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Evolution of food deserts and food swamps in a Brazilian metropolis between 2008 and 2020

Evolução dos desertos e pântanos alimentares entre 2008 -2020 em uma metrópole brasileira

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Abstract *The aim of the current ecological study is to assess the evolution of food deserts and food swamps in the metropolitan city of Belo Horizonte between 2008 and 2020. Food deserts were determined based on the density of healthy establishments per 10,000 inhabitants, whereas food swamps were set based on the density of ultra-processed food procurement establishments per 10,000 inhabitants. The rate of census tracts classified as food deserts has decreased between 2008 and 2020, whereas that of census tracts classified as food swamps has increased within this same period. Furthermore, despite the reduced number of food deserts, these areas have increased in census tracts living under lower socioeconomic vulnerability condition. Food swamps recorded sharp increase in census tracts living under higher vulnerability condition. The population living in the herein investigated city has been increasingly exposed to an unhealthy community food environment over 12 years. Monitoring changes in community food environment is key strategy to enable tracking the effectiveness and efficiency of actions taken in food environments to ensure the human right to adequate food.*

Key words *Food desert, Food supply, Time series studies*

Resumo *O estudo tem por objetivo avaliar a evolução dos desertos e pântanos alimentares entre 2008 e 2020. Os desertos alimentares foram determinados pela densidade de estabelecimentos saudáveis por 10 mil habitantes, e os pântanos alimentares pela densidade de estabelecimentos de aquisição de alimentos ultraprocessados por 10 mil habitantes. O estudo identificou que, entre 2008 e 2020, diminuiu o percentual de setores censitários classificados como desertos alimentares e aumentou o de setores censitários classificados como pântanos alimentares. Além disso, observou-se que, apesar da redução no número de desertos alimentares, essas áreas tiveram aumento em setores censitários de menor vulnerabilidade socioeconômica. E os pântanos alimentares apresentaram aumento acentuado em setores censitários de maior vulnerabilidade. Ao longo de 12 anos, a população está cada vez mais exposta a um ambiente alimentar comunitário pouco saudável. O monitoramento das mudanças no ambiente alimentar comunitário é uma estratégia primordial que possibilita acompanhar a efetividade e eficácia das ações realizadas no ambiente alimentar para a garantia do direito humano à alimentação adequada.*

Palavras-chave *Desertos alimentares, Abastecimento de alimentos, Estudo de séries temporais*

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Introduction

Eating habits can be influenced by different factors, such as cultural and social issues, and food environment features. Food environment is part of the study field focused on assessing population's access to food, and it is done by taking into consideration physical, economic and sociocultural dimensions[1]. Different dimensions can be assessed at the time to investigate individuals' access to food, namely: availability of and accessibility to establishments, food quality, food price, convenience and desirability[2,3].

Food environment has been the topic of discussions about public policies focused on food and nutrition over the years. Using metaphors to describe food environment features is one of the strategies used by government agencies to address this topic[4-8]. Food deserts and food swamps are the mostly used metaphors to characterize the food environment. Discussions about food deserts were observed for the first time in a governmental document addressing health inequities in the UK, in 1998[4]. The approach to food swamps has gained momentum in the United States due to a document issued by the Centers for Disease Control and Prevention, back in 2011[6].

The term "food desert" is used to describe socioeconomically vulnerable areas with limited access to healthy food[9]. On the other hand, the term "food swamp" is linked to areas with high availability of unhealthy food types[10].

Studies about food deserts and food swamps have advanced, both in conceptual issues and in assessment measures, overtime. However, the evolution of these areas over the years has been poorly explored in the literature[11-14]. Thus, the aim of the present study was to investigate the evolution of food deserts and food swamps in a Brazilian metropolis.

Methods

Study design and site

The present research is an ecologically designed study, based on secondary data about Belo Horizonte City, capital of Minas Gerais State. Belo Horizonte is the sixth most populous city in Brazil; its estimated population reached 2,530,701 inhabitants in 2021. Formal workers living in the aforementioned city earned 3.4 minimum wages (U$ 684.59) in 2020, on average, and its Municipal Human Development Index (HDI) reached 0.810 (https://cidades.ibge.gov.br/brasil/mg/belo-horizonte/panorama).

