Impact of the COVID-19 Pandemic on Portuguese Public Health Units: Development and Analysis of a Survey

Mariana Pina Tomé

Master of Science Degree in Biomedical Engineering

Instituto Superior Técnico, Universidade de Lisboa, Portugal

Abstract: In the context of the COVID-19 pandemic, the Public Health Units (PHUs) made countless efforts to respond quickly to the growth in the number of confirmed cases. This cross-sectional study describes the variations in resources, activities, and other levels attached to PHU during the various periods of the pandemic, using the pre-pandemic situation as a reference. To achieve this goal, an online questionnaire was elaborated and sent to all PHUs in mainland Portugal. Considering the challenges inherent to having a high response rate, a PH Research Network was created. The R software was used to perform the statistical analysis. A mobilization of all professional groups was verified, with a peak in the 2nd period of the pandemic (from 1 September 2020 to 28 February 2021). In terms of human and material resources, there was a need to cover current needs. Non-COVID-19 activities were particularly impacted by the pandemic. Additionally, the mobilization of professionals for COVID-19 activities was notorious. Diverse innovative initiatives were implemented during the pandemic, although a group of initiatives was consistent across the PHUs, which suggests they were successful and relevant. Taken together, the study findings demonstrate a significant asymmetry among the analysed PHUs, and also deficiencies in some areas. The reported limitations in their capacities and resources were present before the pandemic period. In addition, the impressive number of innovative initiatives implemented in such a short period indicates that the health workforce in the PHU has a remarkable capacity to adapt and develop a response. Several of these innovative actions may be considered good practices in PH.

Keywords: Public Health Unit, COVID-19, impact, questionnaire, Research Network

Introduction

Public Health (PH) can be characterized by three essential pillars: health promotion, disease prevention, and health protection [1]. To achieve these purposes, PH professionals perform in their various day-to-day activities such as measures to promote favourable conditions for health maintenance, combat infectious diseases, reduce and control 'disease' in general, and educate and inform [2].

Following the identification of the new coronavirus SARS-CoV-2 (COVID-19) in Portugal (on 2 March 2020), there were 1.085,451 confirmed cases, with 18,138 people having died (up to 26 October 2021) [3], [4]. Consequently, and inevitably, the COVID-19 virus has become a PH priority. A proactive and targeted PH response is fundamental for interrupting human-to-human transmission chains and preventing further spread, thereby reducing the intensity of the epidemic [5]. Furthermore, in a rapidly changing epidemiologic scenario, PHUs need to reorganize themselves in terms of resources (expectedly limited, considering the unexpected and overwhelmed dimension of this disease), activities, systems, among others, to respond quickly to the growth in the number of suspected and confirmed cases.

International and multi-nation organizations (example: United Nations and European Union) have developed guidelines that encompass comprehensive recommendations to all types of emergency preparedness, likewise, for the COVID-19 pandemic [6]–[8]. Specifically, the WHO (international

organization) and the DGS (national organization) developed technical guidance papers that recommend the mobilization of the health workforce according to priority services, to ensure the human resources needed for the COVID-19 preparation and a suitable response to each pandemic phase [9]–[11]. In addition, the sources for temporary health workforce surge capacity and essential health care services, including public health services, are enumerated. However, most of the measures described in the WHO technical guidance have been adopted, in particular to increase surge capacity. Nonetheless, one of the great paradoxes of all the above recommendations is that *'pandemic response plans in country after country often failed to explicitly address the health workforce requirements and implications on the workforce itself'* [12]. Specifically, many pandemic preparedness plans were not Covid-19 specific and planning for health professional capacity expansion was limited. It can be seen that the above mentioned DGS recommendations covered the health workforce to at least some extent, but most were not very specific, and majority were not up to date in light of the Covid-19 situation.

Therefore, this study aims to describe and analyse the impact of the COVID-19 pandemic on PHUs' organization. To answer this goal, we developed an online survey to understand the reality of PHU before the pandemic, and therefore what changes the pandemic brought in terms of reorganization, functionally, structuring, resources, among others.

Materials and Methods

Participants and study design

All PH main units (the headquarter) in mainland Portugal (n= 55) were identified and considered the eligible participants of the present study. In addition, the PHUs with more than one sub-unit autonomously involved in management tasks related to the pandemic were also included. Thus, a total of 61 PHUs were identified as the study targeted population.

