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Analysis of discriminant variables for classification of medical schools

Análise de variáveis com potencial discriminante para classificação de escolas médicas

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ABSTRACT

Introduction: This is a methodological study that aims to identify the extent to which a set of variables characteristic of medical schools have a discriminating capacity to classify the courses through cluster analysis. In the last two decades, there has been a significant increase of vacancies in medical courses. This advent has posed challenges for evaluation programs, both because of the need to expand the evaluation process and the need to implement new quality indicators.

Objective: To propose analysis techniques to improve the discriminating capacity to classify medical courses through variables related to structural, operational, and objective aspects that can be incorporated into the already used methods.

Method: Descriptive, analytical-methodological, quantitative study that used data from existing medical courses in December 2020, in the state of São Paulo. Analysis by hierarchical and non-hierarchical clustering of courses was performed to identify the discriminating elements that provide standards that cooperate for the classification of medical schools. The studied variables were: course start, workload, academic regime, methodology, University-Hospital, administrative category of the institution, gratuity. For the construction of the clusters, the Ward method and the Euclidean distance were used to estimate the discrimination between the groups. In the non-hierarchical clustering, the definition of the number of groups was determined by the analysis of the decrease in variance. The correlation between the variables was also evaluated through heatmaps.

Results: The cluster analysis showed the existence of three groups of medical schools by similarity, with one group consisting of older schools with greater workload, and the other two consisting of private schools without a university-hospital, differing by the course time. Furthermore, the correlations reinforced that the adopted variables cooperated for the discriminability between the groups.

Discussion: There is a known heterogeneity among undergraduate courses in Brazil and this also applies to medical courses, which poses methodological challenges for the established assessment processes. However, the inclusion of variables requires methods capable of refining the discriminant capacity of the analysis.

Conclusion: The analysis proposed here proved to be capable of identifying groups of medical schools through objective indicators that can support the evaluation process of medical schools.

Keywords: Medical Education; Medical Schools; Cluster Analysis.

RESUMO

Introdução: *Este estudo metodológico pretendeu identificar em qual medida um conjunto de variáveis características de escolas médicas possui capacidade discriminante na classificação dos cursos por meio da análise de agrupamento. Nas últimas décadas, houve um aumento expressivo do número de vagas ofertadas para cursos médicos. Esse advento impôs desafios para os programas de avaliação, tanto pela necessidade de expandir o processo como pela necessidade de implantação de novos indicadores de qualidade.*

Objetivo: *Esse estudo teve como objetivo propor técnicas de análise para aprimorar a capacidade discriminante na classificação de cursos médicos mediante variáveis objetivas relacionadas a aspectos estruturais e operacionais que possam ser incorporadas aos métodos já utilizados.*

Método: *Trata-se de um estudo descritivo, analítico-metodológico e quantitativo que utilizou dados dos cursos médicos de São Paulo, em dezembro de 2020. Foi realizada análise por agrupamentos hierárquico e não hierárquico dos cursos para identificar variáveis com capacidade discriminante em busca de padrões que cooperem para a classificação das escolas médicas. As variáveis estudadas foram: início do curso, carga horária, regime letivo, metodologia, hospital universitário, categoria administrativa da instituição e gratuidade. Para a construção dos agrupamentos, adotaram-se o método de Ward e a distância euclidiana para estimar a discriminação entre os grupos. No agrupamento não hierárquico, a definição da quantidade de grupos foi determinada pela análise da diminuição da variância. Avaliou-se a correlação entre as variáveis por meio de mapas de calor.*

Resultado: *As análises de agrupamento mostraram a existência de três grupos de escolas médicas por similaridade: um grupo composto por escolas mais antigas e com maior carga horária, e, nos outros dois, consideraram-se as escolas não gratuitas sem hospital universitário, diferenciando-se pela idade das escolas. Além disso, as correlações reforçaram que as variáveis adotadas cooperavam para a discriminabilidade entre grupos. Há reconhecida heterogeneidade entre os cursos de graduação no Brasil, e esse dado também se aplica aos cursos médicos que impõem desafios metodológicos para os processos de avaliação estabelecidos. Entretanto, a inclusão de variáveis requer métodos capazes de refinar a capacidade discriminante da análise.*

Conclusão: *A análise aqui proposta mostrou-se capaz de identificar grupos de escolas médicas por meio de indicadores objetivos e pode auxiliar o processo de avaliação das escolas médicas.*

Palavras-chave: *Educação Médica; Escolas Médicas; Análise por Conglomerados.*

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INTRODUCTION

This is a methodological study that aims to identify the extent to which a set of variables characteristic of medical schools have a discriminating capacity in the classification of courses in the state of São Paulo through cluster analysis. In cluster analysis, it is possible to use a large number of variables, but it is also possible to limit the number of variables to estimate which of them have more weight in the analysis[1]. As this is an exploratory data analysis, the deliberate use of limited sets of variables is permitted to verify differences and similarities in the final result, with the consequent possibility of generating clusters aimed at identifying patterns in the conglomerates according to the defined variables[2].