Analysis unit

Census tracts were herein adopted as analysis unit. According to the 2010 census, Belo Horizonte City has 3,936 census tracts[15]. Uninhabited census tracts were excluded from the current study; based on the 2010 Census data, they corresponded to 106 sectors. Therefore, 3,830 census tracts were included in the analysis (Figure 1).

Social environment

Some sociodemographic variables were extracted from the 2010 Demographic Census to explain social features of census tracts classified as food deserts and swamps. These variables encompassed number of literate individuals, number of households and number of individuals declaring themselves as black and brown. In addition, income *per capita* was calculated based on information about total income and total population living in the census sector[15].

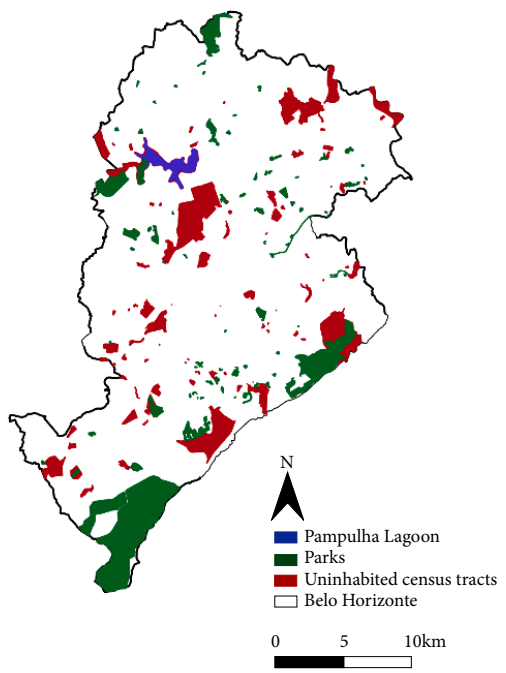

Figure 1. Excluded census tracts.

Source: Authors.

Health Vulnerability Index (HVI) was another variable included in the study. This composite indicator was developed by Belo Horizonte City Hall. It is used as tool to determine the vulnerability of the city's census tracts. HVI comprises variables such as sanitation, housing, education, income, social issues and the surrounding areas of each census sector. Data composing the HVI derived from the Demographic Census[16]. This indicator was categorized as low, medium or high vulnerability.

Food deserts

Food deserts were defined based on the density of healthy food establishments per 10,000 inhabitants[8]. The following types were taken as healthy food establishments: butcher shops, delivery stores, street vendors, hypermarkets, fruit and vegetable stores, dairy shops, mini-markets, bakeries, fishmongers, restaurants and supermarkets. Census tracts below the 25th percentile of healthy food establishment-density distribution[8] were classified as food deserts.

Food swamps

Food swamps were defined based on the density of unhealthy food establishments per 10,000 inhabitants[17]. Bars, snack bars and candy stores were classified as unhealthy food establishments[8]. The cut-off point used to classify the investigated sectors as food swamps lied on density above the 25th percentile of unhealthy food establishment-density distribution[17].

Data analysis

Community food environment features were expressed as mean and standard deviation, based on the following categories: (1) healthy food establishments, (2) unhealthy food establishments and (3) total number of establishments. Secondary data from the State Farm Bureau, from 2008, 2011, 2015, 2018 and 2020, were used to assess food environment. It is worth emphasizing that dates representing important economic and health milestones were included in the current study. The year of 2008 was included in the study because it corresponds to the two-year period after the implementation of the National Health Promotion Policy (PNSP). One of the several PNPS' goals highlighted the importance of including urban and rural planning in public policies aimed at improving individuals' quality of life[18].

The year of 2015 marked the economic crisis that has forced the country to experience strong recession and negative economic growth [19]. The year of 2020, in its turn, marked the first COVID-19 pandemic year. The aforementioned health crisis has worsened the economic crisis that had started in 2019, when the country's Gross Domestic Product (GDP) recorded significant decrease[20].

Data on company's name, address and National Classification of Economic Activities (CNAE) were requested to the State Department of Finance. The investigated establishments were georeferenced based on their full address. This information was used to find their latitude and longitude. Comparison of means between years was carried out through Anova test for repeated measures, with Sidak correction.