Questionnaire structure

A questionnaire was developed through online spreadsheets, *Google Sheets* and organized into 10 separate sections ('tabs'). In some sections, the questions refer to different pandemic periods, namely before (2019 and January 2020 and during 3 periods – 1st period (from 1 March 2020 to 31 August 2020), 2nd period (from 1 September 2020 to 28 February 2021), and 3rd period (from 1 March 2021 to 31 July 2021). The 10 sections of the questionnaire are briefly described below:

- '*0.Apresentação'* – brief presentation of the project and thanks for participating.
- '*1.Coordenação*' – confirmation of data and request for information regarding the PHU and its coordinator.
- '*2.Inovação*' – general reflection of the pandemic. It is questioned what innovative changes and innovative implementations have occurred in the PHU.
- '*3.Recursos*' – subjects related to human and materials resources are questioned. The period of highest demand for human resources was asked.
- '*4.Atividades Gerais*' – issues associated with activities not related to COVID-19.
- '*5. Atividades COVID*' – issues associated with COVID-19 activities.
- '*6.Organização*' – covers how the work is organized.
- '*7.Formação COVID*' – internal training in the context of the COVID-19 pandemic.
- '*8.Sistemas*' – access to systems such as SINAVE and Trace COVID-19, and other topics.
- '*9.Comunicação*' – internal guidelines.
- *'10.Reflexões finais*' – final reflection.

Questionnaire Implementation

A PH Research Network was created to provide direct support to the coordinators of all participating PHUs to complete the questionnaire correctly. Currently, this network comprises public health residents and public health medical. The Research Network also worked as a communication point for questions and/or doubts about the project and/or questionnaire.

Statistical analysis

Descriptive statistics were used for the study data analysis, focusing on changes in the PHU during the different pandemic periods. Analyses were performed using R Software (version 4.0.5) [13]. A total of 2 181 variables were directly extracted from the questionnaire, and they were of three different types: numeric, open text, and categorical.

Data analysis started with the creation of a file in *MSExcel*, with 10 *tabs*, called *'variable map'*. The first *tab* contained the links to the questionnaires on *Google Sheets*. The *tabs* in *'variable map'* refer to the sections presented in the questionnaire, excluding the first section of the questionnaire – '*1.Coordenação'* to *'10.Reflexões finais'.* Each of these 10 *tabs* of the *'variable map'* file includes the respective variables. In addition to the variable name, their spreadsheet coordinates are indicated. A code was developed using the R software that allowed importing and downloading the *Google Sheet* links to a local folder. Subsequently, using the R software, we built a single database (*DataBase*) that compiled all variables (lines and columns refer to the variables and PHUs, respectively). The creation of the single database was aided by the creation of a single matrix, *Variable_matrix,* with the variable information contained in the '*variable map'* file – variable name, tab number, row number, and column number.

In addition, along with all data cleaning, the questionnaires were validated to verify that all answers were clear, coherent, and complete. Therefore, new variables were created to group the different professionals and material resources.

Some standardizations were performed. Considering that the PH units are dependent on the population they serve, it was necessary to adjust the values to the size of each unit's inhabitants. Thereby, data relating to the human resources existing in each unit was standardized by population size. The population served by each PHU, in its geographical area of responsibility, was asked in the questionnaire. While it is also accurate to divide values by population to find a *per capita* rate, those very small decimals would be challenging to interpret by most people, so we multiplied by 100,000 to present the results more clearly. That means that the values shown represent the total number per 100,000 inhabitants. In addition, the activities (COVID and non-COVID-related) were also standardized. The average number of health professionals involved to perform each non-COVID activity (or designated as general activity) in 2019 (pre-pandemic period), by professional group, are standardized. Considering that each activity could be performed by doctors, nurses, technical superiors, and administrative; the number of health professionals involved in each non-COVID activity reported for 2019 were standardized considering the total number of active professionals in 2019 (from each professional group). So, the standardized values represent the average percentage of each professional group (compared with the total number of professionals in the respective group) involved in each non-COVID activity in 2019. In addition, the COVID-19-related activities were also standardized, considering two types of standardization. First, for each unit, the average number of each health professionals involved in each activity was standardized considering the total number of active professionals for each group in 2019. Second, the average number of each health professionals required in each activity was standardized considering the maximum number of each active professional group observed, in each unit, during the four analysed periods (2019, 1st period, 2nd period, and 3rd period). Finally, the values related to some of the material resources (such as fixed computers, laptops, phones, and mobile phones), reported by each unit, were also standardized. The average ratio of availability of computer and telecommunication resources relative to the active human resources and the average ratio of availability of these resources reported as needed are performed. This standardization was performed considering that one professional will have access to each of these material resources, in the ideal scenario. So, an average ratio is presented: the case of 1 material resource for every 2 professionals (an average ratio of 1:2); case of 1 material resource for every 1 professional (an average ratio of 1:1); the case of 1.5 material

