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RESEARCH

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ARTIFICIAL NEURAL NETWORK APPLIED IN THE ANALYSIS OF HEALTH-RELATED QUALITY OF LIFE OF ADOLESCENTS

*Rede neural artificial aplicada na análise da qualidade de vida relacionada à saúde de adolescentes**Red neuronal artificial aplicada en el análisis de la calidad de vida relacionada con la salud de los adolescentes***Adélia Dayane Guimarães Fonseca¹** **Rene Ferreira da Silva Junior²** **Murilo Cesar Osorio Camargos Filho³** **Marcos Flávio Silveira Vasconcelos Dangelo⁴** **Joanilva Ribeiro Lopes⁴** **Carla Silvana de Oliveira e Silva⁴** 

ABSTRACT

Objective: to construct a model that explains the health-related quality of life among school adolescents from the KIDSCREEN-27 instrument through the creation of an artificial neural network. **Method:** cross-sectional and analytical study with 635 adolescents using KIDSCREEN-27. An artificial neural network with four layers was developed to evaluate the variable health-related quality of life by means of the mean responses. For the first three layers of neurons, logistic function was used as transfer function and linear function was used for activation. **Results:** the neural network reached accuracy of 98.96% and when compared the dimensions of kidscreen-27 with sex and practice of physical activities all presented significant statistical association, except the dimensions social support and peer group and school environment. **Conclusion:** the results may have important consequences for the identification of adolescents at risk and the direction of public health policies.

DESCRIPTORS: Adolescent; Health-related quality of life; Public health.

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RESUMO

Objetivo: construir um modelo que explique a qualidade de vida relacionada à saúde entre adolescentes escolares a partir do instrumento *KIDSCREEN-27* por meio da criação de uma rede neural artificial. **Método:** estudo transversal e analítico com 635 adolescentes utilizando-se o *KIDSCREEN-27*. Foi desenvolvida uma rede neural artificial com quatro camadas para avaliar a variável qualidade de vida relacionada à saúde por meio da média das respostas. Para as três primeiras camadas de neurônios foi utilizada função logística como função de transferência e para a ativação foi utilizada função linear. **Resultados:** a rede neural alcançou acurácia de 98,96% e quando comparadas as dimensões do *KIDSCREEN-27* com sexo e prática de atividades físicas todas apresentaram associação estatística significativa, exceto as dimensões suporte social e grupo de pares e ambiente escolar. **Conclusão:** os resultados podem ter importantes consequências para a identificação de adolescentes em risco e o direcionamento de políticas públicas de saúde.

DESCRITORES: Adolescente; Qualidade de vida relacionada à saúde; Saúde pública.

RESUMEN

Objetivo: construir un modelo que explique la calidad de vida relacionada con la salud de los adolescentes escolares a partir del instrumento *KIDSCREEN-27* a través de la creación de una red neuronal artificial. **Método:** estudio transversal y analítico con 635 adolescentes utilizando *KIDSCREEN-27*. Se desarrolló una red neuronal artificial con cuatro capas para evaluar la variable calidad de vida relacionada con la salud mediante las respuestas medias. Para las tres primeras capas de neuronas, la función logística se utilizó como función de transferencia y la función lineal se utilizó para la activación. **Resultados:** la red neuronal alcanzó una precisión del 98,96% y cuando se compararon las dimensiones de *KIDSCREEN-27* con el sexo y la práctica de actividades físicas todos presentaron una asociación estadística significativa, excepto las dimensiones de apoyo social y grupo de pares y entorno escolar. **Conclusión:** los resultados pueden tener consecuencias importantes para la identificación de adolescentes en riesgo y la orientación de las políticas de salud pública.

DESCRIPTORES: Adolescente; Calidad de vida relacionada con la salud; Salud pública.

INTRODUCTION

Adolescence is a unique period in human development, characterized by changes that affect the biological, cultural, and psychosocial fields.¹ According to the World Health Organization – WHO,¹ adolescence comprises the period from 10 to 19 years of age, representing about 17.9% of the Brazilian population and 18% of the world population in 2010.¹⁻² Given the various changes characteristic of this phase and their influence on future physical and cognitive development, ways to measure health-related quality of life in this population are increasingly important for the creation of public health policies and resource allocation.^{1,3-5}

Quality of life is a broad, subjective, and conceptually complex term, related to feelings of well-being, happiness, and satisfaction with life.³ This concept is in line with the definition of health proposed by the WHO in 1946 and ratified in 1948, in which health is a state that includes not only the absence of disease, but primarily a state of complete mental, physical, and social well-being.⁶⁻⁷ Instruments designed to assess health-related quality of life (HRQL) in adolescents are increasingly common.³ HRQOL is a term more restricted to diseases and health interventions, and among the instruments used to assess it, the representatives of the *KIDSCREEN* family stand out because they are public domain, easily accessible and applicable, and have been translated into several languages.⁸