Food deserts and swamps were described based on absolute and relative frequency; chi-square test was used to compare means. In addition, mean variation in these parameters over the 12-year assessed period was calculated, based on variations observed between assessed periods and on averaging that variation. Data on food deserts and swamps were stratified based on the HVI of the investigated census tracts.

Furthermore, descriptive analysis was applied to socioeconomic features of the population living in census tracts classified as food deserts and swamps. Results were expressed as mean and standard deviation. Subsequently, the mean rate of variations observed over 12 years (2008-2020) was calculated based on the following formula:

*Density of healthy food establishments= (healthy food establishments/inhabitants)**10,000

Analyses were carried out in SPSS 19.0 statistical software and in QGIS 2.14.3 software, at 5% significance level (p value = 0.05).

Results

Table 1 describes the overall features of the community food environment observed in the investigated census tracts. There was significant increase in the mean number of total establishments in each census sector between 2008 and 2020 ($p < 0.0001$), as well as increase in the number of places categorized as healthy food establishments ($p < 0.0001$). The number of unhealthy food establishments did not show significant difference between 2015 and 2020 (Table 1).The

rate of census tracts classified as food deserts has decreased between 2008 and 2020, whereas the rate of census tracts classified as food swamps has increased within this same period (Figure 2).

There was mean variation of -3.30% in the rate of census tracts classified as food deserts. The period between 2011 and 2015 was the one recording the most significant reduction in this parameter. However, there was increase in the rate of low-vulnerability census tracts; mean variation reached 4.54%. Mean variation in the rate of census tracts classified as food swamps reached 8.44%. The period between 2011 and 2015 was the one accounting for the highest increase in this parameter. However, there was reduction in low vulnerability census tracts classified as food swamps; mean variation reached -4.49% (Table 2).

Table 3 describes sociodemographic features in census tracts classified as food deserts and swamps. There was increase in mean income *per capita* recorded for census tracts classified as food deserts, between 2008 and 2020 – variation rate reached 52.35%. In addition, there was decrease in the mean number of individuals who declared themselves black or brown in census tracts clas-

Table 1. Community food environment featuring. Belo Horizonte, 2020.

Establishment type	2008		2011		2015		2018		2020		p-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Healthy	2.14^{abcd}	4.21	2.45^{aefg}	4.35	2.76^{behi}	4.43	4.23^{cfhj}	5.10	6.90^{dgij}	6.23	< **0.0001**
Unhealthy	1.12^{abcd}	3.18	1.51^{aefg}	3.69	2.48^{beh}	4.52	2.46^{cfi}	4.10	3.00^{dghi}	4.12	< **0.0001**
Total	3.25^{abcd}	6.89	3.95^{aefg}	7.55	5.24^{behi}	8.37	6.69^{cfhj}	8.59	9.89^{dgij}	9.58	< **0.0001**

* Anave for repeated measures; ** equal letters show statistical difference between the years ($p < 0.05$).

Source: Authors.