resource is for every 1 professional (an average ratio of 1.5:1), and so on.

Again, we developed code to calculate averages of each of the variables of interest and their maximum and minimum values. Finally, the averages of each of the variables and their respective maximum and minimum value were used to create graphs and tables in *MSExcel*. As a result of all this automated code, a dynamic analysis emerged, enabling the repetition of the same analysis, and it is possible to illustrate and present data in graphs and/or tables in seconds.

Regarding the *'2.Inovação'* section, its analysis was divided into two blocks. Firstly, we analysed the functional and organizational changes understood as innovative and the period of activity. Firstly, the content analysis of the answers to the question under study was performed, verifying the coherence and analysing whether the response was related to a change. Therefore, the type of innovative changes was defined, and then each change was categorized. Secondly, innovative implementations were analysed, i.e. the technical and operational aspects produced by the PHU to respond to a need. In the first instance, the content analysis of the answers to the question under study was performed, identifying for each implementation, the active period, the purpose, the negative consequences that the performance brought to the PHU, and the skills (the resources needed for the implementation). Implementations were typified and subsequently allocated to defined categories. The purpose, negative aspects, and skills identified were also categorized by subject area.

Results

Characterization of the participants (PHUs) and inhabitants' coverage

From the 61 questionnaires sent to each PHUs, including headquarters and sub-units, 11 (18% from the total 61) questionnaires were submitted, but 2 were discarded due to highly incomplete data. Thus, from the 9 valid questionnaires, 6 (67%) were fully completed, corresponding to the study analytical sample, except for the question Innovation, where the 9 (100%) questionnaires were considered. After the data cleaning and validation, 5 units were contacted to provide minor clarifications.

The PHU with complete data covers 13% of the mainland Portugal population. As expected, the PHUs from the *Lisbon and Tagus Valley* region covers the highest proportion of inhabitants, representing 9.6% of the mainland Portugal population and 75% of the PHU (with complete data) population. Thus, the remaining PHUs cover 3.2% of the mainland population and 25% of the total PHU (with full data) population.

Periods of highest demand

Prominently, the length of the period indicated does not depend on the total number of inhabitants covered by each unit.

Notoriously, the 4 units in the *Lisbon and Tagus Valley* region indicated a period of highest demand vastly similar. In addition, a high degree of overlapping of the periods indicated by the PHUs is observed. As expected, the 2nd period was the most demanding for all PHUs, which matches the period containing the 2 peaks of new COVID-19 cases.

One of the primary building blocks of any health system is human resources. As previously observed, the 2nd period was the most demanding for all PHUs. Specifically, January 2021 was considered for all units as one of the months of highest demand. Accordingly, all the 6 PHUs needed human resources mobilization to strengthen the screening capacity in January 2021. In addition, during this period, health professionals were infected by the COVID-19 virus, unable to work, and consequently, increasing the difficulty in mobilizing professionals.

Variation on PHU human resources during the pandemic

Compared to January 2020, PHUs reported an average increase of 9 professionals (minimum 0 and maximum 13) in the 1st period, 60 (15 and 163) in the 2nd period, and 32 (6 and 77) in the 3rd period. This corresponds to a ratio of 7 (0 e 17), 28 (9 e 55), and 18 (4 e 34) per 100,000 inhabitants, respectively. However, it

is notorious that after the period of highest demand, there is an apparent decrease in the number of health professionals, given the registered exits in the 3rd period (Figure 1).

In January 2020, 55% of the total PHU professionals were doctors, 11% nurses, 22% senior technicians, and 12% administrative. In the 1st period, a 36% increase (compared with January 2020) in the total number of professionals was attributed to senior technicians, and a 30% increase was due to doctors. In the 2nd period, compared with the 1st period, a 49% increase in the total number of professionals was attributed to doctors. On the other hand, the professional class 'others' (mainly military personnel) contributed to a 19% increase in human resources, especially in the 2nd period.

