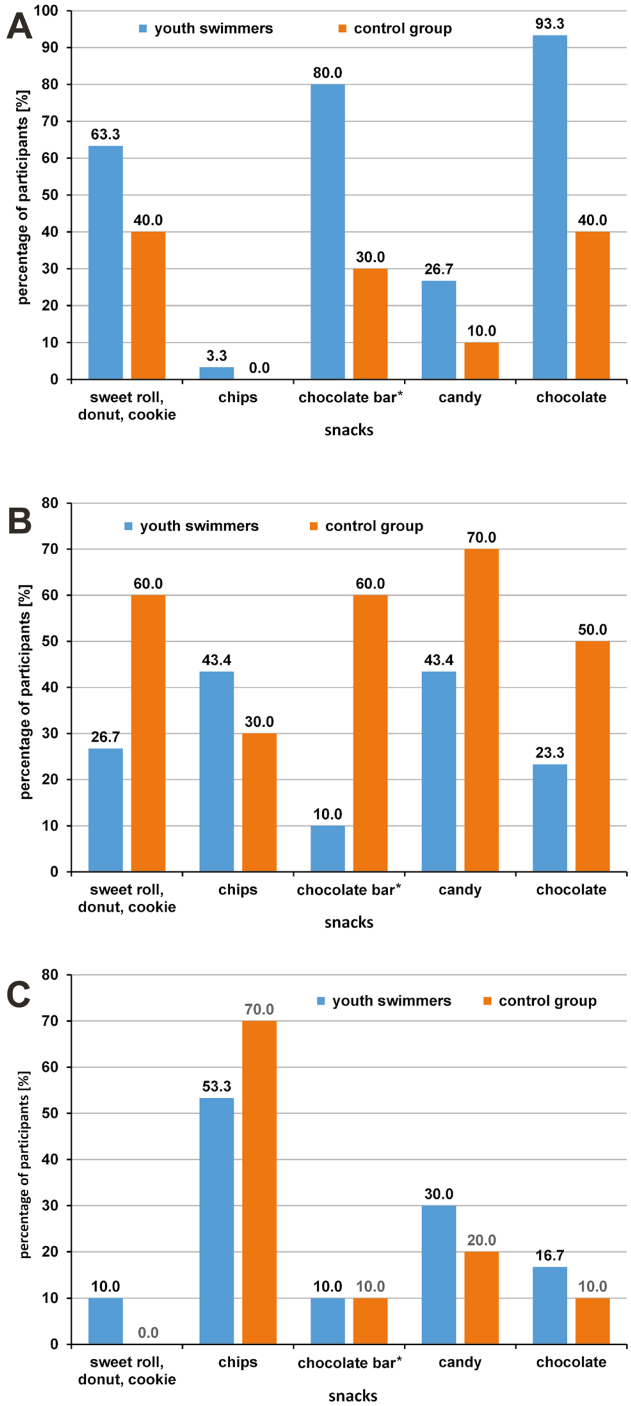

Fig. 2. Types of carbohydrate-containing products (snacks) consumed by youth swimmers and the control group with regard to the frequency of consumption

A – every day or almost every day; B – occasionally; C – never or almost never.
* $p = 0.004$.

Drinks consumed after exercise

Every day, after each swim workout, most swimmers (80.0%) consumed water, followed by fruit drinks (63.3%), vitaminized drinks (43.4%) and energy drinks (20.0%). Swimmers consumed fruit drinks ($p = 0.032$) and vitaminized drinks ($p = 0.023$) after exercise significantly more often as compared to other beverages (Fig. 5).

Also, swimmers drank significantly more vitaminized drinks after the workout session ($p = 0.016$) (Fig. 6).

Changes in the studied saliva parameters according to the time of day

In swimmers, before and after training in the morning, we found a lower V value and higher Ca content than in the samples taken in the afternoon. After training, we observed lower pH levels in the morning than in the afternoon. The buffering capacity before the morning workout was lower as compared to afternoon training. However, in the afternoon, the results were the opposite after swimming training. In the control group, we observed lower V and buffering capacity, as well as a higher Ca level, in the morning as compared to the afternoon, and the pH value was the same in the morning and in the afternoon (Table 3).