Specifically regarding medical courses, there has been a significant increase in the number of vacancies offered in medical courses in the last two decades. Scheffer et al. indicate an increase of 124.7% in the number of vacancies offered from 2010 to 2020[3,4], with new courses accounting for 62% of these new vacancies. Scheffer and Dal Poz have also shown data about the significant increase in the number of private medical schools, resulting in an eminently private medical education[4].

The increase in the number of medical courses is a process that has been present at different moments in the history of Brazil. The expansion and distribution of medical schools in Brazil can be considered a reflection of public policies[5]. The expansionist policy was influenced by the logic of the health system organization, by industrialization and the increasing urbanization. In this context, the 60s were characterized by the creation of new Higher Education Institutions (HEIs) and the increase in the number of vacancies. Higher education becomes part of the market economy, in addition to enabling social ascension through graduations[3,6]. However, the expansion of medical courses increased after the publication of Law N. 12,871/2013, which instituted the 'More Doctors Program' (PMM, *Programa Mais Médicos*)[7,8].

The evaluation of HEIs and their courses play a strategic role in the development of government actions. In this sense, the improvement and incorporation of valid and reliable indicators and analytical methods is a challenge constantly faced by academia and public managers[6]. However, this is a recognized challenging task, especially in Brazil, due to its dimensions, particularities and regional inequalities that reflect in unequal higher education[9]. Add to this fact the creation of new courses and the increase in vacancies in existing courses, so that the evaluation process of HEIs becomes even more complex and demands more sophisticated instruments for a fair and equitable evaluation. These instruments should contemplate a greater number of variables, of HEIs and still have analytical sensitivity to improve the discriminating capacity of the already adopted methods[7]. Moreover, it is reasonable to seek a simple implementation method, of low computational requirement with easy interpretation of results, elements found in the analysis of clusters. Thus, the objective of the present study is to identify the extent to which a set of predictive variables have a discriminating capacity in the classification of medical courses in the state of São Paulo through cluster analysis.

METHOD

This is a descriptive methodological study, with a quantitative approach, which used data from sixty-seven medical courses, published in December 2020 on the electronic portal of the Brazilian Ministry of Education (e-MEC).

The methodological option was the cluster analysis of medical courses in the state of de São Paulo with subsequent clustering of variables. The choice of the state was due to the fact that it contributes with one-fifth of all vacancies offered in medical schools in the country[1].

Cluster analysis is a generic name given to a set of different techniques that can be used to classify cases into groups[8]. In cluster analysis, there is no prior knowledge about which elements belong to which clusters.

Cluster analysis techniques are a form of exploratory data analysis. They are used when one wants to verify similarities and differences in the data pattern, observations related to certain variables and the eventual existence of characteristics that allow the clustering of these observations, which may be hierarchical or non-hierarchical. In this sense, the objective of this analysis is to establish a relatively small amount of internally homogeneous clusters (set of HEIs in the same cluster), with the groups being heterogeneous among themselves and representing the joint behavior of the observations from the defined variables. That is, the observations of a given group must be relatively similar to each other, in relation to the variables included in the analysis, and considerably different from the observations of other groups[9].

Regarding the medical courses, the following variables were collected: administrative category of the teaching institution, gratuity, academic regime, teaching methodology and date of authorization for the start of the course. The variables presence of its own University Hospital (UH) and use of the Unified Health System Network as practice scenarios were collected from the HEI website. For HEIs that have more than one medical course on different campuses, each course was considered as an independent course.

The choice of variables is one of the most important steps in cluster analysis, as only variables that characterize the objects to be grouped and are specifically related to the analysis objectives should be included. In other words, the

study design should only include variables considered relevant for the classification of the cases[10].

The variables were divided into the following categories for analysis: 1- Start date of the medical course; 2- Workload: up to 15% beyond the minimum workload required by law for a medical course, from 16% to 30%, from 31% to 45% and more than 45%; 3- Academic regime: annual or semester; 4- Teaching methodology: traditional, active or mixed; 5- Presence of University Hospital: present or absent; 6- Administrative category: in non-tuition-free private for-profit HEIs, non-tuition free not-for-profit private HEIs, tuition-free public and non-tuition free public HEIs. It is worth noting that non-profit private HEIs are constituted in the form of an association or foundation and do not distribute any type of earned assets (profits, operating surpluses, dividends and/or bonuses). Non-tuition-free public HEIs correspond to educational institutions created by state or municipal law and that are not maintained exclusively with public resources and are, therefore, not tuition-free[11].