The *KIDSCREEN* instruments were designed by the project "Screening and Promotion for Health-related Quality of Life in Children and Adolescents – A European Public Health Perspective" between the years 2001 to 2004. These instruments

stand out because they were developed from a large project that included several countries and because they assess the overall health-related quality of life, creating means to identify children and adolescents at risk and may indicate early interventions.⁹

In general, common statistical programs are the most used to analyze and predict information, statically, based on the analysis of the data provided.¹⁰⁻¹¹ However, computational systems inspired by the neurological connections of the human brain, the artificial neural networks (ANN), have the advantage of adapting and learning, as do neuronal connections, and are being increasingly employed in health research.¹⁰⁻¹² Given the complexity of predicting and defining HRQL in a period of such important changes as adolescence, ANNs can help establish data that are even closer to the individual reality of each person.

Given the relevance of adolescence in the world and especially in Brazil, it is important to define models that can measure HRQL in this population, especially considering that the losses that occur during adolescence are reflected in future adulthood. Cross-sectional studies were developed in Canada and Colombia using the *KIDSCREEN-27* instrument to assess HRQL among adolescents, however, without using artificial neural networks.¹³⁻¹⁴

Understanding the variables that influence HRQoL among adolescents may contribute to the organization of work management of professionals in health services in the construction and implementation of educational and care actions, as well as support as a deliberative tool for allocation of resources, planning and strengthening of national public policies within the Brazilian health system, serving society in the sense of improvement in HRQL among adolescents. Thus, this study aimed to build

a model that explains the health-related quality of life among adolescent students aged 10 to 16 years enrolled in the public school system of the city of Montes Claros – Minas Gerais, from the KIDSCREEN-27 instrument by creating an artificial neural network.

METHOD

Cross-sectional and analytical study with the development of an artificial neural network with four layers to evaluate the variable health-related quality of life. The study was conducted with schoolchildren aged 10 to 16 years enrolled in the network of state schools in the city of Montes Claros, Minas Gerais, Brazil. The study population consisted of 77,833 schoolchildren of both genders who met the following inclusion criteria: they were aged between 10 and 16 years, were regularly enrolled in the public state school network, attending elementary and/or high school and who obtained the consent of their parents or legal guardians to participate in the study.

In the sampling process, a reliability level of 95% was adopted, with an acceptable margin of error of 5%. The selection of the conglomerates was conducted randomly and probabilistically, so that each participant had equal probability of being selected for the sample. A frequency of 0.50 was established for the event studied. Correction was made for finite population and correction for design effect, assuming $deff$ equal to 1.5. In order to correct for possible losses and non-responses, an additional 10% was also adopted, resulting in a final sample of 634 participants.

The sample selection was conducted by probabilistic conglomerate, the population was divided into regions, and then a representative draw was made from the analyzed universe. The population was selected by segregating the municipality into regions: north, south, east, and west, the number of schools was listed, and the number of students enrolled was quantified. The total of 63 school institutions was used as conglomerates (sampling units) and grouped. Thus, the complex sampling by stratification and conglomeration was conducted in two stages. In the first stage the selection of the institutions (primary sampling unit) was done by systematic sampling with probability proportional to the number of institutions in the strata.

In the second phase, the students (secondary sampling unit) were selected from each defined class, in accordance with the age of interest (10 to 16 years). The selection of the students was made through a systematic probabilistic sampling process, using as reference the student's enrollment number. Thus, the final sample corresponded to 635 students from five schools evaluated, and met the population representativeness, having as reference for this proportionality the number of students in relation to sex and age.

The variable health-related quality of life was assessed by applying the KIDSCREEN-27 instrument. The KIDSCREEN is based on self-reports of healthy individuals and/or individuals with chronic diseases aged 8 to 18 years old, with three versions: KIDSCREEN-52, KIDSCREEN-27 and KIDSCREEN-10 index.

The versions have from 10 to 52 items scored on a 5-point Likert scale: 1=not at all/never, 2=somewhat/rarely, 3=moderately/sometimes, 4=very much/often, and 5=always/always. Each item is scored from 1 to five points, with higher scores being related to greater HRQL.⁹

Although the long version with 52 items of the KIDSCREEN assesses more HRQL domains, this instrument is difficult to apply because of its length, making its use in large epidemiological studies unfeasible.⁹⁻¹⁰ Therefore, the KIDSCREEN-27 was created, maintaining satisfactory psychometric properties and with the least possible loss of information, and it can be used as a short screening instrument. This version assesses the following HRQL domains (1) Physical well-being; (2) Psychological well-being; (3) Autonomy and relationship with parents; (4) Social support and peer group; and (5) School environment.