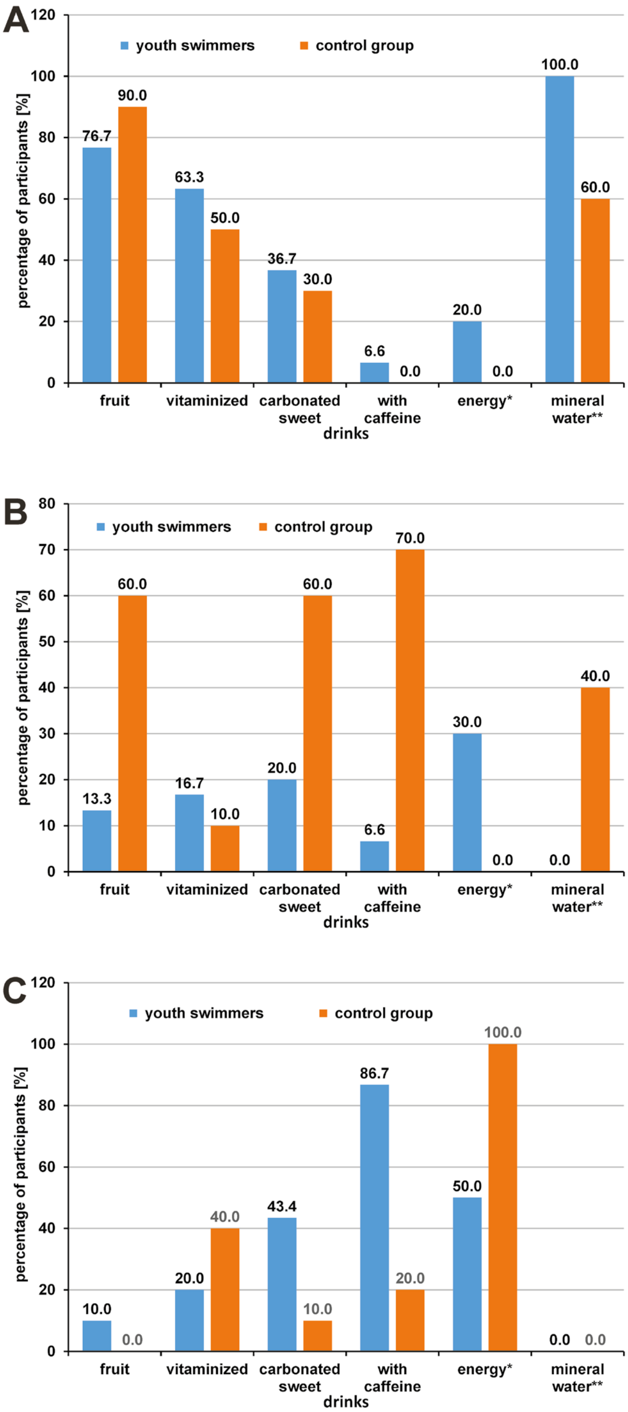

Fig. 3. Types of drinks consumed by youth swimmers and the control group with regard to the frequency of consumption

A – every day or almost every day; B – occasionally; C – never or almost never. * $p = 0.017$; ** $p = 0.002$.

Table 3. Salivary parameters of the samples collected from swimmers and non-swimmers

Salivary parameter	Time of day	Non-swimmers (control group)	Swimmer study group: before training	Swimmer study group: after training	Swimmers before training vs. non-swimmers	Swimmers before vs. after training
V [mL/min]	a.m.	0.26 ±0.15	0.47 ±0.37	0.36 ±0.22	$u = 2.499$ $p = 0.012^{b*}$ (↑ 45%)	$z = 2.746$ $p = 0.006^{c*}$ (↓ 23%)
	p.m.	0.35 ±0.19	0.63 ±0.63	0.49 ±0.39	$u = 1.812$ $p = 0.070^{b}$ (↑ 44%)	$z = 2.606$ $p = 0.009^{c*}$ (↓ 22%)
	a.m. vs. p.m.	$z = 1.376$ $p = 0.168^{c}$ (↑ 26%)	$z = 2.417$ $p = 0.016^{c*}$ (↑ 25%)	$z = 2.931$ $p = 0.003^{c*}$ (↑ 26%)	–	–
pH	a.m.	7.53 ±0.33	7.01 ±0.46	7.15 ±0.33	$t = -3.192$ $p = 0.003^{a*}$ (↓ 7%)	$t = -1.713$ $p = 0.097^{a}$ (↑ 2%)
	p.m.	7.53 ±0.49	7.13 ±0.33	7.27 ±0.24	$t = -2.932$ $p = 0.006^{a*}$ (↓ 5%)	$t = -2.647$ $p = 0.013^{a*}$ (↑ 2%)
	a.m. vs. p.m.	$t = 0.729$ $p = 0.486^{a}$ (const. 0%)	$t = -1.597$ $p = 0.121^{a}$ (↑ 1.6%)	$t = -2.060$ $p = 0.048^{a*}$ (↑ 1.6%)	–	–
Buffering capacity [mmol/L]	a.m.	4.29 ±1.94	4.23 ±2.04	4.53 ±1.90	$u = -0.250$ $p = 0.802^{b}$ (↓ 1%)	$z = 0.182$ $p = 0.855^{c}$ (↑ 7%)
	p.m.	4.50 ±2.25	4.98 ±2.63	4.48 ±1.90	$u = 0.765$ $p = 0.444^{b}$ (↑ 10%)	$z = 1.278$ $p = 0.201^{c}$ (↓ 10%)
	a.m. vs. p.m.	$z = 0.770$ $p = 0.441^{c}$ (↑ 5%)	$z = 1.326$ $p = 0.184^{c}$ (↑ 15%)	$z = 0.746$ $p = 0.455^{c}$ (↓ 1%)	–	–
Ca level [mg/L]	a.m.	3.25 ±0.79	3.83 ±1.33	4.99 ±2.24	$t = 1.307$ $p = 0.199^{a}$ (↑ 15%)	$t = -4.182$ $p = 0.001^{a*}$ (↑ 23%)
	p.m.	3.18 ±0.96	3.72 ±1.34	4.61 ±1.58	$t = 1.191$ $p = 0.241^{a}$ (↑ 15%)	$t = -4.439$ $p = 0.001^{a*}$ (↑ 19%)
	a.m. vs. p.m.	$t = 0.185$ $p = 0.856^{a}$ (↓ 2%)	$t = 0.440$ $p = 0.663^{a}$ (↓ 3%)	$t = 0.890$ $p = 0.376^{a}$ (↓ 8%)	–	–