Cluster analysis took place in two ways: hierarchical and non-hierarchical cluster. The hierarchical cluster was generated by Ward's method, which is also known as the Increment sum of squares method and is based on analysis of variance. In this method, the sums of squares between and within the groups in relation to the p variables are used as a cluster criterion. The principle of Ward's method is to cluster groups in such a way that they minimize the sum of squares within the groups, that is, the sum of squares of errors[2,9].

The indication of the number of clusters is done *a priori*, that is, it is a defined parameter for the analysis. Thus, the choice of how many clusters is optimal depends on the analyst's judgment and the practical significance of group separation. Ideally, the smallest possible overlap between clusters is suggested. However, this decision is not random and can be aided by the elbow method, in which the total sum of squares within the cluster measures its homogeneity. In other words, it is expected that within the cluster the homogeneity will be maximum and between the clusters the homogeneity will be minimum, to estimate what the optimal number of groups is[9]. Therefore, the optimal number of clusters is defined.

To confirm the hierarchical cluster analysis, a non-hierarchical cluster analysis was performed, with the distributions of observations (medical schools) on the plane. This analysis predicts the reduction of dimensionality by starting from a high number of variables and generating a graph that can show the distribution of schools considering the weights of the variables. Simulations were also performed with the number of central clustering points on the plane (seed points), in order to confirm whether the number of clusters adopted after the elbow analysis would be maintained.

Additionally, a bivariate correlation analysis was performed between all study variables, presented in a correlation matrix. Spearman's correlation was used, as they categorical data. This analysis aimed to identify other patterns among the variables within each subgroup generated in the cluster analysis, in search of more details about potentially discriminating characteristics for the study variables. In this case, all correlations were defined as significant for p values <0.05, with only significant correlations being presented.

The analyses were performed using the RStudio software (version 1.4.1717), with the dendextend and FactoExtra packages, and in Python (version 3.7) with the SciPy. Stats, matplotlib and seaborn packages.

The present study is exempt from appraisal by the ethics committee in accordance with CNS Resolution n. 510/2016, since it used secondary data, available for public access under the terms of Law n. 12,527, of November 18, 2011.

RESULTS

Figure 1A shows the data variance in relation to the number of clusters. The deterioration, or "elbow", evidenced in the graph, suggests that the optimal number of clusters may be three or four. Ideally, the optimal value is the one where a less pronounced drop is observed in the difference between each of the values indicated on the y-axis in relation to the next value on the x-axis (number of clusters). However, the greater the difference between the clusters, the greater the information gain. Hence, in this study, three clusters were chosen to reinforce the discriminating character of the analysis. Two clusters would provide more heterogeneous groups and four clusters would produce a double overlap between clusters and a group of only two schools. (Figure 1B)

After it was determined that three clusters would be the ideal number for this study, the analysis by hierarchical clustering was performed. This analysis shows the Euclidean distance calculated on the y-axis and the observations (medical schools) on the x-axis. The decision regarding the number of clusters depends on the evaluation of the existence of differences between the clusters and the similarities within each group in a coherent way. It is important to emphasize that the hierarchy presented herein is between the measured distances and between the obtained degree of similarities. The medical courses were numbered for a better reading of the dendrogram (Chart 1).

Table 1 below contains the descriptive statistics for each variable for general medical courses and for each of the three clusters. Thus, it is possible to identify the characteristics in each clustering.

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Figure 1. Graphical representation of the analyses performed to define the optimal number of clusters to classify medical courses in the state of São Paulo, in December 2020. "Elbow" Method (1A) and Non-Hierarchical Cluster Analysis (1B).

Figure 1A: Optimal value of the number of clusters defined using the "Elbow" clustering method. Relation of the total number of clusters with the inter-cluster similarity.

