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Risk assessment for HIV infection in men who have sex with men and the contribution of sexual partner networks

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Abstract *This study aimed to evaluate the risk of HIV infection in men who have sex with men (MSM) by developing an index that considers sex partner networks. The index variables were age, ethnicity/skin color, schooling, relationship type, condom use in receptive and insertive relationships, self-perception of the possibility of HIV infection, sexually transmitted infections, and rapid HIV testing results. We used data from a cross-sectional MSM egocentric network survey conducted in Rio de Janeiro between 2014 and 2015. The initial research volunteer is called ego, each partner is called alter, and each pair of people in a relationship is called the dyad. Multiple logistic regression was used to define the coefficients of the equations for the elaboration of the indices. The index ranged from 0 to 1; the closer to 1, the higher the risk of HIV infection. HIV prevalence was 13.9% among egos. The mean egos index with an HIV-reactive test was 57% higher than non-reactive, and the same profile was observed in the index values of dyads. The index allowed the incorporation of network data through the dyads and contributed to the identification of individuals with a higher likelihood of acquiring HIV.*

Key words *HIV, Male homosexuality, Social network, Sexual behavior, Risk indicator*

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Introduction

Several investments and advances for the early detection and treatment of HIV/AIDS have occurred in Brazil since the 1990s. However, a high prevalence still affects mainly specific populations, such as drug users, men who have sex with men (MSM), and sex workers[1-4]. MSM have one of the highest prevalence of HIV infection among these populations, and several Brazilian studies show values around 10% or higher[5-9].

Given the complex dynamics of HIV transmission among MSM, a strong association is observed between HIV infection and sexual practices and behaviors, condom use, type and number of sexual partners, and drugs/alcohol use[10-13]. However, most of these studies assessing vulnerabilities and risk factors for HIV/AIDS highlight the individual component.

In this context, studies that consider other aspects, such as the social network, have shown high relevance in understanding the spread of HIV among MSM. The structure of social relationships in a network influences the content of such relationships. Thus, the network of sexual partners can influence the risk of acquiring a sexually transmitted infection (STI). Thus, incorporating network aspects in studies adds data beyond individual characteristics[14-20].

The social network analysis allows evaluating the influence of interpersonal connections in the process of transmission of a given disease. That is, it considers the relationships and how they affect individual and group dynamics. Thus, network analysis allows transforming the data collected at an individual level into data from their group interactions[21-23]. Among the social network study designs, the self-centered type stands out in this paper and is also called personal or local network. Egocentric analysis can be performed through dyads. A dyad is defined as a pair of people in a relationship, and is, thus, the central data unit in an egocentric network. The analysis of dyads in an egocentric network allows studying the influence of the network on the behavior of individuals in health situations, such as the acquisition and transmission of HIV infection[24].

Besides the incorporation of social networks into risk analysis for acquiring HIV infection, it is essential to find a practical and accessible way of measuring individual and network aspects that can be used for the development of public policies. In this sense, we highlight the construction of indices that allow synthesizing the risk for HIV into a single value. A recent Brazilian study showed how an index could summarize several aspects[7]. Other international studies have also worked on a proposal for a synthesis or risk behavior scale for HIV infection based on the combination of different characteristics[25,26]. Given the mentioned above, this study aimed to assess the risk of HIV infection in MSM from the development of an index that considers the networks of sexual partners, which is justified by the growing trend of HIV infection, especially among younger MSM, and the need to improve prevention and early treatment strategies in this group.

Methods

We used data from a cross-sectional, egocentric network study conducted in the municipality of Rio de Janeiro in an MSM population: "Use of social network analysis for the study of factors associated with HIV acquisition among men who have sex with men"[9]. Data about each individual is collected in the design of the egocentric network, and, subsequently, data about individuals who have had some type of interaction or relationship with the individual are also collected[27].

Recruitment and data collection

Participants eligible for the survey were men 18 years of age or older who have reported sex with men in the past six months. Furthermore, volunteers non-reactive for HIV or unaware of their HIV status was also an eligibility criterion of the study. Recruitment was carried out as follows: 1) personally inviting people who were visiting any of the research data collection sites, whether for some activity, medical appointment or just familiarizing with the unit; 2) personally inviting passers-by close to these units; 3) invitation by recruiters, who handed a card with survey information, place and time to answer the questionnaire, to people in previously selected places with an influx of MSM population, such as bars, parties, nightclubs, saunas in different districts of Rio de Janeiro. The data collection locations were two Non-Governmental Organizations (NGOs) or a Family Health Strategy (ESF) unit located in the central region of the city of Rio de Janeiro. The research was approved by the Research Ethics Committee of the Sergio Arouca National School of Public Health (ENSP/Fiocruz/Brazil).