V – salivary flow rate; Ca – calcium; * statistically significant ([a] Student's *t* test, [b] Mann–Whitney *U* test, [c] Wilcoxon's test).

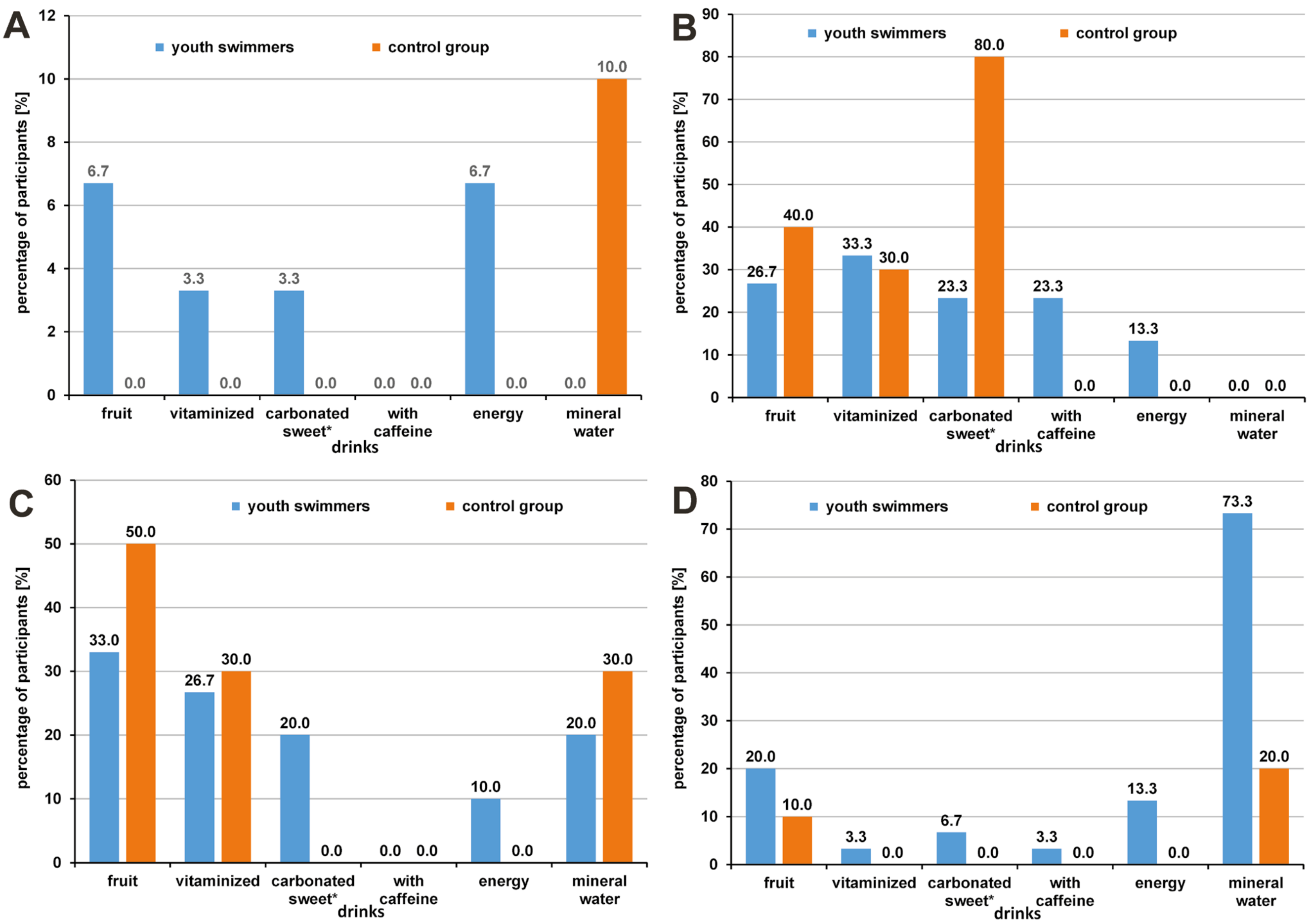

Fig. 4. Types and amount of drinks consumed per day by youth swimmers and the control group

A – can; B – 0.3-liter bottle; C – 0.5-liter bottle; D – 1-liter bottle.