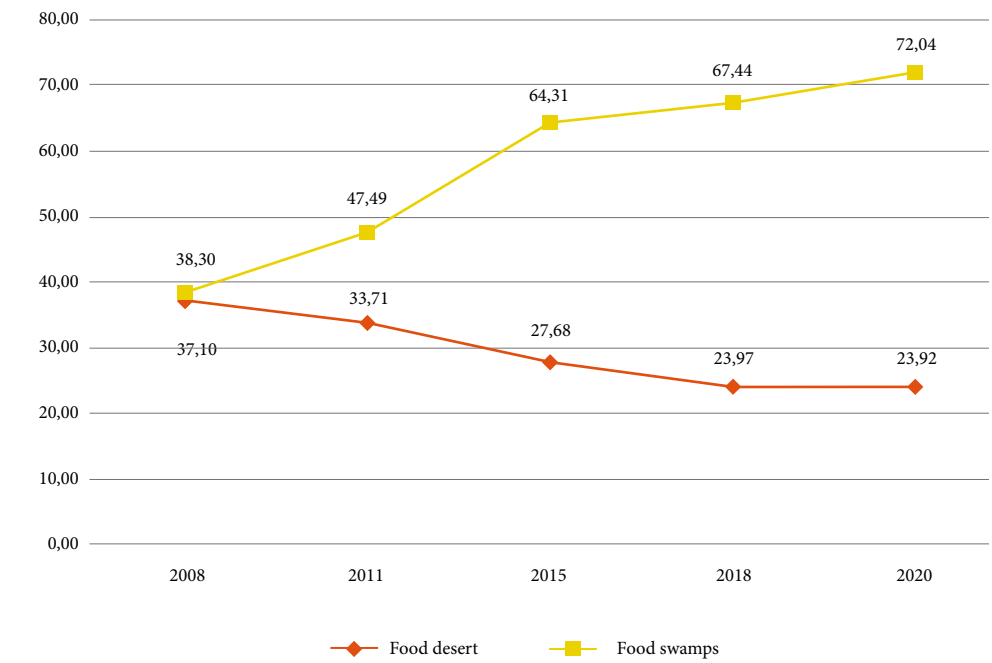

Figure 2. Evolution rate of census tracts classified as food deserts and swamps between 2008 and 2020. Belo Horizonte, 2020.

Source: Authors.

Table 2. Food deserts and swamps' evolution in Belo Horizonte City, between 2008 and 2020, based on HVI. Belo Horizonte, 2020

	2008	2011	2015	2018	2020	Mean variation
Food desert						
Total (3,830)	37.10 (1,421)[abc]	33.71 (1,291)[def]	27.68 (1,060)[ad]	23.97 (918)[be]	23.92 (916)[cf]	-3.30
Low (1,330)	23.43 (333)[a]	28.12 (363)[b]	29.06 (308)[c]	33.99 (312)[d]	41.59 (381)[abcd]	4.54
Medium (1,460)	32.37 (460)[a]	31.27 (405)[b]	30.00 (318)	25.60 (235)	22.49 (206)[ab]	-2.47
High (1,040)	44.20 (628)[a]	40.51 (523)	40.94 (434)	40.41 (371)	35.92 (329)[a]	-2.07
Food swamps						
Total (3,830)	38.30 (1,467)[abcd]	47.49 (1,819)[aefg]	64.31 (2,463)[behi]	67.44 (2,583)[cfhj]	72.04 (2,759)[dgij]	8.44
Low (1,330)	50.44 (740)[abcd]	43.6 (785)[aefg]	35.57 (876)[be]	34.42 (889)[cf]	32.48 (896)[dg]	-4.49
Medium (1,460)	39.88 (585)	42.77 (778)	42.51 (1,047)	41.42 (1,070)	41.83 (1,154)	0.49
High (1,040)	9.68 (142)[abcd]	14.24 (259)[aefg]	21.92 (540)[be]	24.16 (624)[cf]	25.70 (709)[dg]	4.01

* Statistical difference calculated through chi-square test; ** equal letters show statistical difference the years ($p < 0.05$); *** data represented as percentage (absolute value).

Source: Authors.

sified as food deserts – variation rate reached -13.22%. On the other hand, census tracts classified as food swamps presented opposite behavior, i.e., decrease in mean income *per capita* (variation rate reached -26.71%) and increase in mean number of individuals who declared themselves black or brown (variation rate reached 19.26%).

Discussion

Community food environment

There was significant increase in the number of food-selling establishments in Belo Horizonte City, over 12 years. The number of both healthy and unhealthy food establishments recorded significant increase. Previous study focused on assessing the evolution of food establishments in the investigated city between 2008 and 2018 had already evidenced the trend of increased the number of the aforementioned establishments[14].

A national study, have pointed out the trend of community food environment to present worsened features over 10 years. The aforementioned authors reported increase by 154% in the number of unhealthy food establishments over the investigated period-of-time[14].

In addition, other studies conducted in Brazil have already shown higher prevalence of unhealthy food procurement establishments in more urbanized regions, such as metropolises[8,17,21]. It is also noteworthy that previous studies conducted in middle- and low-income countries have shown that the sociodemographic features of a given investigated area can influence the availability of establishments; thus, areas presenting greater socioeconomic vulnerability have lower availability of all establishment types[14,17].

A cohort study conducted in a high-income country has shown increased density of convenience stores, fast food and full-service restaurants, as well as decreased density of supermarkets, between 1971 and 2008[12]. There was increase in the number of food establishments, as well as in food and beverage availability, in New York City, between 2010 and 2015. In addition, a study pointed out increased food and beverage trade in establishments that did not have the trade of these products as end activity[22].