The ANN used in this work has four layers with 10, 8, 4 and 1 neurons, respectively (Figure 1).

Predicted QVRS	1-2	1 1.0%	0 0.0%	0 0.0%	0 0.0%
	2-3	0 0.0%	9 9.4%	1 1.0%	0 0.0%
	3-4	0 0.0%	0 0.0%	56 58.3%	0 0.0%
	4-5	0 0.0%	0 0.0%	0 0.0%	29 30.2%
		1-2	2-3	3-4	4-5
		Real QVRS			

The ten neurons of the first layer represent the 10 input variables of the problem and the final neuron computes the value of health-related quality of life (HRQL) from the degrees of activation of the neurons of the inner layers. The activation function of the neurons in the first three layers is the sigmoidal, or logistic, function given by the equation below. The activation function of the last layer is purely linear: $f(x) = x$.

$$f(x) = \frac{1}{1 + \exp(-x)}$$

The variable of interest, health-related quality of life (HRQL), is the mean of the answers from the KIDSCREEN – 27 questionnaire, in which each question could be answered on a five-point Likert-type scale. In order for the highest values of this mean to represent the highest qualities of life, some questions in the questionnaire had their scores reversed (1 → 5, 2 → 4, 3 → 3, 4 → 2, and 5 → 1) because their scale was inverted. Thus, the variable of interest HRQL ranges continuously between 1 and 5, with 5 indicating high HRQL and 1 indicating low HRQL. The final variable was categorized into 4 intervals: 1-2, 2-3, 3-4, and 4-5.

To begin data collection, a letter of introduction and a Term of Institutional Consent (TCI) were drawn up and sent, as well as a copy of the research project, to the Municipal Secretary of

Education and also to the school management of each educational institution in order to obtain authorization to carry out the study. The school representatives were instructed about the project, and all of them signed the TCI authorizing the study to be carried out in the respective institution. Since the study participants were children and adolescents aged 10 to 16 years, we obtained the consent of parents or legal representatives by signing the informed consent forms.

The study met the standards of Resolution No. 466/12 of the National Health Council of the Ministry of Health. The study was approved by the research ethics committee of the signatory institution under opinion number 1,503,680 and CAAE 51040315.3.0000.5146.

RESULTS

Of the 635 adolescents who participated in this study, most were male (60.2%), self-declared as brown (57.5%), and had family incomes of up to three minimum wages (83.9%). Other sociodemographic data are described in Table 1.

When asked about the practice of physical activities, the majority (59.9%) said they did not practice, and of those who did practice, most (33.7%) had the habit of practicing only twice a week.

When the perception of HRQL measured by the five dimensions of the KIDSCREEN-27 was compared to gender and physical activity practice, it was noted that only the dimensions "social support and peer group" and "school environment" did not show statistically significant results ($p\text{-value} > 0.05$) when compared to gender. Regarding the practice of physical activity, all assessed dimensions of the KIDSCREEN-27 showed statistically significant results ($p\text{-value} < 0.001$).

A four-layer feedforward ANN with supervised learning was used, whose output was represented by the variables of the KIDSCREEN-27 questionnaire. The inputs were the factors used to predict HRQL (smoking, drinking, physical activity practice, food survey, body self-perception, weight loss practices – vomiting induction, excessive exercise, prolonged fasting periods; fear of getting fat, body mass index).

Table 1 – Sociodemographic profile of adolescent students from public schools.

Variables	N	%
Gender		
Male	381	60,2
Female	252	39,8
Total	633	100
Color/race		
White	118	18,7
Brown	362	57,5
Yellow	21	3,3
Indigenous	20	3,2
Black	109	17,3
Total	630	100
Income		
Up to 3 minimum wages	516	83,9
From 3 to 10 minimum wages	75	12,2
From 10 to 20 minimum wages	11	1,8
More than 20 minimum wages	13	2,1
Total	615	100
Number of residents in the house		
2 residents	29	4,6
3 residents	99	15,7
4 residents	238	37,8
5 or more residents	263	41,9
Total	629	100
School Year		
5th grade elementary school	29	4,6
6th grade elementary school	93	14,9
7th grade elementary school	66	10,6
8th grade elementary school	95	15,2
9th grade elementary school	91	14,6
1st year of high school	204	32,7
2nd year of high school	46	7,4
Total	624	100

Table 2 – Physical activity practice in adolescents students from public schools.