* $p = 0.026$.

Saliva parameters in swimmers before training compared to the control group

In comparison with the control group, swimmers had higher V value and Ca level, and lower pH before training, which was performed both in the morning and in the afternoon. A lower buffering capacity was observed in the morning as compared to the control group, but a higher buffering capacity was observed in the afternoon as compared to the control group (Table 3).

Saliva parameters before and after the training session

After training, both in the morning and in the afternoon, V showed a significant decrease ($p = 0.006$ and $p = 0.009$, respectively), while there were increases in pH and the Ca level. The pH value was significantly higher after training in the afternoon ($p = 0.013$), and for the Ca content, the increase was significant both in the morning ($p = 0.001$) and in the afternoon ($p = 0.001$). Moreover, there was an increase in the buffering capacity after morning training, and a decrease after afternoon training (Table 3).

Correlations between changes in salivary parameters, hygiene and dietary habits and DMFT

With regard to the relationship between changes in salivary parameters and the DMFT scores, there was only a significant positive correlation with V in the morning before exertion in youth swimmers ($\rho = 0.448$; $p = 0.010$). As V increased, DMFT increased as well. However, in the control group there was no correlation between salivary parameters and DMFT in the morning. Such a result could be explained by the diet used. Therefore, the correlations between DMFT and hygiene and dietary habits in swimmers were checked. There was no correlation between DMFT and hygiene habits. However, the correlation came out positive for the consumption of sweet rolls, donuts and cookies, as well as chocolate bars ($\rho = 0.747$; $p = 0.000$ and $\rho = 0.408$; $p = 0.003$, respectively). As the frequency of consumption of these sweet snacks increased, DMFT increased as well. On the other hand, in the case of post-exercise beverage consumption, it was observed that DMFT increased as the frequency of energy drink consumption raised ($\rho = 0.375$; $p = 0.044$).

Correlation between changes in salivary parameters and dietary habits

Since a positive correlation was found between V and DMFT, the correlations between the studied salivary parameters and dietary habits in athletes were checked.

Taking into account differences in the pre- and post-training values of salivary parameters in the morning relative to dietary habits, there was a significant positive correlation between V and the frequency of consumption of sweet rolls, donuts and cookies ($\rho = 0.551$; $p = 0.001$ and $\rho = 0.503$; $p = 0.004$, respectively). The negative correlation between the consumption of carbohydrate-containing snacks and the salivary Ca level, before and after training in the morning is also noteworthy; as the frequency of consumption of sweet rolls, donuts and cookies increased, the Ca level decreased ($\rho = -0.383$; $p = 0.036$ and $\rho = -0.369$; $p = 0.044$, respectively).

Other significant Spearman's correlations, both positive and negative, before and after morning and afternoon training, are highlighted in Table 4.

Table 4. Significant Spearman's correlation between the salivary parameter values, before and after the workout session in the morning and in the afternoon, and dietary habits in swimmers

Carbohydrate-containing products	Saliva parameters	Time of day							
		morning				afternoon			
		before training		after training		before training		after training	
		ρ	p-value	ρ	p-value	ρ	p-value	ρ	p-value
Sweet roll, donut, cookie	V	0.551	0.001*	0.503	0.004*	0.340	0.065	0.212	0.260
	pH	0.212	0.259	0.098	0.605	0.306	0.099	0.038	0.839
	buffering capacity	−0.071	0.708	−0.134	0.479	−0.144	0.446	−0.077	0.685
	Ca	−0.383	0.036*	−0.369	0.044*	−0.159	0.339	−0.071	0.707
Chocolate bar	V	0.387	0.034*	0.183	0.332	0.023	0.901	0.045	0.812
	pH	0.118	0.533	0.360	0.050	0.207	0.270	0.053	0.779
	buffering capacity	−0.389	0.033*	0.102	0.588	−0.122	0.517	0.139	0.461
	Ca	−0.067	0.724	−0.095	0.614	0.060	0.751	−0.058	0.759
Fruit drink	V	−0.081	0.667	−0.055	0.769	−0.375	0.040*	−0.020	0.916
	pH	−0.113	0.552	−0.044	0.815	−0.374	0.041*	−0.348	0.059
	buffering capacity	0.101	0.593	−0.131	0.489	−0.129	0.494	−0.048	0.797
	Ca	−0.001	0.996	−0.152	0.421	−0.081	0.668	−0.084	0.656
Carbonated sweet drink	V	0.155	0.412	0.183	0.331	0.024	0.898	−0.081	0.667
	pH	0.049	0.793	−0.179	0.342	0.100	0.598	0.036	0.847
	buffering capacity	0.085	0.654	−0.113	0.550	−0.117	0.536	−0.493	0.005*
	Ca	−0.234	0.212	−0.265	0.156	−0.126	0.505	−0.333	0.071
Drink with caffeine	V	0.140	0.459	0.005	0.976	0.024	0.898	0.028	0.881
	pH	0.261	0.163	0.420	0.020*	0.095	0.616	0.285	0.126
	buffering capacity	−0.297	0.110	0.008	0.964	−0.155	0.410	−0.267	0.152
	Ca	−0.184	0.328	0.064	0.735	0.049	0.795	−0.099	0.600
Energy drink	V	0.283	0.128	0.435	0.016*	0.253	0.175	0.228	0.224
	pH	0.368	0.045*	0.196	0.296	0.134	0.477	0.223	0.234
	buffering capacity	0.035	0.853	−0.413	0.023*	0.339	0.066	−0.011	0.952
	Ca	−0.378	0.039*	−0.437	0.015*	−0.138	0.465	−0.127	0.501

ρ – Spearman's rank correlation coefficient; * statistically significant.