The sample of the MSM population in the study was calculated from the hypothesis that several essential factors in HIV transmission will

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be more significant in HIV-positive volunteers when compared to HIV non-reactive volunteers. Thus, we decided to estimate the smallest size of the detectable effect based on fixed sample sizes to form an HIV-reactive group of 100 volunteers, considering a mean HIV prevalence of 15%[2,4,6,28] in the MSM population. Then, the final total sample was 700 MSM individuals, an alpha value equal to 0.05, power of 0.8, and imbalanced allocation (1:6).

In this study, the initial research volunteer was called ego, and each member of his relationship network, whether sexual or friendship, was called alters. Moreover, all questions about sexual partners or friends have been answered by the ego. The egos answered the computerized online questionnaires alone using the Survey Gizmo software in individualized rooms at the survey sites. Four different questionnaires were used, the first with specific questions about oneself, such as sociodemographic characteristics, clinical history of STI, sexual practices, and behaviors.

At the end of this questionnaire, the volunteer was asked to list up to a maximum of five people with whom he had had a sexual intercourse in the last six months, and from that list, he answered another specific questionnaire for each sexual partner listed. The same was done for the social friendship network, where the volunteer could list up to five people he had befriended in the last six months and answered another specific questionnaire for each listed friend. Finally, the volunteer answered about the relationships between sexual partners and friends listed in the previous questionnaires. A technique called "name generator" was used to increase the recall of sexual partners[29,30] in order to remember all their partners.

After completing the questionnaires, the volunteers (egos) were tested for HIV. Two types of tests were used depending on the location of the research: rapid diagnostic test by laboratory blood test; and rapid oral fluid test for HIV detection screening, which required confirmation when they returned a reactive result. Data on the social friendship network and the relationship matrix between sexual partners and friends were not used in this study.

Four databases were generated from the four survey questionnaires, of which only two were used in this study for the following questionnaires: 1) ego data with questions about themselves, and 2) data for each sexual partner of their network.

Building the HIV infection risk index

The development of the HIV infection risk index, which considers the influence of the sexual partner network among MSM, occurred in three stages. First, we calculated an index that summarized sexual characteristics, practices, and behaviors of individuals (egos) in a single value. Then, we calculated another index that synthesized the same information for the sexual partners (alters). Finally, the result of these two indices was compared to verify how much an index that includes information from the network of sexual partners influenced the risk of acquiring HIV.

The variables that underpinned the index were selected from a literature review, which sought to identify aspects that were associated with HIV infection[10,15,31-35], and through a debate with specialists in HIV/AIDS research in Brazil. Furthermore, we had to employ variables that represented similar situations in both egos and alters questionnaires to build these two indices. Thus, the variables included in the study were age group (≤ 30 years, > 30 years), ethnicity/skin color (black, non-black), schooling (none to incomplete high school, high school and over), type of relationship (married/living together, single/separated), condom use in receptive anal sex with a steady or casual partner, condom use in insertive anal sex with a steady or casual partner, the self-perceived likelihood of becoming infected with HIV (score 0-2, 3-5, 6-10), having had an STI, result of egos' HIV test.

The following definitions were included in the questionnaire to answer the questions by type of sexual partnership: "steady (fixed) partners" were those with whom he had sex and had an affair, dating, frequent encounters, marriage, or any type of involvement; "casual partners" were those with whom he had sexual intercourse without scheduling other encounters or without making any commitment to continue the relationship.

New variables were built from the aggregation or combination of categories. The ethnicity/skin color variable's options "black" and "brown" were grouped under the "black" category, while "white" and "yellow/indigenous" were grouped under the "non-black" category. In this question, we verified that the text variable was filled in for those who marked the option "other", and the answer "dark" was grouped under the "black" category.