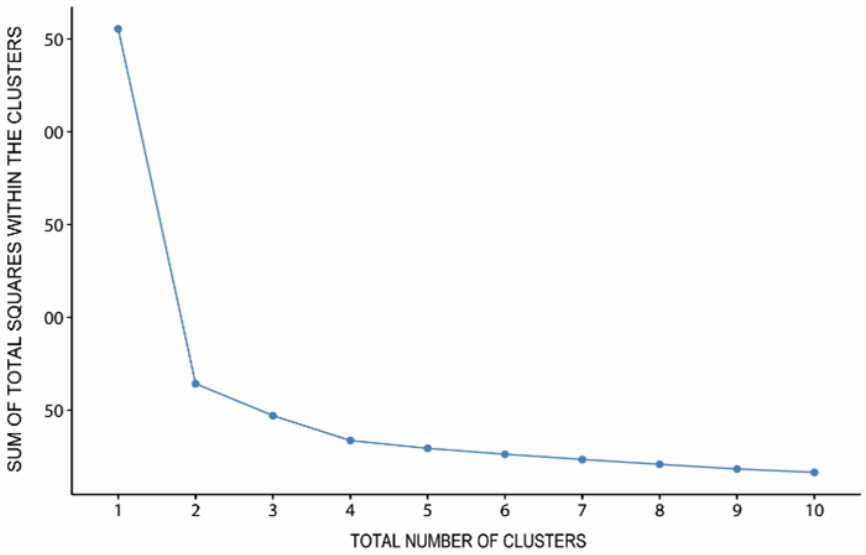
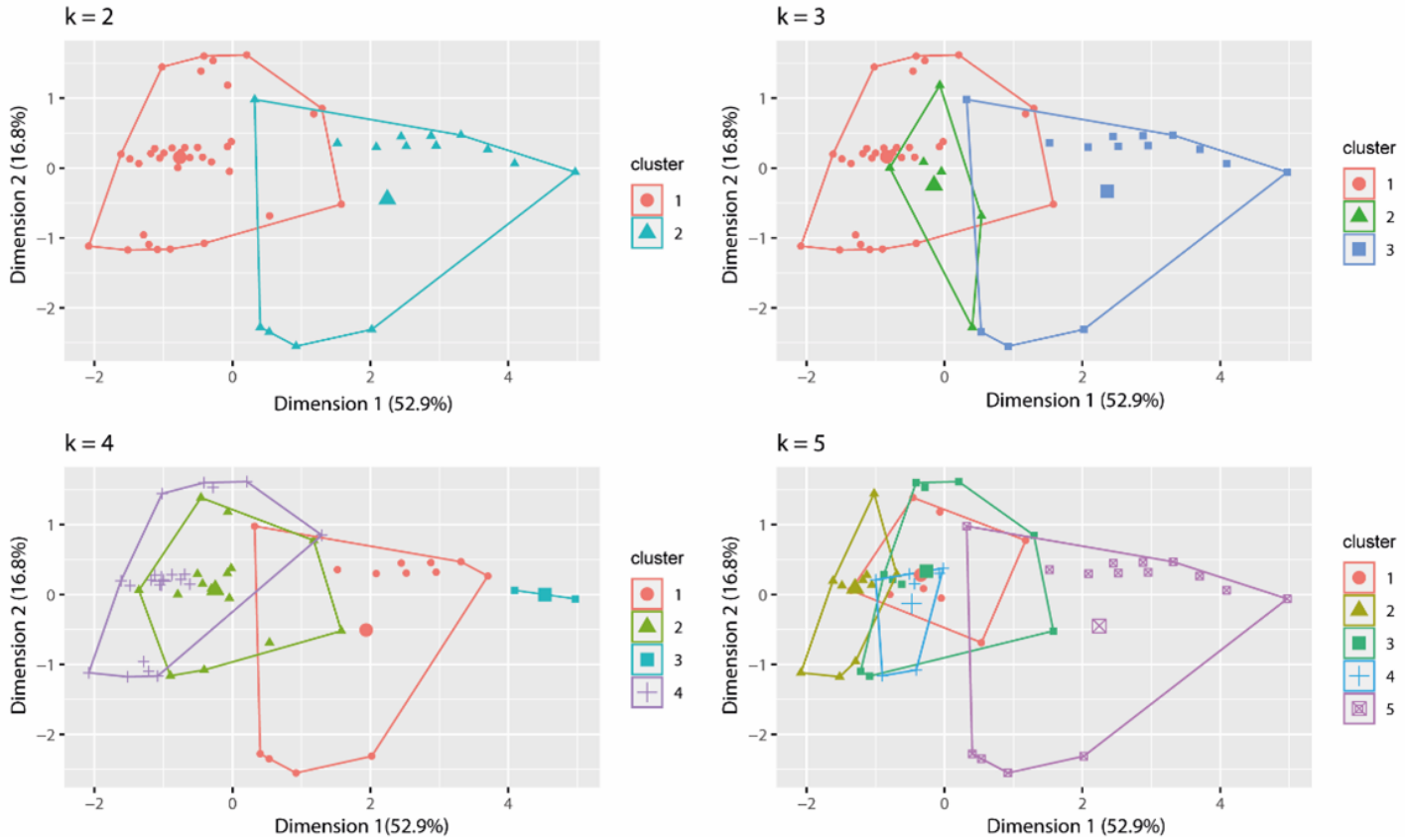


Figure 1B: Graphical representation of the classification of medical courses in the state of São Paulo in December 2020, in two (k=2), three (k=3), four (k=4) and five (k=5) clusters: non-hierarchical cluster analysis.