Correlation between changes in salivary parameters and the drinks consumed after swimmer training in the morning and in the afternoon

With regard to the relationship between changes in the post-training values of salivary parameters and the drinks drunk after swimmer training, both in the morning and in the afternoon, there was a significant positive correlation between V and the frequency of the consumption of sweet carbonated drinks ($\rho = 0.398$; $p = 0.029$ and $\rho = 0.364$; $p = 0.047$, respectively) and energy drinks ($\rho = 0.666$; $p = 0.000$ and $\rho = 0.531$; $p = 0.002$, respectively). However, there was a significant positive correlation between the frequency of consumption of caffeinated beverages and salivary pH after training in the afternoon ($\rho = 0.425$; $p = 0.019$), and a negative correlation for sweet carbonated beverages and the saliva buffering capacity after exercise ($\rho = -0.411$; $p = 0.020$) (Table 5).

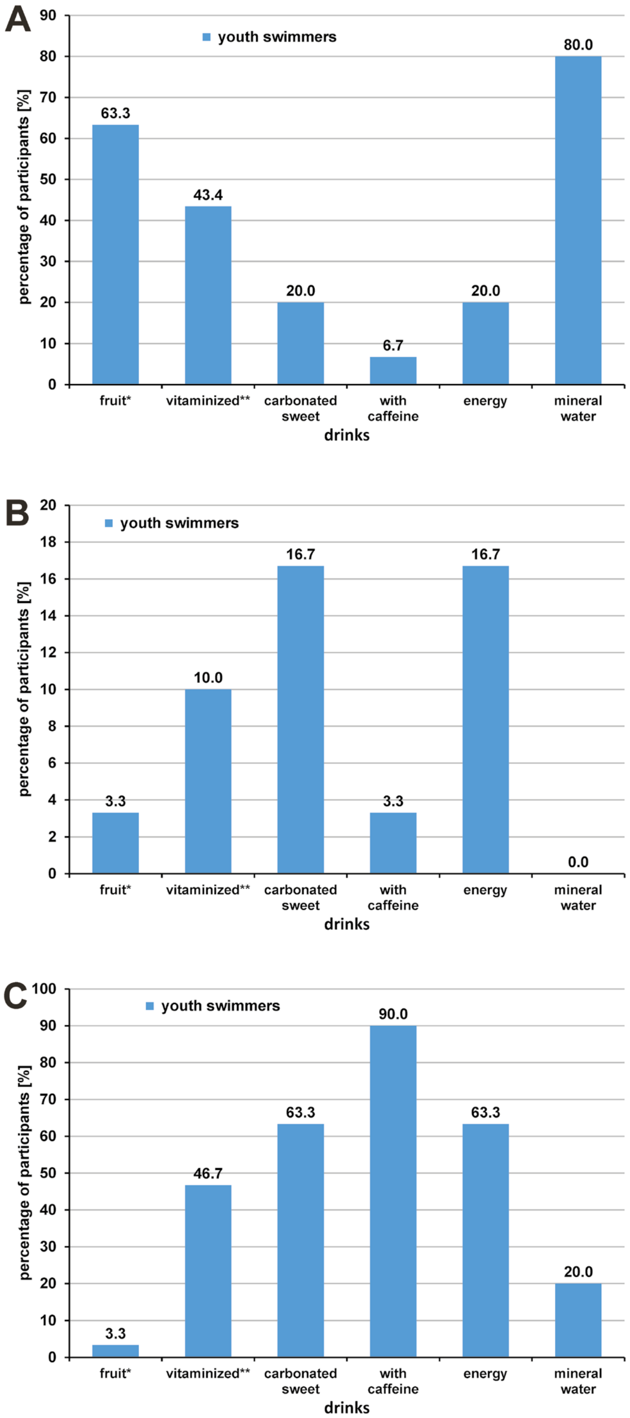

Fig. 5. Types of drinks consumed by youth swimmers after the workout session with regard to the frequency of consumption

A – every day or almost every day; B – occasionally; C – never or almost never. * $p = 0.032$; ** $p = 0.023$.