Variables	N	%
Do you practice physical activity?		
Yes	252	40,1
No	377	59,9
Total	629	100
How many times a week?		
Does not practice	250	41,2
Once a week	57	9,4
2 times a week	120	19,9
3 times a week	73	12
4 times a week	26	4,3
5 times a week	26	4,3
6 times a week	4	0,8
7 times a week	50	8,2
Total	606	100

To test the learning ability of the ANN, the data were divided into two randomly chosen sets, one for training the ANN and the other for testing, in the proportions of 80% and 20%, respectively. It is important to note that the test data were not presented to the network at any time during training. The ANN was able to predict HRQL with an accuracy of 98.96% on the test data. Figure X shows the confusion matrix of the results, where the elements outside the main diagonal represent those whose prediction was different from the actual one, or the network errors for each HRQL category. All simulations were performed using MATLAB® version R2017a software.

DISCUSSION

The ANN proposed in this study to explain HRQL in adolescents based on the variables of the five dimensions assessed by the KIDSCREEN-27 instrument proved to be satisfactory, with high levels of accuracy, fulfilling the role for which it was proposed.

Analysis models based on the functioning of biological neural networks, such as the ANN proposed here, are increasingly common.¹⁰⁻¹¹ This is due to the numerous advantages that these models present when compared to other means of analysis. Among them is the possibility of solving problems without having to define rules and cast models, which allows better analysis of situations in which there are changes in the environment that interfere with the variable of interest. Other advantages are the great capacity to process complex data in a non-linear manner, with the ability to learn and generalize new information.^{11,15} All these characteristics attributed to this type of artificial intelligence allow ANNs to classify patterns in a broad manner and to be used for prediction, which justifies their use in public health research.

Similar to brain activity, ANNs have the ability to extract knowledge and infer new data from examples. This property gives ANNs the opportunity to progressively improve their performance through the use of learning algorithms, making content available for practical use and decision making.^{11,15-16} Given the difficulty

Table 3 – Perception of health-related quality of life measured by the KIDSCREEN-27 instrument in adolescents according to gender and physical activity.

Dimension	Gender		P value	IC 95%
	Female Mean (SD)	Male Mean (SD)		
Physical well-being	49 (17,6)	62,2 (17,5)	0,000	(-16,0 a - 0,3)
Psychological well-being	66,7 (18,6)	75 (15)	0,000	(-10,9 a - 5,6)
Autonomy and relationship with parents	62 (21,1)	67,4 (19,7)	0,002	(-8,6 a - 2,0)
Social support and peer group	74,9 (21,9)	75,3 (22,8)	0,861	(-3,9 a 3,2)
School Environment	66,5 (20,8)	65,8 (19,4)	0,682	(-2,5 a 3,9)
General	63,9 (15)	69,7 (13,4)	0,000	(-8,0 a - 3,4)
Do you practice physical activity?				
Dimension	Female Mean (SD)	No Mean (SD)	P value	IC 95%
Physical well-being	59,7 (18)	46,3 (16,8)	0,000	(-16,2 a - 0,5)
Psychological well-being	72,9 (16,4)	65,4 (18,9)	0,000	(-10,3 a - 4,5)
Autonomy and relationship with parents	65,6 (20,1)	61,87 (21,4)	0,026	(-7,1 a - 0,46)
Social support and peer group	77,5 (20,2)	71,5 (24,5)	0,001	(-9,7 a - 2,3)
School Environment	67,2 (19,8)	64,8 (20,8)	0,140	(-5,7 a 0,8)
General	68,9 (13,7)	62,1 (15,2)	0,000	(-9,12 a - 4,4)

in defining HRQL and, consequently, evaluating it, the use of an ANN is an interesting way to better analyze this indicator.

Other health researchers are also investing in the use of ANNs in their work for prediction problems.¹⁷⁻¹⁸ Recently, Baquero et al.⁶ used an ANN model to make predictions about dengue in the city of São Paulo, Brazil. Xie et al.¹⁸ sought to build an ANN for orthodontic treatment decision making in adolescents between eleven and fifteen years old, in order to determine the need of tooth extraction. These authors built an effective ANN with 80% accuracy.

The present study developed an ANN that predicts HRQL in adolescents aged 10 to 16 years, with 98.96% accuracy. Studies assessing HRQL in adolescents are scarce, especially when we take Brazil and adolescents without any health problems as examples.⁸ This fact limits the adoption of public health policies that meet the physical and mental health needs of this population, since the lack of assessment does not allow the identification of gaps and specific needs.

