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The application of artificial intelligence algorithms for testing the correlation between the state of oral health and adolescent behavior concerning oral health

Primena algoritama veštačke inteligencije za ispitivanje korelacije stanja oralnog zdravlja i ponašanja adolescenata u vezi sa oralnim zdravljem

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Abstract

Background/Aim. A period of adolescence is characterized by turbulent emotional, physical and physiological changes. There are numerous risk factors that may endanger the oral health of adolescents as the influence of parents reduces, while the influence of the environment and peers increases. Therefore, the main aim of this study was to determine the behavior of adolescents concerning oral health, using a new statistical method – artificial intelligence algorithms. **Methods.** In the first part of the survey, data on the behavior of adolescents related to oral health were collected. Hiroshima University Dental Behavioral Inventory (HU DBI) questionnaire was used, and additionally expanded with three questions. The second part of the study included clinical examination. The research was conducted at the Faculty of Dentistry in Pančevo, Serbia. The first and second grade high school students were selected for the observation unit. The total sample consisted of 374 students (128 males and 246 females). We applied a special programming language called Python for parsing data, creating a database in digital form, processing data by standard statistical methods and through the Singular Value Decomposition (SVD) method. **Results.** The artificial intelligence algorithms clustered the respondents into two groups, based on their responses from the HU DBI questionnaire. Thus, the quality of the method and the need for analysis of this type in dental studies are demonstrated and proven. **Conclusion.** Based on the results obtained through artificial intelligence algorithms, we could conclude that respondents should rather be clustered into characteristic groups and analyzed than divided and observed according to sex, as it is the intuitive division.

Key words:
mouth; health; intelligence, artificial; adolescence; algorithms.

Apstrakt

Uvod/Cilj. Period adolescencije karakterišu burne emocionalne, fizičke i fiziološke promene. Javljaju se brojni faktori rizika koji mogu ugroziti oralno zdravlje adolescenata jer se uticaj roditelja smanjuje, a raste uticaj okoline i vršnjaka. Stoga je glavni cilj istraživanja bio da se utvrdi ponašanje adolescenata u vezi sa oralnim zdravljem, pri čemu je primenjena nova statistička metoda – algoritmi veštačke inteligencije. **Metode.** U prvom delu istraživanja, prikupljeni su podaci o ponašanju adolescenata u vezi sa oralnim zdravljem. Korišćen je upitnik Univerziteta u Hirošimi (Hiroshima University Dental Behavioral Inventory – HU DBI), koji je proširen sa tri pitanja. Drugi deo istraživanja obuhvatio je klinički pregled. Istraživanje je sprovedeno na Stomatološkom fakultetu u Pančevu, Srbija. Za jedinicu posmatranja izabrani su učenici prvog i drugog razreda srednje škole. Veličina ukupnog uzorka bila je 374 ispitanika (128 ispitanika muškog pola i 246 ispitanika ženskog pola). Za analizu podataka, pravljenje baze podataka u digitalnoj formi, obradu podataka standardnim statističkim metodama i metodom Dekompozicija na singularne vrednosti [*Singular Value Decomposition* (SVD)], korišćen je Piton (*Python*) programski jezik. **Rezultati.** Algoritmi veštačke inteligencije klasterifikovali su ispitanike u dve grupe, na osnovu njihovih odgovora iz HU DBI upitnika. Na ovaj način se pokazao i dokazao kvalitet metode i potreba za analizama ovog tipa u stomatološkim studijama. **Zaključak.** Na osnovu rezultata dobijenih primenom algoritama veštačke inteligencije mogli

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smo zaključiti da bi bilo logičnije da se ispitanici klasterifikuju u karakteristične grupe i zatim analiziraju, nego da se dele i posmatraju po polu, jer je to intuitivna podela.

Ključne reči:
usta; zdravlje; inteligencija, veštačka; adolescencija; algoritmi.