Table 5. Significant Spearman's correlation between the salivary parameter values and the drinks consumed by swimmers after the workout session in the morning and in the afternoon

Drinks consumed after training	Saliva parameters	Time of day: morning		Time of day: afternoon	
		ρ	*p*-value	*ρ*	*p*-value
Fruit drink	V	−0.267	0.152	−0.010	0.954
	pH	0.012	0.949	−0.308	0.096
	buffering capacity	0.064	0.736	0.085	0.653
	Ca	−0.138	0.465	−0.042	0.825
Vitaminized drink	V	0.057	0.761	0.190	0.313
	pH	−0.011	0.952	−0.126	0.506
	buffering capacity	0.242	0.197	0.045	0.811
	Ca	0.177	0.349	0.233	0.214
Carbonated sweet drink	V	0.398	0.029*	0.364	0.047*
	pH	0.069	0.716	0.181	0.338
	buffering capacity	0.037	0.842	−0.411	0.023*
	Ca	−0.162	0.391	−0.185	0.325
Drink with caffeine	V	0.137	0.470	0.132	0.486
	pH	0.354	0.054	0.425	0.019*
	buffering capacity	0.191	0.310	−0.238	0.204
	Ca	−0.124	0.510	−0.076	0.686
Energy drink	V	0.666	0.000*	0.531	0.002*
	pH	0.313	0.091	0.338	0.067
	buffering capacity	−0.197	0.294	−0.054	0.776
	Ca	−0.244	0.192	−0.343	0.062
Mineral water	V	−0.085	0.654	0.069	0.717
	pH	−0.017	0.927	0.224	0.232
	buffering capacity	0.002	0.991	−0.067	0.723
	Ca	0.196	0.298	−0.011	0.950

ρ – Spearman's rank correlation coefficient; * statistically significant.

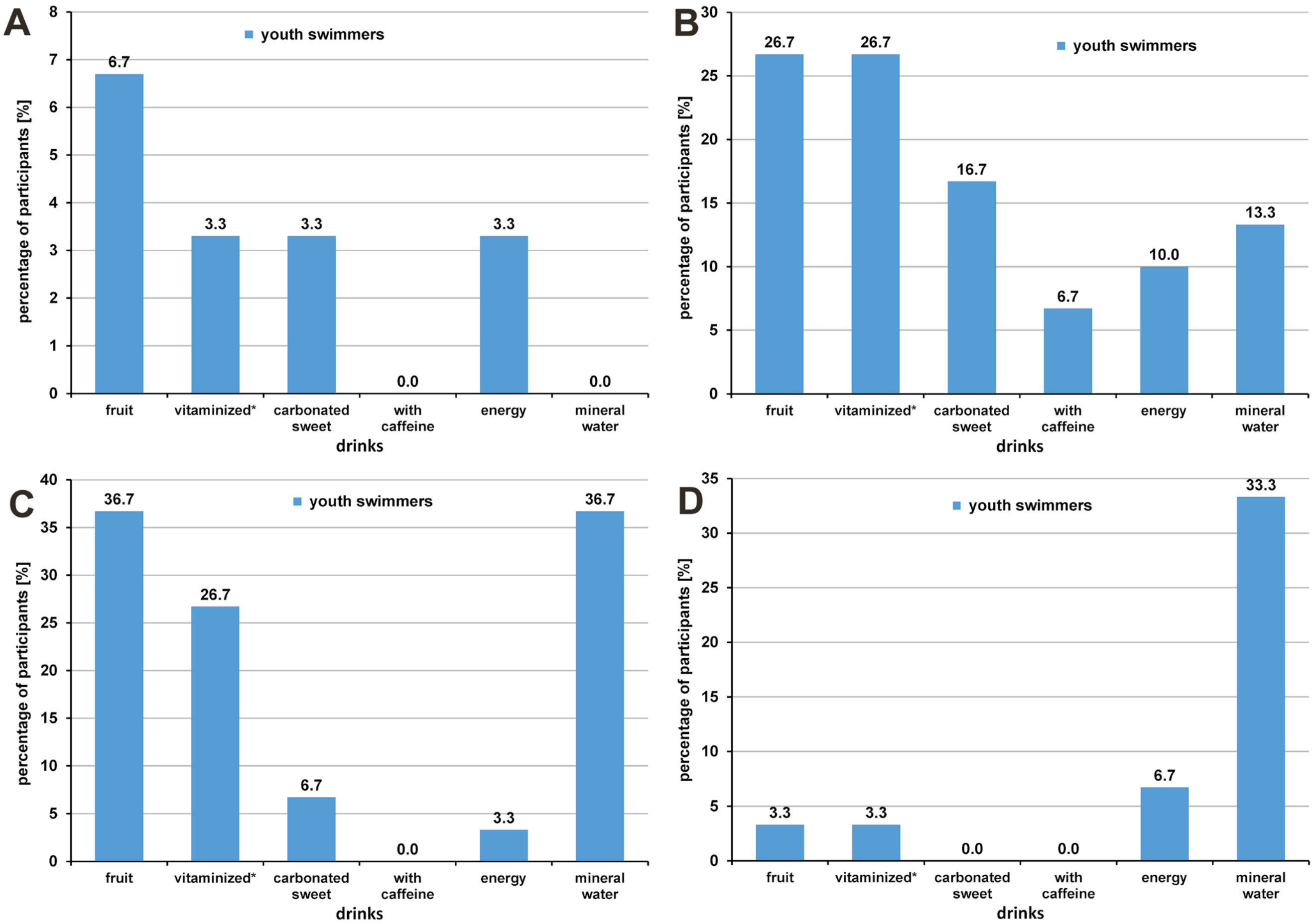

Fig. 6. Types and amount of drinks consumed by youth swimmers after the workout session

A – can; B – 0.3-liter bottle; C – 0.5-liter bottle; D – 1-liter bottle.
* $p = 0.016$.