Source: Prepared by the authors.

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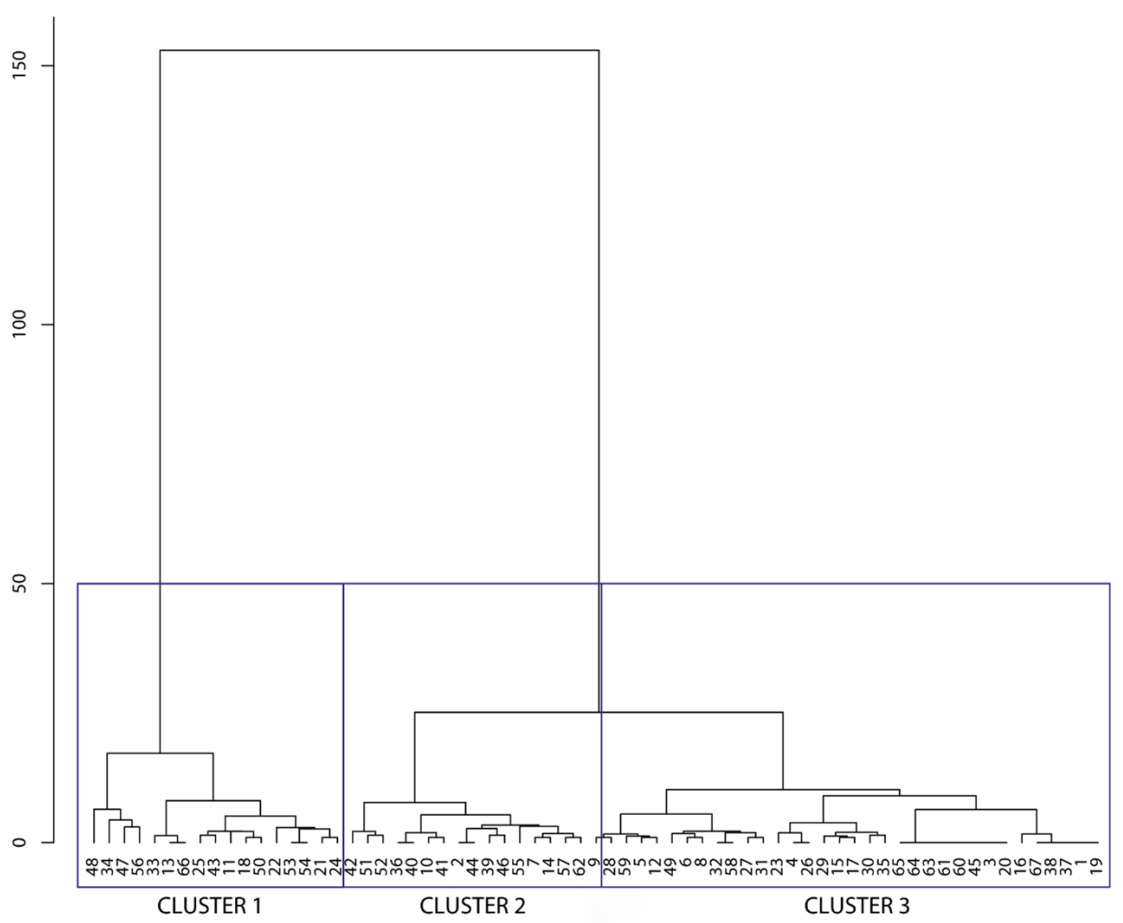
Chart 1. Dendrogram of the Analysis by Hierarchical Clustering of Medical Courses in the state of São Paulo in December 2020.



Source: Prepared by the authors.

Table 1. Distribution of the absolute and relative frequency of the variables: presence of a University Hospital, workload, academic regime, beginning of the course, administrative category of the Higher Education Institution, teaching methodology used and tuition-free medical courses, overall and in the clusters, in the state of São Paulo in December 2020.

VARIABLE		OVERALL		CLUSTER 1		CLUSTER 2		CLUSTER 3	
		N	%	N	%	N	%	N	%
Presence of University Hospital	No	47	70%	1	6%	13	81%	33	97%
	Yes	20	30%	16	94%	3	19%	1	3%
Percentage of workload in relation to the minimum required for medical courses	Up to 15% beyond the minimum	38	57%	5	29%	8	50%	25	74%
	16% to 30 % beyond the minimum	19	28%	6	35%	7	44%	6	18%
	31% to 45% beyond the minimum	8	12%	5	29%	1	6%	2	6%
	More than 45% beyond the minimum	2	3%	1	6%	0	0%	1	3%
Academic regime	Annual	11	16%	8	47%	2	13%	1	3%
	Semester	56	84%	9	53%	14	88%	33	97%

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Table 1 Continuation.