Introduction

The World Health Organization (WHO) defines adolescents as individuals who go through a period of growth and development. This phase, between 10 and 19 years of age, begins after childhood and lasts until adulthood [1]. Adolescence is characterized by the acceleration of physical growth, as well as changes in psychological development. The adolescent population is a vulnerable group with regard to preserving oral health. In the period of turbulent emotional, physical and physiological changes there are many risk factors that can endanger the oral health of adolescents. During this period, the influence of parents reduces, while the influence of the environment and peers increases. Despite the common knowledge about health risks, many adolescents adopt high-risk behaviors, such as smoking, alcohol, or the use of narcotics [2].

In order to determine the real needs of adolescents in terms of oral health and to set future goals of preventive and therapeutic programs, numerous public health and epidemiological studies have been conducted. In this way, large amounts of data are obtained that can determine the existence of a link between socio-demographic factors, habits, oral health behavior and the state of oral health [3]. Modern technology has devised ways to efficiently store data in order to take the least possible amount of space and to preserve the main information. The large increase in the production of multimedia data implies constant development and further optimization of various compression algorithms [4], like digital image compression [5]. The basic concept of the Singular Value Decomposition (SVD) algorithm is based on the principles of decreasing dimensionality through decomposition onto singular values [6] in order to increase the degree of image compression [6, 7].

The main objectives of this study were focused on identifying behavior of adolescents concerning oral health and the objective state of oral health, as well as on the correlation of oral health behavior and actual clinical oral health condition. One of the main goals was to compare the results obtained with standard statistical methods and application of artificial intelligence algorithms, which until now have not been applied to this type of analyses in dental research.

Methods

A special programming language called Python was applied for parsing data, creating a database in digital form, and processing data by standard statistical methods and through the SVD [8].

The SVD algorithm provides a simple approximation strategy for the original matrix by which the digital image is represented, using a matrix of smaller dimensions [9]. After sorting the singular values in a descending order, it is possible to keep the first "k" largest, and to set the others to zero. The result is a new "k" matrix, which depends on the value of "k", a good approximation of the original matrix, in terms of the smallest squares [10]. The choice of the value of the matrix rank, which, after applying the SVD algorithm presents the representation of the original image matrix, is a compromise between achieving a certain desired degree of compression and retaining the acceptable quality of the digital image [9]. According to input matrix "A", the computer program classifies the respondents into groups by a cluster method, thanks to logical machine learning (artificial intelligence).

To assess the impact of different forms of behavior on oral health, the Serbian version of the Hiroshima University Dental Behavioral Inventory (HU DBI), expanded with three questions, was applied. The original questionnaire was developed by Kawabata et al. [11]. It contains twenty questions that primarily relate to oral hygiene habits. All questions have two possible answers (I agree / disagree). A quantitative assessment of attitudes and behaviors related to oral health is possible based on the established total number of adequate responses, with a maximum score of 12. Bigger score means more adequate attitudes and behaviors in relation to oral health [12]; one point is assigned to each answer "I agree" to questions 4, 9, 11, 12, 16 and 19, as well as for each answer "I do not agree" for questions 2, 6, 8, 10, 14 and 15. Scoring any question, which relates to a particular attitude or behavior in the HU DBI questionnaire, is based on analytical research within which the statistical model has been developed [13].

The examinations were performed at the outpatient clinic, with artificial lighting, using a dental probe and a mirror. The total number of healthy, carious, extracted and sealed teeth for each respondent was determined [Decayed, Missing Filled Teeth (DMFT) index]. The criteria for setting caries diagnosis was the breakdown of the continuity of the tooth enamel (the presence of cavities).

The research was conducted at the Faculty of Dentistry in Pančevo. The observation unit was comprised of students of the first and second grade of high school who, as patients, visited the Faculty of Dentistry in Pančevo, Serbia. The total sample consisted of 374 students (128 males and 246 females). All of them with their parents agreed to participate in this anonymous research.

Results

The average number of diseased teeth calculated for the whole sample was 4.27 ± 0.24. For the probability level $p = 0.95$ we ascertained that in the basic sample it ranged from 3.78 to 4.76. The DMFT index values ranged from 0 (for both sexes) to 17 in boys or 15 in girls. The distribution of DMFT Eudex by the number of respondents is graphically presented in Figure 1.