Discussion

The results regarding carious disease prevalence, as defined by the DT number, showed that an average of 1.2 teeth in swimmers and 0.8 in the control group were affected by the carious process. The MT number was 0 in both groups. On the other hand, the average number of filled teeth (FT) was 3.3 and 0.8, respectively. The average DMFT score in the 2 groups differed, and was 4.5 for swimmers and 1.6 for the control group. The prevalence of caries in the study group of athletes was 56.7%, and 40.0% in the control group. The results of a study by Kaczmarek, conducted among swimmers aged 13–43 years, were as follows: the average DMFT score was 4.71, while in the control group it was 5.32.[6] The author also reported the values of the components of the index, with DT = 1.42, MT = 0.19 and FT = 3.10. In contrast, the prevalence of caries in both groups was similar, at 54.8% vs. 53.6%.[6] In the case of the elite athletes participating in the 2012 London Olympics, caries was found in 55% of them.[2] Gallagher et al., studying elite athletes aged 18 and above from various sports, along with swimming, found that 49.1% had teeth involved in caries.[28] A similar study assessing oral health was conducted by D'Ercole et al. in young swimmers (mean age: 12.5 years) compared to those not regularly involved in swimming (mean age: 9.85 years).[29] The researchers found tooth decay in 38.24% of competitive swimmers, and 42.86% in the non-competitive group.[29] Another study found that in non-sports children aged 12–14 years with DMFT ≥ 5, 61.1% had tooth decay.[14] Many studies show that for athletes, where good oral health is expected, the actual results do not confirm it. A review study on the oral health of elite athletes found caries in up to 75% of them.[5]

Increased consumption of carbohydrate-rich foods may contribute to the risk of caries, tooth erosion and periodontal inflammation in athletes, especially when they also exhibit dehydration due to endurance training and poor oral hygiene habits.

The present study also provided data on hygiene habits, related to the time and frequency of tooth cleaning, and the type of toothbrush used, as well as the frequency of dental visits in both groups. Swimmers and the control group brushed their teeth twice a day (66.7% vs. 80.0%), with swimmers brushing more often before breakfast (60.0%) and the control group after breakfast (70.0%).

Before sleep, both groups cleaned their teeth similarly (93.9% vs. 100.0%). The participants – both swimmers and controls – used a manual toothbrush in most cases (86.6% vs. 100.0%). Similar responses were obtained by Mulic et al. in a study of people in Norway, actively engaged in sports, who declared brushing their teeth twice a day and making regular dental visits at intervals ranging from 6 months to 2 years.[30] In a study conducted among Finnish adolescents actively engaged in sports, 95.0% brushed their teeth every day and 83.6% twice a day.[31] Different results were obtained by Khan et al. in athletes from Pakistan, who overwhelmingly (51.5%) brushed their teeth once a day – in the morning, while only 28.6% brushed their teeth in the morning and before going to bed.[4] In our study, both swimmers and the non-competitive group regularly visited the dentist twice a year, with the reason being a check-up (76.6% vs. 60.0%) and less often a toothache (33.3% vs. 0.0%). In a study by Kragt et al, 81% of Dutch athletes had their last dental visit within a year.[3] Different results were obtained by Khan et al.; the researchers reported that 37.5% of athletes had never been to the dentist, with only 5.8% making regular visits (every 6–8 months).[4] In most cases (50.5%), the reason was a toothache. The lack of regular visits, or even the lack of visits, translated into a high prevalence of dental caries in the subjects, which was 63.5%, and DMFT was equal to 2.7. The higher prevalence of dental caries, associated with the lack of good hygiene habits, along with the lack of check-up visits, could be due to the fact that the study was conducted in a developing country.[4] In their cross-sectional study, Needleman et al. noted that continental location was significantly associated with dental caries.[2]

The data on dietary habits showed in both groups, except for one person, the lack of adherence to a specific diet. Similar results were presented by D'Ercole et al., studying young swimmers.[29] To achieve peak performance, athletes often consume high-carbohydrate foods and energy drinks. The amount of sugary snacks and beverages consumed by competitive swimmers differed from that in the control group. Also, swimmers consumed sweet drinks significantly more often as compared to the control group. Similar results regarding the more frequent consumption of sweet snacks and drinks by active athletes as compared to the control group were obtained by Anttonen et al.[31] In our study, the subjects did not consume beverages during training. In a study by Frese et al., conducted among athletes involved in running, biking and swimming, 45.7% consumed sports drinks, 51.4% consumed water and 2.9% did not drink during exercise.[7]

Rinsing the mouth with water or a neutral beverage after exposure to carbohydrates or acidic sports nutrition products can reduce carbohydrate contact time and more quickly restore oral pH levels to neutral, reducing the risk of tooth decay and erosion.[32] In our study, the post-workout subjects predominantly drank water, while a smaller proportion drank energy drinks.