VARIABLE		OVERALL		CLUSTER 1		CLUSTER 2		CLUSTER 3	
		N	%	N	%	N	%	N	%
Start of the Medical course	Up to 6 years	26	39%	0	0%	0	0%	26	76%
	From 7 to 12 years	10	15%	0	0%	2	13%	8	24%
	From 13 to 24 years	11	16%	0	0%	11	69%	0	0%
	From 25 to 36 years	6	9%	0	0%	6	38%	0	0%
	From 48 to 60 years	8	12%	8	47%	0	0%	0	0%
	More than 60 years	9	13%	9	53%	0	0%	0	0%
Type of administration	Public, tuition-free	9	13%	7	41%	1	6%	1	3%
	Public, non-tuition-free	11	16%	2	12%	0	0%	9	26%
	Private, for profit	16	24%	1	6%	5	31%	10	29%
	Private, not-for-profit	31	46%	7	41%	10	63%	14	41%
Methodology	Traditional	20	30%	12	71%	4	25%	4	12%
	Active	35	52%	0	0%	10	63%	25	74%
	Mixed	12	18%	5	29%	2	13%	5	15%
Tuition-free schools	No	58	87%	10	59%	15	94%	33	97%
	Yes	9	13%	7	41%	1	6%	1	3%
TOTAL		67	100%	17	100%	16	100%	34	100%

Source: Prepared by the authors.

Cluster 1 consists of schools where the medical course is at least forty-eight years old; however, more than half (53%) are over sixty years old, all with the presence of a teaching hospital. Most of the schools (71%) use traditional methodology. They are free public or not-for-profit private schools. In cluster 2, there is a predominance of schools without a university hospital; half have up to 15% beyond the minimum workload required in the curricular guideline for medicine and 94% up to 30%, most (88%) have a semester regime, more than half (69%) are between thirteen and twenty-four years old and 94% are private schools. Cluster 3 represents the newest schools, all are up to twelve years old, most are six years old (76%), not tuition-free (97%), which use the active methodology exclusively (74%) or the mixed methodology (15%) and 74% have up to 15% beyond the minimum workload required for medical courses (Table 1).

The variables correlate differently within each cluster (Figure 2). The hierarchical heatmaps were produced by Pearson's correlation. The colors indicate direct (blue shades) or inverse (red shades) correlation between variables. The organization in correlation clusters indicates the proximity between the correlations of the study variables. This different correlation pattern in each cluster reinforces the heterogeneity of the subgroups and shows which variables are correlated within each cluster.

DISCUSSION

Higher education in Brazil has a great heterogeneity of institutions, both public and private. Magno Gomes[11] points out that the use of the expression 'Brazilian university', with the objective of designating a set of HEIs, must be applied with care. In this sense, it is necessary to present adequate classifications for a higher education system as diverse and heterogeneous as the Brazilian one[11]. The deliberate choice of one variable to determine a pattern of medical schools is not enough. From the National Curriculum Guidelines (DCN, *Diretrizes Curriculares Nacionais*) of 2001 and 2014, the stringency of forms and content of the minimum curriculum grids were replaced, thus allowing innovation and the diversification in professional training through the flexibility of the pedagogical project construction[12,13]. Douglas Pereira et al.[14], in the cartography of medical schools, describe the need to detail the category "tuition-free and paid" due to the existence of public administration HEIs that charge monthly fees, thus pointing to more sophisticated analyses in this regard. From this perspective, it is interesting to note that 82% of non-tuition-free public courses are contained in cluster three, while cluster one contains 78% of tuition-free courses in the state of de São Paulo.

Vacancies in medical courses have been predominantly offered by private HEIs since the 1970s and have been progressively increasing[4,3]. The distribution of groups shows