The STI variable was constructed from specific questions for diseases in the egos question-

naire, which were organized as follows: having been diagnosed with syphilis, gonorrhea, chlamydia or other sexually transmitted diseases was grouped under "yes, I had STI" and the rest under "no STI". However, in the alters' questionnaire, only one direct question did not require clustering, as we only asked whether the ego knew whether that partner had any STIs (yes or no).

The question about condom use had the options grouped as follows: "yes, used a condom" only when they answered that they had always used a condom in all sexual intercourses; and "did not use a condom" for the remaining options. The variable use of condoms in anal intercourse (insertive or receptive), by type of partner (steady or casual), was a combination of three variables: whether this sexual practice (receptive or insertive anal) took place in the last six months; frequency of condom use in this type of sexual practice (receptive or insertive anal intercourse); and if they have had a steady or casual partner in the past six months. Finally, the variable condom use by sexual practice (receptive or insertive anal intercourse) and type of partner (steady or casual) was categorized as follows: "yes, used condoms"; "did not use a condom" and "did not have anal sex (receptive or insertive)/had no partner (steady or casual)".

The continuous quantitative variables referring to the age group and the self-perceived likelihood of becoming infected with HIV were categorized by data distribution frequency.

The first step in calculating the egos index was performing logistic regression[36], with the result of the egos' HIV test as the dependent variable, and all the others as independent variables generating the following equation, known as the logistic function:

$$P(Y_i = 1) = \frac{1}{1 + e^{-x_i T \beta}} \qquad \text{(Equation 1)}$$

Where Y_i is the HIV test status for the participant *i*, assuming value 1 if the test is reactive and 0 if not reactive, x_i are the independent variables of participant *i*, and β are the regression coefficients of equation (1). The coefficients were estimated using the egos data by adjusting a logistic regression model, and when applying equation (1) for each ego, a unique value called "ego index" was obtained.

For the second stage that involved the construction of the sexual partner index, this equation (1) was applied to the data of the alters, generating another unique value for each sexual partner, which was called "alter index". The final value of the indices ranged from 0 to 1, with values closer to 1 meaning a higher risk of HIV infection. The alter index was considered as the infection risk index that considered the influence of the sexual partner network among MSM.

Moreover, for the third step, the results between the egos and alters indices were compared according to the result of the HIV test of egos. For this reason, the egos and alters databases, with the respective results of the indexes, were related from a critical variable with identification code for each ego forming a single database. This procedure was required because the rapid HIV test was applied only to the egos. Thus, the dyads between each sexual partner and the ego were considered for the analysis of the alters' indices, allowing the inclusion of the HIV test result of their respective egos.

Finally, the variable "difference in indices", which represented the result of subtracting the values of the egos and alters indices was constructed. If the result was positive, it meant that that specific alter had a lower risk than the ego. If the value was negative, then that alter had a higher risk than the ego, and if it was null, it meant that egos and alters had equal risks – that is, the same index values. We sought to verify the influence of the network of sexual partners on the risk of acquiring HIV infection when comparing the results of the egos' and alters' indices. The verification of the difference between the egos and alters indices is an indication that using data from sexual partners from an egocentric network study can provide relevant additional information for the HIV infection risk analysis.

The results of the risk indices for HIV infection were presented as follows: first, the indices of the egos considering the result of the HIV test; then, the indices of sexual partners (alters only) with the result of the HIV test of the egos; and, finally, the description and comparison of the indices with the dyads between each alter and the ego according to the result of its HIV test. The analysis of the indices was descriptive based on proportions, mean, median, percentiles, and minimum and maximum values. The construction of the indices and their analysis was carried out using the R free software.

Results

The questionnaire was filled out by 341 individuals (egos), which represented 49% of the planned sample[9]. However, for the construction of the

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equation that generated the indices, there could be no variables without information. Therefore, those who did not fill in any of the questions/variables used in this study were excluded. Furthermore, among the volunteers (egos), two refused to take the HIV test at the end of the questionnaire and were excluded. Thus, of the total egos, 331 (97.1%) had complete information for all variables used in the construction of the index and were included in this analysis. These egos answered the questionnaire of 622 sexual partners, and it was necessary to exclude some records for the reasons previously described. In the end, 588 alters were considered (94.5%).