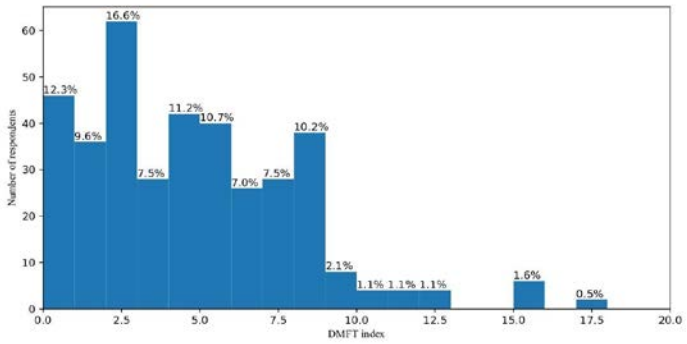

Fig. 1 – Distribution of the Decayed, Missing, Filled Teeth (DMFT) Index.

Table 1

Behavior concerning oral health according to the Hiroshima University Dental Behavioral Inventory (HU DBI)

Parameter	Males	Females	Total
Number of respondents	128	246	374
Minimum value	5	3	3
Maximum value	9	9	9
Average value	7.14	6.854	6.95
SE	0.154	0.106	0.087
SD	1.223	1.166	1.194
CV (%)	17.128	17.02	17.174
95% CI			
lower limit	6.832	6.642	6.777
upper limit	7.449	7.065	7.127
Significance of differences in average values			
$t = 1.561$			
$p = 0.120$			

SE – standard value error; SD – standard deviation; CV – coefficient of variation; CI – confidence interval; *t* – value for Student's *t*-test; *p* – value of statistical significance.

Concerning distribution between genders, with a probability of $p = 0.95$, it may be expected that the average values of the DMFT index range would be from 3.31 to 4.97 in males and from 3.73 to 4.94 in females. There were 46 respondents who did not have any carious, extracted and sealed teeth, and whose DMFT index was 0. Consequently, the number of persons with the DMFT index > 0 was 328 (87.7%).

There was no difference in the responses of boys and girls ($p > 0.05$); so the hypothesis that there is no difference between males and females was confirmed (Table 1). In almost one third of the questions (7 out of 23) in the HU DBI, respondents gave identical answers in more than 90% of cases (Table 2; Figure 2).

It is interesting that 22% of the respondents considered it inevitable to get artificial teeth at an old age. A large number of adolescents (95%) were concerned about the possible presence of halitosis and were constantly checking for their unpleasant breath, while a third of the respondents (31%) were concerned with the color of teeth, while 71%

Table 2

Percentage of agree and disagree with the HU DBI items

HU-DBI Item	Agree (%)	Disagree (%)
1. I go to see the dentist at least once a year.	72	28
2. My gums bleed when I brush my teeth.	6	94
3. I am worried about the color of my teeth.	31	69
4. I've noticed some white sticky deposits on my teeth.	10	90
5. I think that I cannot help having false teeth when I am old.	22	78
6. I think my teeth are getting worse despite my daily brushing.	7	93
7. I brush each of my teeth carefully.	47	53
8. I have never been professionally taught how to brush.	31	69
9. I think I can clean my teeth without using toothpaste.	9	91
10. I often check my teeth in a mirror after brushing.	96	4
11. I worry about having bad breath.	95	5
12. It is impossible to prevent gum disease with tooth brushing alone.	60	40
13. I put off going to the dentist until I have a toothache.	20	80
14. I have used a dye to see how clean my teeth are.	3	97
15. I use a toothbrush with hard bristles.	44	56
16. I don't feel I've brushed well unless I brush with strong strokes.	37	63
17. I feel I sometimes take too much time to brush my teeth.	62	38
18. I have had my dentist tell me that I brush very well.	81	19
19. I am satisfied with the appearance of my teeth.	71	29
20. I brush my teeth twice a day or more.	90	10
21. I use dental floss every day.	20	80
22. I use mouthwash on regular basis.	32	68
23. I smoke cigarettes every day.	3	97

HU DBI – Hiroshima University Dental Behavioral Inventory.