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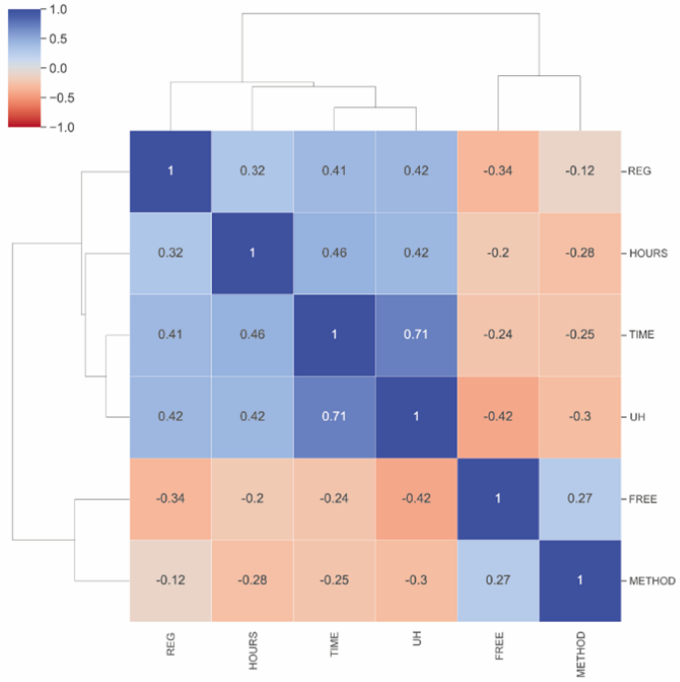
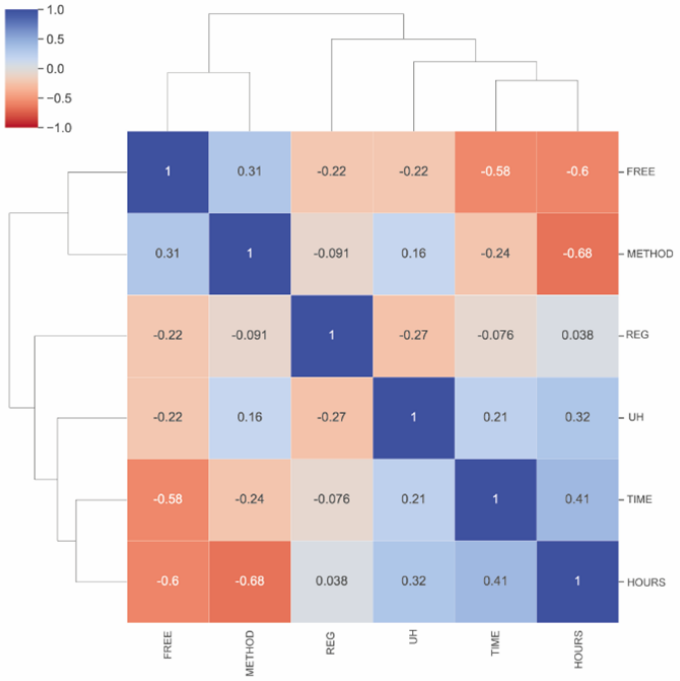
Figure 2. Hierarchical heatmaps: Pearson's correlation analysis between the variables: presence of University Hospital (UH), workload (HOURS), academic regime (REG), beginning of the course (TIME), administrative category and tuition-free Higher Education Institution (FREE), teaching methodology used (METHOD) among all medical courses in the state of de São Paulo, in December 2020, (Graph A) and in cluster 1 (Graph B), cluster 2 (Graph C) and cluster 3 (Graph D).

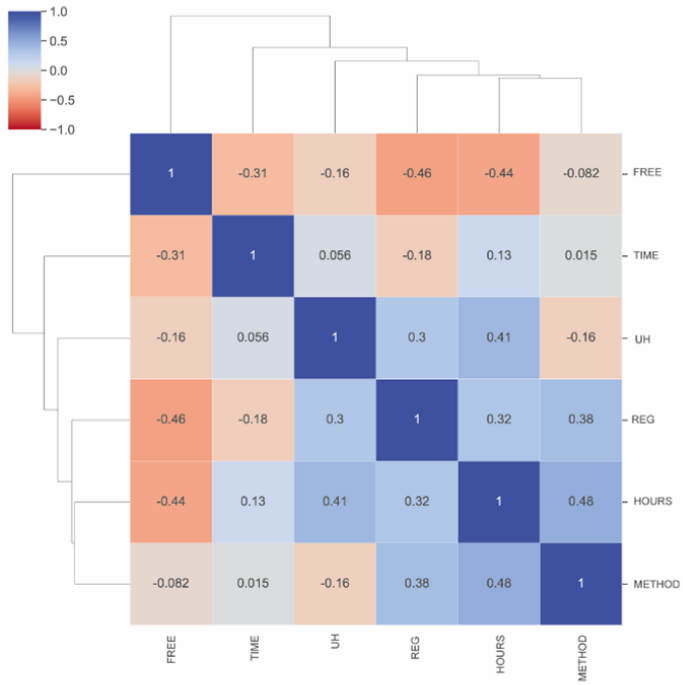
Graph A: Correlation analysis of the variables of all medical schools in the state of São Paulo