The HIV prevalence among the egos that took the HIV test was 13.9% (46/331). Approximately 11% (65/588) of the dyads derived from HIV-reactive egos. The descriptive analysis of egos was presented in a previous publication[9]. In summary, the total group of egos (341) was mostly brown, with a high level of education, single or separated, and with a mean age of 30.6 years. The STI report was low among the egos, but most of them mentioned having had an HIV test before the research. On average, egos have reported two steady sexual partners and five casual partners in the past six months. However, the mean number of sexual partners, to whom the egos answered a specific questionnaire for each partnership, was 1.9 partners, being 1.1 for steady and 2.0 for casuals. The characteristics of the alters have also been described in a previous publication[9]. They had a mean age of 28 years and, in most cases, a high level of education, and were black. The egos declared that most alters represented non-steady relationships and that they had simultaneous partnerships besides the ego-alter dyad[9].

The estimated coefficients of equation (1) via adjustment of the logistic regression in the egos' data and used for the construction of the alters' indices are shown in Table 1. It is worth noting that we are ignoring the uncertainty associated with the estimated coefficients, since we included all the common variables in the egos' and alters' data sets that are associated with HIV infection, as per the literature and debate with experts.

Table 2 addresses the descriptive statistics of the egos and alters indices by the result of the HIV test. We observed that the mean of the index of all egos was 0.14. However, the egos with an HIV-reactive test (0.27) evidenced a 57% higher index than the non-reactive ones (0.12). Concerning the median, 25th, and 75th percentiles, the values of the egos' indexes with an HIV-reactive test were higher than the non-reactive ones. It is important to note that 25% of the HIV-reactive egos had indexes above 0.41, and the maximum index value in this group was 0.89 (Table 2).

Among the alters, the mean and median of the indices were 0.14 and 0.08, respectively. A slightly higher mean index (24% higher) was also found among those in the egos' network with an HIV-reactive test (0.19) compared to non-reactive ones (0.14). The minimum and maximum index values were 0.004 and 0.85, respectively (Table 2).

The values of the egos' and alters' indices in a similar way are found in Table 3. Among the dyads with HIV-reactive egos, we observed that most of the alters had lower HIV risk index values than those of the egos (73.8%). Among dyads with HIV-nonreactive egos, the difference between the values of the egos and alters indices was around 50% (Table 3).

Discussion

Brazilian studies investigating the influence of the sexual partner network for acquiring HIV infection in the MSM population are scarce[18,37]. This implies non-access to qualified information about sexual partnership networks and the use of that information to improve prevention strategies for more vulnerable social groups, as in the case of MSM. Thus, this study aimed to consider the contribution that information from the network of sexual partners can provide in understanding the dynamics of HIV infection transmission.

In this study, we chose to adopt the study of the egocentric network where only the recruitment of egos is carried out, with information on sexual partnerships (alters) being answered by the egos themselves[18,38]. This characteristic increases the size of the analysis sample without necessarily increasing the study's complexity and cost. Another relevant aspect of the network studies, which was used in this work was the analysis of the dyads. That is, analyses of ego-alter pairs, to relate the characteristics of the sexual partners (alters) with the result of the HIV test of their respective egos[24,38,39]. In this way, it allowed incorporating the risk factors of the partners (alters) and their interactions with the egos into the general computation of the personal risk of each ego. Hedberg[40] showed how social networks are built with dyads and how the results of dyadic relationships are influenced by the quality of the dyads and the network.

Table 1. Estimated coefficients for adjusted logistic regression for HIV infection of egos. 2015. Rio de Janeiro. Brazil.