Based on another study conducted in New Zealand, there was increase in the number of fast-food outlets and supermarkets within a decade (2005-2015). The authors of the aforementioned study have also observed that the distance traveled by car to fast-food stores and supermarkets has reduced, even in the most vulnerable regions[13].

Food deserts

Findings regarding food deserts have shown decreased rate of census tracts presenting these features in the herein assessed 12-year period.

Table 3. Sociodemographic features observed in food deserts and swamps between 2008 and 2020. Belo Horizonte, 2020.

	2008		2011		2015		2018		2020		Variation rate*
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Food desert											
Income per capita	579.91^{abc}	681.36	626.01^{d}	690.67	654.59^{a}	749.00	722.73^{be}	801.52	883.49^{cde}	923.83	52.35
Number of households	161.99^{ab}	99.39	155.26^{cd}	95.93	150.06^{bef}	96.13	163.78^{ceg}	104.40	178.54^{bdfg}	103.21	10.22
Number of literate individuals	460.01^{ab}	281.85	438.87^{ac}	269.20	420.02^{bd}	264.12	457.01^{e}	287.69	491.89^{cde}	280.90	6.93
Number of people who declare themselves black and mixed race	300.92^{abcd}	229.76	273.58^{a}	214.01	256.89^{b}	201.72	267.76^{c}	222.45	261.15^{d}	219.68	-13.22
Food swamps											
Income per capita	964.25^{abcd}	853.58	858.97^{aefg}	812.64	756.72^{beh}	765.57	729.65^{cf}	750.34	706.70^{dgh}	792.33	-26.71
Number of households	220.68^{a}	84.56	223.13^{bcd}	86.86	217.54^{be}	89.92	215.43^{c}	90.72	210.67^{ade}	89.87	-4.54
Number of literate individuals	614.37	244.75	626.39^{a}	254.06	615.92	261.72^{b}	611.41	263.88	598.51^{ab}	260.72	-2.58
Number of people who declare themselves black and mixed race	295.39^{abcd}	199.89	329.87^{aefg}	218.86	349.07^{be}	226.35	353.77^{cf}	228.40	352.29^{dg}	223.91	19.26

* [(mean 2020-mean 2008)/mean 2008] * 100; ** statistical difference calculated through chi-square test; *** equal signs show statistical difference the years ($p < 0.05$).

Source: Authors.

This finding contradicts what international studies have been showing, i.e., that the number of food deserts shows stability[23] or increases number of food deserts[24]. However, it is worth emphasizing that these studies considered supermarkets as marker to determine food deserts, and that they were conducted in high-income countries.

There is evidence that using supermarkets as the only marker of healthy food availability is not the most appropriate strategy for middle-income countries[17,25]. A study conducted in Mexico has shown that families living in food deserts (defined exclusively based on supermarkets' availability) had access to multiple food retailers[25]. A study conducted in Brazil has emphasized the need of taking into consideration the specificities of each location at the time to design and propose ways to measure food deserts[17].

Furthermore, the present study has evidenced change in the socioeconomic features of census tracts classified as food deserts. The social pattern of food deserts has improved over the years, since food deserts are more often observed in lower-vulnerability census tracts.

A study conducted in a high-income country focused on assessing the evolution of food deserts between 1970 and 2010. Results have evidenced changes in the socio-demographic features of the population living in food deserts over the years. The black population accounted for the highest rate of individuals living in food deserts, overtime. Furthermore, household income in food desert areas was lower in all analyzed periods; consequently, the population living below the poverty line was larger in these areas[24].

The literature on food deserts has evidences that reinforce the need of always including social issues at the time to assess the environments. Some measurement procedures already use social indicators to assess food deserts[26]. Social changes observed in food deserts may be associated with changes in establishments' concentration location. There is evidence in the literature about changes in establishments' location. Semple and Giguere (2018) assessed the layout of food establishments over the years; they observed that these establishments were more concentrated in the downtown area of the investigated city at the beginning of the evaluation period, but they migrated to the most outlying areas over time[24].