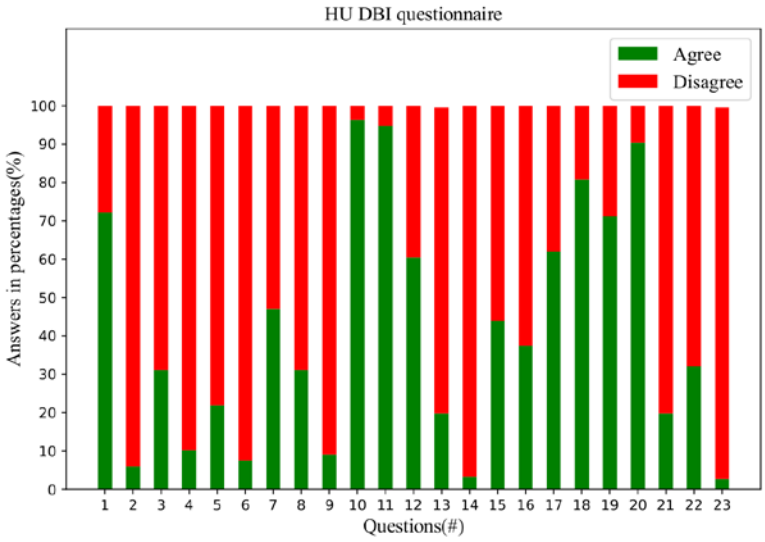

Fig. 2 – Distribution of the answers to questions from the Hiroshima University Dental Behavioral Inventory.

were satisfied with the appearance of their teeth. Although a large number of respondents used a hard toothbrush (44%), gingival bleeding during brushing was seldom (6%). A possible explanation was a fact that children mostly do not use strong/rough brushing movements (63%). A large number of respondents (62%) thought that they need to spend too much time for basic tooth wash. More than half of the respondents (60%) said that it is impossible just to brush teeth to prevent gingival inflammation. Most respondents did not consume cigarettes, which represents a health-safe behavior.

In the group of questions related to the HU DBI, the answers were assigned the following colors (Figure 3): I disagree – purple; I agree – yellow.

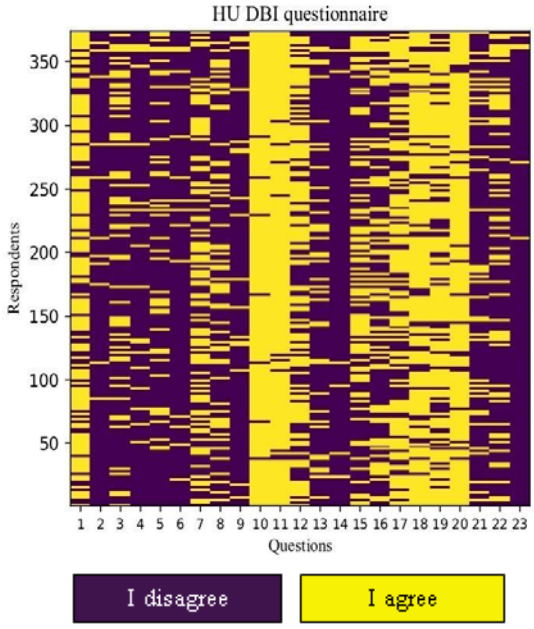

Fig. 3 – Hiroshima University Dental Behavioral Inventory (HU DBI) – Initial matrix.

By determining the most important element of the initial matrix, we got a new matrix (Figure 4), which, with the accuracy greater than 80%, showed that 47% of the respondents answered identically 4 questions from the HU DBI questionnaire with affirmative answer: Question 10 – After washing my teeth, I often check in a mirror how clean my teeth are; Question 11 – I'm worried/checking for an unpleasant smell out of my mouth; Question 18 – My dentist told me to wash my teeth well; Question 20 – I wash my teeth two or more times a day.