Although our study revealed an increase in the number of health professionals during the period of highest demand, this increase was not sufficient to cover the experienced needs.

The number of new cases COVID-19 varies over time and, therefore, the workload of the units. Although, in the 1st and 3rd periods, the pandemic had different behaviours and the number of professionals is different the need indicated in each of the periods is constant over time. Moreover, this need was not influenced by the pandemic, predicting that it is a need before the pandemic, concretely a structural need. Otherwise, in the 2nd period, despite the peak of entries in the total professionals, an extreme need is revealed. As previously designated, the 2nd period was the most demanding for all PHUs, leading to a need highest than the need identified as structural. Concretely, a contextual need is verified. Regarding the professional class "others" the same conclusions emerged. Considering nurses, senior technicians, and administrative, our data shows a structural need (i.e., a constant need over time).

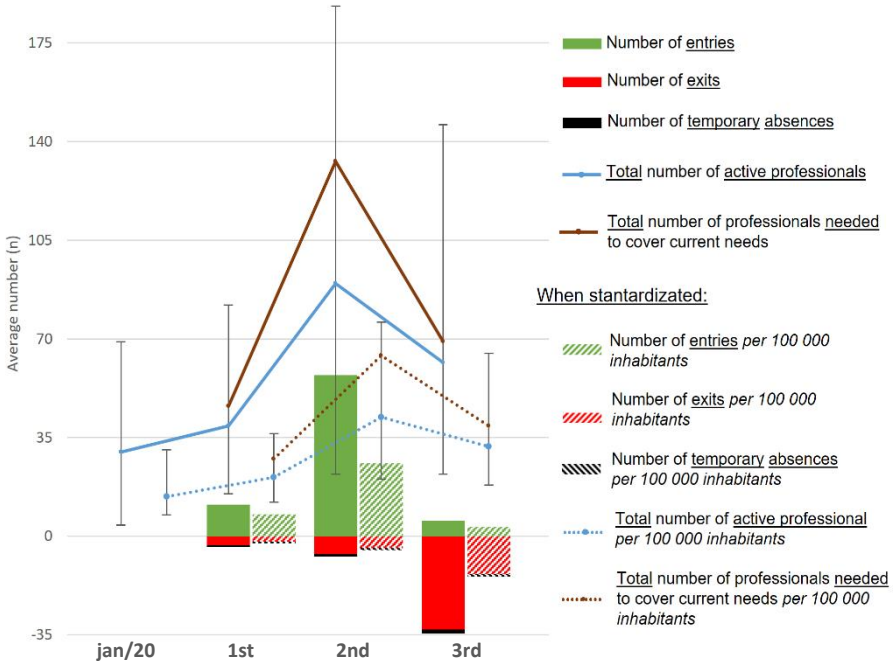

Figure 1 – Variation in the total number of active professionals and the number needed to cover the needs of all professional groups in the PHUs.

It is curious and noteworthy that the professional categories indicated as most needed for an adequate response were categories without specialization, such as public health medical residents and medical residents of the general training year.

In addition, it appears that the mobilization of professionals was quite unequal among PHU, even adjusting to its population coverage.

Variation on material resources during the pandemic

The observed increase in laptops from January 2020 to the 2nd period led to an increase in computer resources. However, the standardized show that this increase was apparently not enough considering the total number of active health professionals within the unit (which increased between January 2020 and the 2nd period, as verified in the human resource analysis). Therefore, it is possible to confirm that in the period of highest demand (2nd period), there was 1 computer resource for every 2 health professionals on average.

Although the number of phones increased on average from January 2020 to the 2nd period, the most considerable increase is relative to mobile phones, especially in the 2nd period, where on average, the number of mobile phones available triple. In addition, the standardized graphs show that from the 1st period to the 2nd period, mobile phone coverage by healthcare professionals increased. However, seemingly, such an increase was not enough, given the total number of active health professionals in the unit.

The highest need is for laptops, with the set of computer resources being an approximately constant need, regardless of the accentuated mobilization of human resources in the 2nd period. Whereby it is possible to infer a structural need in computer resources. Additionally, the same scenario in telecommunication resources is verified.