	Estimated coefficient	Confidence interval of 95%	p-value
Intercept	-2.936	(-4.678; -1.252)	0.001
Age group: ref. < 30 years;			
>= 30 years	-0.272	(-1.027; -0.457)	0.470
Ethnicity/skin color: ref. non-black;			
black	0.374	(-0.371; 1.161)	0.336
Schooling: ref. < high school;			
>= high school	-0.108	(-1.081; 0.974)	0.834
Relationship: ref. married/living together;			
single/separated	-0.655	(-1.458; 0.179)	0.114
Condom use passive sex with a STEADY			
partner: ref. passive WITHOUT condom;	0.602	(-0.778; 2.010)	0.395
passive WITH condom;	0.671	(-0.417; 1.848)	0.242
no sex or steady partner			
Condom use passive sex with a CASUAL			
partner: ref. passive WITHOUT condom;	-1.548	(-3.043; -0.105)	0.037
passive WITH condom;	-2.116	(-3.580; -0.725)	0.003
no sex or steady partner;			
Condom use active sex with a STEADY			
partner: ref. active WITHOUT condom;	-0.107	(-1.517; 1.307)	0.881
active WITH condom;	-0.031	(-1.102; 1.079)	0.955
no sex or steady partner			
Condom use active sex with a CASUAL			
partner: ref. active WITHOUT condom;	0.648	(-0.957; 2.232)	0.435
active WITH condom;	2.128	(0.633; 3.814)	0.008
no sex or steady partner			
Probability of acquiring HIV: ref. 0 to 2			
points;	1.398	(0.597; 2.249)	0.001
3 to 5 points;	2.320	(1.320; 3.359)	< 0.001
6 to 10 points			
STI: ref. no;			
yes	0.636	(-0.121; 1.391)	0.098

Source: Authors' elaboration.

Studies of egocentric networks in Brazil are still rare[9,18] but have been used in other countries. Rodriguez-Hart et al.[19] conducted an egocentric network study in Nigeria, where serosorting practices by volunteers were analyzed by HIV serological status. The authors identified that those seroconcordant dyads showed a lower risk for HIV infection.

Another self-centered network survey conducted in the United States, which aimed to investigate racial disparities for the risk of HIV infection among MSM, showed that there was a more considerable influence of the characteristics of the networks of sexual partners than aspects of individual behaviors[17]. Rinehart et al.[41] also analyzed dyads of heterosexual couples to verify the structural and interpersonal power in the relationship and the sexual risk for HIV infection in African American and Latina women. Another study that considered heterosexual dyads among young people to analyze depressive symptoms and sexual risk behavior for STIs identified that a dyad in which one of the partners had depressive symptoms, mainly among women, was associated with an increased risk for STIs[42].

Data from the sexual partner network found in the current study were incorporated into the construction of an HIV infection risk index among MSM. This method is believed to be adequate because it is a practical and straightforward way of summarizing several individual (ego) and network (alters) aspects in a single val-

ue to assess the risk of HIV infection. The index allowed, above all, to discriminate against those individuals who were at higher risk of acquiring HIV infection. Moreover, some variables of the proposed method for building this index were included in a logistic regression model and were defined based on the literature and debate with experts. This method allowed summarizing the characteristics, practices, and risk behaviors addressed in the literature as associated with the acquisition of HIV of the various actors in the networks into a single value.

The proposal to synthesize into a single value the variables to assess the risk of HIV infection has also been found in other studies[7,25,26]. Although a direct comparison of the results is not possible due to the diverse methods used, we can highlight some similarities with the results found in the current study. Mattson et al.[25] developed a scale to measure sexual risk behavior among men in Kenya by combining 18 variables. Among the results of this study, the statistically significant association between the risk scale proposed by the authors and the acquisition of STIs and HIV stands out.

A Brazilian study conducted by Rocha et al.[7] developed a risk behavior score for HIV infection for the MSM population and found a low score. In this research, the score ranged from 0 to 48 points, with a mean score of 5.7 points among MSM individuals. According to the classification adopted in the study, 26% and 54.2% were classified as low (0 to 2 points) and medium (3 to 8 points) risk behavior for HIV, respectively. However, the researchers identified that the high-risk score was found in 28.8% of HIV-reactive individuals, which represented a higher proportion than that found among non-reactive HIV individuals (19.7%).

In the same way as the research by Rocha et al.[7], this study also found low values for risk indexes, although the method of constructing the score and the sampling method were different. While the mean and median values of the indices between the HIV-reactive egos and dyads were low, they were higher than those found in HIV-nonreactive egos and dyads, which shows that the index allowed identifying the individuals with higher risk. Regarding the incorporation of data from the sexual partner network to construct the HIV infection risk index, we observed that the values of the egos indexes were higher than the indexes of the alters among the dyads of HIV-reactive egos, which may mean that egos are more involved in HIV risk behaviors and have a low-risk perception concerning their network of sexual partners. In other words, the index managed to identify that the responding volunteers (egos) had elevated HIV risk characteristics, but believed that their partners (alters) had low sexual risk behavior, resulting in lower values between partners.