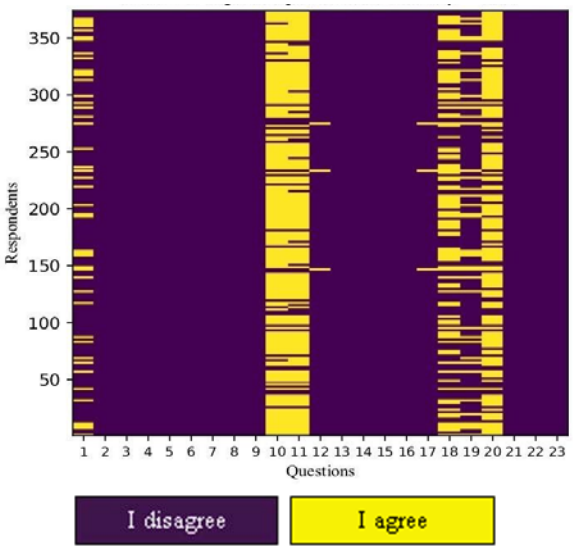

Fig. 4 – Hiroshima University Dental Behavioral Inventory (HU DBI) – Sigma importance 1, accuracy > 80%.

The artificial intelligence algorithms clustered the respondents into two groups ($p < 0.05$) regarding the answers "I agree" (Group 1) and "I disagree" (Group 2); so the hypothesis that there is a statistical significance between these two groups was confirmed (Figure 4, Table 3). The scale on the right side of the graph (Figure 4) represents the

Table 3

Decayed, Missing, Filled Teeth (DMFT) in respondents clustered into two HU DBI groups

Parameter	Group 1	Group 2	Total
Number of respondents	176	198	374
Minimum value	0	0	0
Maximum value	12	17	17
Average value	3.62	4.84	4.27
SE	0.32	0.36	0.24
SD	2.95	3.56	3.34
CV (%)	81.32	73.54	78.28
95% CI			
lower limit	2.99	4.12	3.78
upper limit	4.26	5.56	4.76
Significance of differences in average values			
	t = -2.508		
	p = 0.013		

HU DBI – Hiroshima University Dental Behavioral Inventory; Group 1 – respondents who answered "I agree" to questions number 10, 11, 18 and 20 from the HU DBI; Group 2 – respondents who answered "I disagree"; SE – standard value error; SD – standard deviation; CV – coefficient of variation; CI – confidence interval; *t* – value for Student's *t*-test; *p* – value of statistical significance.

equivalent color to the group to which the respondents belong: "Exact" (Group 1) – yellow; "Incorrect" (Group 2) – purple. Through the analysis of questions 10, 11, 18 and 20, we got an impression that these respondents were seriously concerned about the health of their teeth and took care of their mouth and teeth (Table 3). These results indicate that it would be interesting to examine the clinical condition of their oral health (DMFT index).

Through the analysis of basic statistical parameters for these two groups of respondents, one could notice a significant difference in the average values of the DMFT index (3.62/4.84) between these two groups of respondents. The respondents who were particularly concerned for the condition of their mouth and teeth had a significantly lower DMFT index and hence a better clinical state of oral health than the other group of respondents. Also, the average value for the D (decayed) component of the DMFT index was lower for the Group 1 (D = 1.69), compared to the Group 2 (D = 2.15), the M (missing) component was almost the same (0.33 / 0.32), while the number of filled (F) teeth was significantly lower in the Group 1 (F = 1.60) compared to the Group 2 (F = 2.00). By comparing these results with the results obtained with the basic statistical methods, we found the largest number of answers "I agree" in relation to the following questions: Question 10 – After washing my teeth, I often check in a mirror how clean my teeth are (96%); Question 11 – I'm worried/checking for an unpleasant smell out of my mouth (95%); Question 18 – My dentist told me to wash my teeth well (81%); Question 20 – I wash my teeth two or more times a day (90%).

Discussion

The state of oral health of adolescents is characterized by the presence of diseased teeth in most respondents (87.7%). At the level of the overall sample, the caries index average value was 4.27. According to literature data, the average value of this index in German 15-year-olds is 1.8 [14], in Greece 3.19, in Slovenia 4.3, in Bosnia 6.6 and in Serbia 5.5 [13–17].