Combining the data from human resources, we found interesting results. The average number of active professionals was higher in the 3rd period compared with the pre-pandemic period and the 1st period. However, the units reported that they needed fewer computer resources in the 3rd period. This finding may be partially explained by the difficulty associated with the subjective assessment of the needs after experiencing high demands in the PHUs. In addition, there were periods of less demand that contrasted with others of great difficulty to respond. There were periods of less demand that contrasted with others of great difficulty to respond, whereby the calculation of the material resources needed for an adequate response becomes even more difficult.

Variation on non-COVID-19 Activities

An evident impact of the pandemic on the hours used in the various activities was observed. Mostly, there is an accentuated decrease immediately in the 1st period, maintaining or continuing the reduction in the 2nd period. Of the activities with a high number of hours of execution, the number of hours used for sanitary surveillance programs for drinking water had a minor reduction.

The activities that had the highest impact on the number of total weekly hours required the highest number of hours for their execution before the pandemic. Thus, the longer the hours required for its execution in 2019, the high the decrease in time spent during the pandemic. In addition, the activities with the highest impact on the number of total weekly hours are (in ascending order of variation): ‘health surveillance of food and beverage establishments’, ‘health planning’, ‘sanitary surveillance programs for drinking water’, ‘disability assessments and multipurpose certificate issuance’, and ‘national program for the promotion of oral health’.

After the period of higher demand, there were activities that partially recovered their hourly levels, such as ‘audit and accreditation programs’, ‘vector surveillance network’, ‘sanitary surveillance programs for drinking water’, and ‘national program for the promotion of oral health’ (an activity that recovered more). However, it should be noted that these activities did not return to the 2019 values.

Regarding the variation in the percentage of execution of activities compared to planned, two activities were not executed during the pandemic – ‘disability assessments and multipurpose certificate issuance (medical boards + households)’ and ‘pre-travel consultation’.

In addition, the activities ‘verification of deaths’ and ‘mental health law enforcement’ were the only ones that maintained their percentage of execution compared to 2019. This strongly suggests that these activities are essential in PH, without the possibility of having their complete suspension.

COVID-19 Activities

Table 1 shows the percentage of health professionals involved in COVID-19-related activity during the period of highest demand, standardized to the total number of active professionals before the pandemic (January 2020). It is observed that, in some cases, the number of health professionals involved in COVID-19-related activities is higher than the average number of effective health professionals in 2019 (percentages greater than 100%). Of note, the 'contact management' activity represented the highest workload for the various professional classes.

Notoriously, the 'case management' and 'contact management' activities are the activity with the most mobilization of PH professionals. This is plausible since these COVID activities (compared to the remaining two) are performed in contact tracing.

Use of Information Systems

Information systems are essential for the performance of various PH functions. Hence, it is crucial to analyse the impact of the COVID-19 pandemic on the different existing systems.

Despite being a system used for activities such as pre-travel consultation and international vaccination, it is observed that out of the 6 PHUs analysed, *SONHO* is a system that none of the units report using it. This observation may be because these units use alternative systems, or the PHUs' coordinators may not know this system well. In addition, one of the units did not report having access to the *RNU* system. This system and the *SINAVE Public Health module* were used before and during the pandemic. Additionally, the use of the systems *SINAVE-Med*, *SINAVE-Lab,* and *Excel* software increased during the pandemic. Notably, systems such as *SINAVE-Med*, *Excel software*, *SINAVE-Lab,* and *SINAVE Public Health module* had a pivotal use during the pandemic.

The *Trace COVID-9* system, implemented during the pandemic, has added several features, including the task manager, information on priority tasks, and code provision to the user for use in the *StayAway COVID* application. All 6 units analysed used *Trace COVID-19*, and the task manager functionality was used by most (67%), while only a small fraction of PHUs supported the priority managed by the platform to perform COVID-19 tasks.

Table 1 – Table Percentage of professionals in COVID-19 activities, standardized for the number of professionals in Jan 2020.