Food swamps

There was increase in the rate of census tracts classified as food swamps, over the years. These

findings are similar to the ones observed in a study conducted in Belgium, which presented increase in the number of food swamp areas between 2008 and 2020, despite the different features presented by the two countries[23].

Unhealthy food trading presents ascending curve in several Latin American countries presenting community food environment features close to the Brazilian ones[27]. Moreover, it is importante emphasizing the lower price and longer lifespan of this food type. The demand for cheaper and more durable food grows in times of both economic and sanitary crises[28].

Furthermore, the rate of food swamps in census tracts presenting higher socioeconomic vulnerability has increased overtime. It is importante highlighting that food swamps are still more often observed in less vulnerable areas.

There is no consensus in the literature about correlation between social features and incidence of food swamps. There is evidence that census tracts classified as food swamps present more favorable socioeconomic conditions than those classified as food deserts, in Brazil[17].

Final considerations

The present study has some limitations. The first one refers to the use of secondary data, which only enables making inferences about the Evolution of community food environments registered in inspection agencies. Nevertheless, it is essential emphasizing that knowledge about formal food environments can be used as important indicator of community food environment features. The second limitation refers to the use of socioeconomic data from 2010 as vulnerability indicator.

We are aware that the herein used socioeconomic information may be obsolete, but these data comprise the latest official records available in Brazil for the whole investigated population. On the other hand, the current study presentes some strong points, since it was one of the first studies focused on assessing the evolution of the so-called food desert and swamp areas in a major Brazilian metropolis. Furthermore, it is noteworthy that two different periods-of-time (economic crisis – 201519; COVID-19 pandemic – 202020) accounting for substantial impact on Brazilian citizens' lives were included in the study.

There is evidence that infrastructure inequalities are mainly associated with experienced historical moments. These moments trigger changes that range from adaptation to innovation processes taking place in all regions of the city[29]. It is therefore food environment analyses must include different points in time in order to capture the influence of importante historical moments changes in the food environment.

The first year of the pandemic was included in the current study due to its impact on the daily lives of the world's population. This period representes the time when measures to stop the pandemic were most rigorously applied. Some food retailing areas, such as food-selling apps, have boosted during the first pandemic year[30]. On the other hand, some food-selling establishment categories, mainly the ones selling ready-to-eat food, were affected by measures taken to stop the pandemic[31,32].

The current findings enabled observing increased availability of establishments selling unhealthy foods throughout the assessed period, a fact that rose the number of food swamps. On the other hand, the number of food desert areas has decreased within the same period. However, decreased number of food deserts does not mean increased access to healthy food.

Findings in the current study reinforced the need of developing public and community actions focused on increasing fresh food availability in residential areas, mainly in the lower income ones. In addition to increase healthy food availability, initiatives to provide access to healthy food to the most vulnerable populations should be promoted by civil society, as well as by the government and private institutions.

One strategy to increase access to healthy food would be to expand the availability of Public Food and Nutrition Security Facilities (EPSAN). Examples of EPSANs include: popular restaurants, agro-ecological and organic producers' fairs. In addition, strategies such as food banks can also contribute to improving access to healthy food. Another important initiative to increase the availability of healthy food is urban agriculture, such as the production units in Belo Horizonte[33].

On the other hand, promoting changes in food swamp areas requires significant efforts, since changing this environment type demands multidimensional interventions. Changing food swamps requires public regulatory policies focused on limiting the trade of unhealthy food in certain areas or on prohibiting the opening of unhealthy food establishments.

The findings here show that, in the long term, the food environment in cities will increasingly be made up of establishments selling unhealthy food. And that to reverse this scenario, greater

action by the public authorities is needed, since reducing the availability of unhealthy food requires regulatory action. For example, an important step to advance regulation would be to approve the taxation of ultra-processed foods.

Furthermore, it is note that for public policies to shape the food system and food environment, long-term action is needed. Another point is that food policies regulating are heavily influenced by food commodities, which often makes such legislations limited.

Collaborations

Conceptualization: MC Pessoa, LL Mendes and OS Honório. Methodology: OS Honório, MC Pessoa and LL Mendes. Formal analysis: OS Honório and ML Araújo. Writing – original draft preparation: OS Honório, MC Pessoa, ML Araújo, CC Moreira and LL Mendes. Supervision: LL Mendes and MC Pessoa.

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