Table 2. Descriptive statistics of the HIV infection risk indices for egos and alters by the HIV result of the dyads, 2015, Rio de Janeiro, Brazil.

	Dyad HIV test result		Total
	Reactive	Non-reactive	
Egos (n = 331)			
Mean	0.27	0.12	0.14
Median	0.22	0.06	0.08
P25*	0.13	0.04	0.04
P75**	0.41	0.14	0.18
Alters (n = 588)			
Mean	0.19	0.14	0.14
Median	0.11	0.08	0.08
P25*	0.04	0.04	0.04
P75**	0.27	0.19	0.19

* 25th percentile. ** 75th percentile

Source: Authors' elaboration.

Table 3. Frequency and proportion of the comparison between the HIV infection risk indices of egos and alters as per the HIV result of the dyads, 2015, Rio de Janeiro, Brazil.

	Dyad HIV test result		
	Reactive (n = 65) % (n)	Non-reactive (n = 523) % (n)	Total (n = 588) % (n)
Alter rate higher than ego	26.2 (17)	50.1 (262)	47.4 (279)
Equal ego and alter rates	0	1.1 (6)	1.0 (6)
Alter rate lower than ego	73.8 (48)	48.8 (255)	51.5 (303)

Source: Authors' elaboration.

The study showed relevant results in the context of the risk of acquiring HIV infection among MSM. However, the analysis of the results must be seen considering its limitations. One of the great difficulties of the research was to access the MSM population, requiring modifications in the recruitment of participants throughout the development of the study. Notwithstanding this, it was not possible to reach the total of the planned sample, which may have reduced the power of the study to identify some essential variables. It should be noted that the MSM population is not very accessible, as described in previous research[15,43,44].

Furthermore, we selected volunteers among those who visit specific places like NGOs and an ESF aimed at MSM and trans people, which may have generated a selection bias in the study, where the selected group may represent those who are more concerned with physical and psychological well-being or individuals more engaged in activities of the LGBT population. Another limitation identified in the study is related to the time to complete the questionnaire – about one hour, which limited the number of volunteers who could answer the questionnaire in full every day.

Individuals known to be HIV-reactive were excluded from the study since the proposal to build the HIV risk index was precisely to assess the risk before seroconversion. Although a possible information/memory bias may be identified due to the behavioral and specific issues of each of their sexual partners referring to aspects in the last six months, we emphasize that the period adopted was shorter than that used in other studies. We decided to use the name generator techniques[29,30] developed to minimize this bias, which contributed to remember the aspects of sexual partnerships.

Although the research has faced difficulties in accessing the MSM population and limitations in data collection, the importance of this study is highlighted as it reached 49% of the planned sample of a not very accessible population. Moreover, the data indicate a differentiated sample with high risk for HIV acquisition. The findings showed that the studied MSM population is at high risk of HIV infection and that an egocentric network study can contribute to the collection of relevant information from the sexual partner network, enabling a better understanding of the spread of HIV infection in this population.

The use of a combination of aspects of individual risk behaviors and sexual partners to build an index can contribute to a better assessment of the risk of acquiring HIV. In practice, this index can help to better assess the risk of becoming infected with HIV in the MSM population and thus support the development of specific prevention and treatment strategies for HIV/AIDS directed at this population. Furthermore, the proposal to use a risk index for HIV infection also focused on the practical use in the routine of health services, which can be employed, for example, to screen individuals at higher risk.

The results indicate that the proposal to develop an HIV infection risk index may be relevant to identify MSM most likely to acquire HIV. The significant difference in the use of the constructed index was the incorporation of information from the network of sexual partners and interactions between ego and alter to the detriment of the single use of individual (personal) risk characteristics, a method typically used in behavioral research. However, due to the challenges and limitations in conducting the study, resulting in a small and different sample of the MSM population, we believe that further studies are required to validate the use of the score better. Thus, the method proposed in this study could be complemented or enhanced.

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Collaborators

RMC Torres contributed in the conception and design of the study, in data analysis and interpretation and in the final manuscript. LS Bastos and MFC Gomes participated in the conception and design of the study, in data analysis and final review of the manuscript. RI Moreira contributed in the design of the study, in data collection and in the final review of the article. ARS Périssé worked on the conception, in the study design, in data analysis and interpretation and in the final review. MM Cruz participated in the design, data interpretation and final review of the manuscript.

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