Prolonged exercise can reduce the unstimulated salivary flow.[33] In the present study, salivary parameters were determined twice a day, i.e., in the morning and in the afternoon. Saliva is the fluid responsible for cleaning the teeth and oral mucosa, has a buffering capacity and affects pH in the mouth. By analyzing salivary parameters, especially the flow rate, pH and buffering capacity, as well as the growth of caries-forming bacteria, it is possible to assess the risk of caries.[16] The literature shows that if there is a reduced salivary flow rate, and decreased pH and buffering capacity, the incidence of caries increases.[13] A decreased salivary flow can be explained by an increase in the activity of the sympathetic nervous system during intense exercise, causing the constriction of blood vessels in the salivary glands, resulting in a decreased salivary volume.[24] It can also be a consequence of sweat-induced dehydration and restricted fluid intake during exercise. However, in our study, the heat produced by the bodies of swimmers was released directly to water of a temperature ranging from 16°C to 28°C. Therefore, they were not exposed to dehydration. The significant ($p < 0.05$) reduction in saliva secretion after swimming exercise in the morning and in the afternoon observed in our study is consistent with previous studies.[7,30] In contrast, different results were reported by Anttonen et al., who observed a significant increase in saliva secretion after exercise, which returned to the baseline value after 30 min.[31] Such a result was explained by the fact that the study was conducted at a temperature of 10°C, which limits the dehydration of the body.[31] Our own data, like the results obtained by Dimitriou et al. for swimmers,[34] showed saliva secretion to be higher in the afternoon than in the morning, which is related to the higher activity of the sympathetic system in the morning than at other times of day.

In our study, an increase in salivary pH was observed after swimming training. It is unanimously confirmed by data from other authors.[7,23] Different results were reported by Tanabe-Ikegawa et al., who observed a decrease in pH following cycling exercise, which would support the rationale that as saliva secretion decreases, pH also decreases, and this can be explained by the fact that changes in salivary pH are related to the blood levels of CO_2.[35] The level of CO_2 in blood increases with athletic performance, which consequently causes a high concentration of CO_2 to pass from blood to saliva, thus causing a decrease in salivary pH. Our own data are different, which is probably related to the training environment; swimmers are in an aquatic environment all the time and feel less exhaustion during exercise as compared to training in a dry environment.

The buffering capacity of saliva helps maintain a normal acid–base balance in the oral cavity. A high concentration of acids adversely affects the condition of the teeth in terms of dental caries. The buffering capacity is responsible for maintaining proper saliva homeostasis. In our study, an increase in the buffering capacity was observed after training in the morning in contrast to afternoon training, where it was found to decrease. A decrease in the buffering capacity was also observed by Frese et al., who studied the effects of endurance training on oral health, with reference to tooth decay, among other factors.[7]

Moreover, an essential factor in caries prevention is the remineralization of the initial carious lesions. The protective effect on the hard tissues of the tooth is related to the presence of the Ca and phosphate ions in saliva, which are crucial for the remineralization of tooth enamel.[36] Physical exercise of varying intensity and duration can alter the concentration of these ions in saliva.[20] Our study showed a significant increase in the salivary Ca concentration after training in the morning, as well as in the afternoon, with respect to the baseline levels. This data differs from the results of Chicharro et al., who noted a slight decrease in the mean values of mixed saliva Ca levels after maximal cycloergometer exercise.[37] In contrast, our own results are consistent with those of Bretz and Carrilho, who noted a significant increase in Ca after a swim session.[38]

Conclusions

The oral health status in athletes should be considered a priority during sports participation. The prevention and promotion of oral health through greater awareness of the impact of oral hygiene and diet on the overall health of the body should become an important part of the care of athletes. Swimmers consumed carbohydrate-containing products more often as compared to the control group. Greater consumption of cariogenic products could translate into a higher number of decayed teeth in swimmers as compared to the control group. Caries prevalence in swimmers was higher than in the control group. After the workout session, both in the morning and in the afternoon, there was a significant decrease in V and a significant increase in Ca in swimmers. Comparing swimmers before training with the control group in the morning, significantly higher V and lower pH were observed in swimmers. It is necessary to raise awareness about the impact of oral health on sports performance.

Ethics approval and consent to participate

The study protocol was approved by the Bioethics Committee at Wroclaw Medical University, Poland (approval No. KB-327/2009). All examinations were conducted in accordance with the relevant guidelines and regulations, and all the recruited participants provided written informed parental consent.

Data availability

The datasets supporting the findings of the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Use of AI and AI-assisted technologies

Not applicable.

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