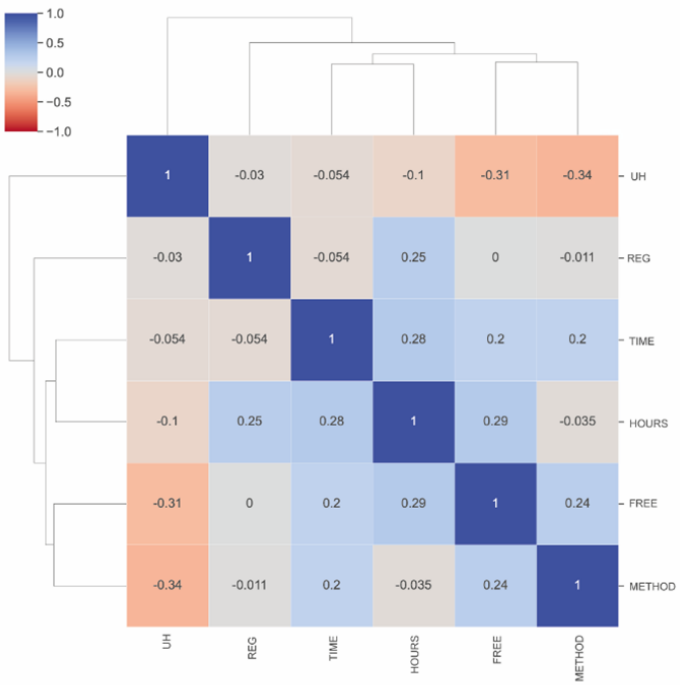
Graph B: Correlation analysis of variables in cluster 1



Graph C: Analysis of the correlation of variables in Cluster 2



Graph D: Analysis of the correlation of variables in Cluster 3



FREE: type of administration and tuition-free schools.
TIME: how long the medical school has existed.
UH: University Hospital.
REG: Annual or semester regime.
HOURS: workload of the medical course.
METHOD: methodology used (active or traditional or mixed).

Source: Prepared by the authors.

three moments of course expansion. Cluster one represents the oldest schools, of which the newest of this group is 48 years old and 78% of tuition-free schools in the state are in this group. Cluster two, the intermediate schools, has only one tuition-free school and medical courses range in age from 7 to 36 years. The third cluster contains non-tuition-free (paid) courses (97%) with up to twelve years of existence; however, most of them (76%) have a maximum of one graduated class and have their authorization following the PMM[15] notice.

One of the objectives of the PMM was to decrease the concentration of physicians and medical schools in some economically more developed regions. However, a predominantly private expansion process was observed and in regions that concentrate a large part of the country's income[4]. Practically half (47%) of the medical courses in the state of São Paulo is located in the regions corresponding to Grande São Paulo, Baixada Santista e Campinas, with the city of de São Paulo accounting for 28% of the medical schools. All HEIs use the SUS as a practice setting and 30% have their own University Hospital (UH). In cluster one, this number rises to 94%, in cluster two, 19% and in cluster three, 3%. There is a concentration of schools with a UH in cluster one.

The Brazilian Constitution of 1988, in Article 207, in addition to defining the autonomy of HEIs, commits them to the principle of inseparability between teaching, research and extension[14,16].

Most of the produced research, mainly in basic sciences, is the result of public investment in public universities[17]. Taking the postgraduate programs and courses, collective health, medicine I, II and III, recommended by CAPES, it is possible to confirm that this observation is repeated in the classification presented herein of medical courses in the state of São Paulo. All postgraduate programs and courses in collective health are located in cluster 1. Of the eight programs, only two are not in tuition-free schools. When observing the area of medicine I, II and III, together, CAPES recognizes 107 postgraduate programs; of these, 95 (88%) are located in cluster 1. Only one course in a private school and four in a non-tuition-free public school. Group 2 has eight postgraduate programs, whereas Group 3 has no postgraduate program. It is noteworthy that there are four programs linked to hospitals and study centers that belong to the same administrative group as the medical courses in cluster three.

Postgraduate studies are not the object of this study, but *stricto sensu* courses comprise an important dimension of health education and are directly related to teacher training and the structure of HEIs[7]. The aforementioned distribution of postgraduate programs among the formed clusters, cooperates in the sense of ratifying the proposed modeling, constituting one more element to confirm the discrimination capacity of the used variables.

One limitation of this study is inherent to the database used, that is, they were taken from official sources – the MEC website –, however it is possible that some HEIs have made changes to the courses without changing the registration. The inclusion of new variables makes it necessary to reapply the modeling, so that, eventually, new clusters are generated[9].

CONCLUSION

This study allowed the classification and clustering of medical schools according to their similarities. This analysis enhances and contributes to future studies, aiming at improving and understanding the patterns and relationships of each cluster with the different variables, identifying differences in the respective similarities between medical courses in the state of São Paulo.

AUTHORS' CONTRIBUTION

Gabriela Furst Vaccarezza: Study conception, data collection, analysis of the results and writing of the manuscript. Erik Montagna: Statistical analysis and interpretation of results. Rita Barradas Barata: Study conception, discussion and interpretation of results. Nivaldo Carneiro Junior: Study conception, discussion of the results and final review of the article.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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