Several instruments have been proposed to assess HRQL in adolescents. This is particularly important because it has been shown that the assessment of health status itself is a strong predictor of morbidity and mortality, and is often more effective than objective measures of health. Among them are the "Vécu et Santé Perçue de l'Adolescent (VSP-A)", an instrument originally developed and validated in France to assess HRQL in healthy and sick adolescents¹⁷; the "Healthy Days", a tool developed by the American "Centers for Disease Control and Prevention" that assesses HRQL and the "Patient-Reported Outcomes Measurement Information System (PROMIS) Measure of Global Health", also developed in the United States by the "National Institutes of Health" to assess, through ten questions, the overall physical, mental, and social HRQL.¹⁸ However, due to the technical difficulties imposed by the use of these instruments, such as lack of validation in the national environment, not having been translated into Portuguese, and low availability, we chose to use the KIDSCREEN-27 in the ANN.

The KIDSCREEN-27 is a HRQL assessment instrument that aims to understand the perception of the individuals assessed as to HRQL and the factors that promote it, whether social or personal.²⁰ This tool may be used in epidemiological surveys and as a means to follow up individuals with chronic diseases, identifying differences of sex, nationality, socioeconomic status and health condition.²⁰ Moreover, it has also been extensively evaluated as to its psychometric properties, reproducibility and validity in populations of various ethnicities.⁹

In Brazil, it has already been translated into Portuguese and validated between the years 2014 and 2017 by a research group from the Federal University of Paraíba entitled LONCAAFS (Longitudinal Study on Sedentary Behavior, Physical Activity, Diet, and Health of Adolescents). During the validation process, the instrument obtained satisfactory levels of reproducibility, internal consistency, and validity among adolescents aged 10 to 15 years.⁹

The KIDSCREEN-27 has also been applied in the Brazilian population by several researchers to assess HRQL in adolescents. Bertoletti.¹⁹ in a cross-sectional study with 203 adolescents with congenital heart disease from a Brazilian hospital showed that the type of heart disease, either cyanotic or acyanotic, and the initial diagnosis did not influence the perception of HRQL.¹⁹ Another study developed in southern Brazil that also used the KIDSCREEN-27 among individuals from eleven to thirteen years of age showed, similarly to what was presented here, that boys showed a higher HRQL than girls in four of the five dimensions assessed: Physical well-being, Psychological well-being, Autonomy and relationship with parents, and Social support and peer group. In the fifth dimension (school environment), girls showed better HRQL scores.²⁰

The ANN constructed here also showed that the practice of physical activities by adolescents was related to higher scores on HRQL indices. Andersen et al.³ in an evaluation of school-children in Norway showed that better cardiorespiratory fitness was positively associated with better scores in the five domains of the KIDSCREEN-27, i.e., better HRQL indices.

In this study, most adolescents did not practice physical activity or if they did, it was at levels below those recommended by the WHO.⁵ According to the "Global Accelerated Action for the Health of Adolescents",²⁰ a document produced by the WHO in 2017, adolescents between ten and seventeen years of age should practice at least sixty minutes of moderate to high-intensity physical activity daily.²⁰ Sedentary lifestyles are associated with the development of chronic diseases, mainly related to metabolism and the cardiovascular system, such as obesity, dyslipidemias, and hypertension.^{1,3-4} Adding sedentary lifestyles to the fact that adolescence is a formative period in which the individual acquires habits for adult life, it is extremely important to institute actions in this phase to reduce sedentary lifestyles.

This work presents several positive points that should be highlighted. This is the first study that sought to estimate HRQL among adolescents using an ANN from the KIDSCREEN-27. In addition, a diverse sample was used that included adolescents of all races/colors and with a high degree of representativeness of neighborhoods and social classes. Added to this is the fact that the adolescents selected were from the general population, without specific health problems, which are usually overlooked in surveys to the detriment of those with some specific disease or difficulty. Nevertheless, it should also be seen in the light of some limitations that may limit the generalizations of the information obtained here with the analysis performed by ANN. Among them, we highlight the fact that the adolescents belonged only to the public school network, which may have interfered with the HRQL of adolescents, since those who belong to the private network tend to have a different lifestyle.

CONCLUSION

HRQL measures are important health indicators. The ANN built here can be reproduced by other studies and help to estimate

the quality of life, and can guide public health policies for regions where low health-related quality of life is observed. Furthermore, it may also be used to assess health-related quality of life among adolescents diagnosed with chronic diseases, which, despite medical advances in the diagnosis and treatment of diseases, do not mean that they also have health-related quality of life.

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