In Central and Eastern European countries, the increased prevalence of caries in school children and adolescents is associated with inadequate application of preventive measures and the lack of organized health promotion activities with younger age groups [18]. Also, high prevalence of caries in developing countries can be attributed to the fact that the system of dental healthcare in these countries is in transition [19, 20]. Serbia, unfortunately, belongs to countries with insufficient health education activities and the healthcare system is primarily oriented towards therapy and not the prevention of oral diseases. Therefore, a high DMFT index value in the sample of 15-year-olds is not surprising.

The lifestyle of adolescents is directly and indirectly related to the development of caries [21]. Studies in the Netherlands and Australia have proved the influence of parents on the development of oral hygiene behavior of children - the transfer of knowledge, but also the control over the health behavior [22].

A survey conducted on the territory of the Republic of Serbia in 2013 showed that there is a significant correlation between good oral hygiene of parents and practice of controlling children habits and good oral health [23].

The respondents of both genders who gave 9 correct answers, out of possible 12 that are scored in the HU DBI questionnaire, filled out the questionnaires with focus. The standard deviation was much higher than the standard error value, plus the coefficient of variation was large enough, which all leads to the conclusion that we had a satisfactory sample of respondents. More recently, this questionnaire has been used in a research in which the attitudes and behaviors related to the oral health of dentists and dental hygienists around the

world have been compared [24]. It has been found that there are significant differences among students from different countries and cultural groups, as well as among students in relation to the grade of their studies [25].

Many oral health studies suggest that one of the reasons for neglecting oral hygiene in adolescence is that young people feel that they have no time to thoroughly brush their teeth [26], which we have noted in this study, too. Namely, 60% of respondents stated that they need too much time for basic tooth care.

Generally, it has been established that adequate behaviors in relation to oral health are associated with a better oral health status of adolescents [27]. The DMFT index of 4.27 is not at all satisfactory, indicating that adolescents have greater care of oral health but do not work as they should, do not use adequate pastes in the right way. Certainly, the most important component is the diet that is not treated as the key risk factor in our country. Research has clearly indicated that significant preventive effects are missing when taking free sugar up to 7 times a day even in good oral hygiene and with the use of fluoride pastes [28]. Additionally, brushing teeth without adequate fluoride paste also has no preventive effect [29].

A large number of researches mark the school as a very convenient place for conducting public health education campaigns, as children spend most of their time at school. The Oral Health Education (OHE) program in Bangladesh, conducted by educated dentists in primary schools, 6 months after the implementation, showed a significant increase in knowledge, changes in children's behavior and more frequent visits to dentists after the education [30]. Numerous results show that oral health significantly worsens after leaving primary school.

Gathering medical information and storing these data in the future (with the protection of patient privacy) should help early identification of risk patients and application of better treatment modalities. Accordingly, these possibilities should become reality [31, 32].

Multivariate analysis is by far the greatest power of artificial intelligence as it makes intelligent decisions, such as the human mind, based on the data from the photographic memory from the hard disk. No analysis is needed through emotions, and there is no negative attention deficit. Artificial intelligence does not need sleep and does not get tired after focusing on one topic for too long. At the same time, it benefits from a massive parallel processing. With enough memory and processing power, artificial intelligence could keep the medical records of the entire family tree and use it to quickly search the database with relevant diagnostic information and simultaneously call the banks of medical and social resources [32]. At present, it is not trusted enough to be completely autonomous.

Further research in the field of machine learning should be increased. It would be a good idea to integrate them into clinical practice as much as possible because, in this way, science can benefit greatly from this technology in the future. This type of research is also a basis for identifying health risks that could be followed by the use of electronic medical records [31, 32].

Conclusion

Habits related to oral health and determined by the HU DBI questionnaires are, in the case of the tested sample, predictors of oral health. In order to inform teenage children about the importance of oral health and to adopt healthy behaviors concerning oral hygiene and proper nutrition, educational interventions are needed. In studies based on the HU DBI, it is recommended to determine whether there is a group of respondents who gave affirmative answers to all four questions (Questions 10, 11, 18, and 20), since the algorithm of artificial intelligence identifies these subjects as a separate cluster with better oral health than respondents who did not give affirmative answers to these 4 questions.

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