	Health professional class % [min% – max%]			
COVID-19 activity	Doctors	Nurses	Senior Technicians	Administrative
Case entry	64 [14 - 150]	**106 [a] [0 - 280]**	60 [0 - 300]	67 [0 - 300]
Case management	**149 [a] [14 - 431]**	86 [0 - 25]	79 [0 - 300]	50 [0 - 300]
Contact management	**129 [a] [0 - 354]**	**195 [a] [0 - 350]**	**193 [a] [114 - 300]**	75 [0 - 300]
PDI *	50 [67 - 150]	37 [0 - 100]	83 [0 - 300]	**114 [a] [0 - 300]**

[a] activities that require more than 100% of active professionals in Jan 2020

* *Prophylactic Isolation Declaration*

Innovation

Thirty-two functional and/or organizational changes were identified, with an average of 3,4 changes per PHU (from 1 to 7 changes). These changes were grouped into 21 types, of which 6 (28,6%) occurred in more than one PHU. It should be noted that the type "Inclusion of professionals outside the PHU" (4 [12,5%]) is the most frequent type of change. Of the total changes, 15 (46,9%) are unique in the respective PHU. Regarding the categorization

of the described changes, "Team and work management" is the one that presented the most described changes (10 [47.6%] of all 21 types of change). Seven PHUs (77.7%) reported changes in "Reorganization of internal functions", 5 (55.5%) PHUs in "Team and work management", 4 (44.4%) PHUs in "Human resources reinforcement" and 2 (22.2%) PHUs in the "Organization of knowledge resources".

Moreover, 47 innovative implementations were reported, with an average of 5.2 implementations per PHU (minimum 1 and maximum 10). Therefore, these innovative implementations were grouped into 15 non-exclusive types. "Organization of notification data" (10 [21.3%]) is the most frequent type of implementation. "Management/reduction of workload" (38 [80.9%]) and "Efficiency improvement/error reduction" (35 [74.5%]) were the two purposes in which the majority of initiatives fitted. This is to be expected, as the COVID-19 pandemic contributes to an unprecedented increase in the volume. Six (12.8%) implementations brought negative results to the PHUs, mostly related to "Human resources overload" (3 [6.4%]) and to "Difficulty in data transmission" (2 [6.4%]). In addition, "Information / computing / data management" is the most required skill to implement the implementations (29 [61.7%]).

It is essential to recollect that all PHUs analysed in the section human resources (6 units) had an increase in PH professionals. Therefore, at least 6 units should report changes in "Human resources reinforcement" in the topic of innovative change. Considering that the question related to changes was an open text question, the units did not identify several changes, possibly due to an oversight or forgetfulness.

Conclusions

This cross-sectional study describes and analyses the impact of the COVID-19 pandemic on PHUs' organization. To perform this mapping of the reality of the units, an online survey of PHU's coordinators was developed and applied. The questionnaire was addressed to all PHU and some sub-units in mainland Portugal (eligible n= 61). The questionnaire was developed through online spreadsheets (*Google Sheets*) and covered topics such as resources (human and material), activities (non-COVID-related and COVID-related), information systems, innovation, and others. In addition, some topics covered different periods, before the pandemic and during the pandemic – 1st period (from 1 March 2020 to 31 August 2020), 2nd period (from 1 September 2020 to 28 February 2021), and 3rd period (from 1 March 2021 to 31 July 2021). Throughout the development of the questionnaire, several phases were performed to ensure that the final questionnaire was appropriate and could be accurately collected data. Moreover, a PH Research Network was created to provide direct support in completing the information for this survey. At the time of the completion of this thesis, 45 Public Health Medical Residents and Public Health Medical Specialists integrated this research network. From the 61 questionnaires sent to each PHUs, 11 questionnaires were submitted. However, two were discarded due to highly incomplete data. Thus, six were fully completed from the nine valid questionnaires, corresponding to the study analytical sample, except for the question Innovation, where the 9 questionnaires were considered.

In a rapidly changing epidemiologic scenario, the PHUs had to reorganize themselves. Predictably, a mobilization of all professional groups is verified, with a peak in the period of highest demand of human resources reported by the units, 2nd period (an increase of, on average, 129% in total professionals compared to 1st period). In addition, a rise of 49% in the total number of professionals was attributed to doctors. Furthermore, ascribe to the overlapping of the periods of highest demand of human resources in the analysed units, the results observed in terms of quantity and distribution of PH professionals was expected. It is noteworthy that there was not only a great asymmetry among the analysed PHUs and shortages. Precisely, a structural need is verified in all professional categories, being notorious a contextual need in doctors in the 2nd period. Strong evidence emerges that the limitation capacities and resources were already before the pandemic.

Notably, non-COVID activities have been particularly impacted by the pandemic. The epidemiology of the virus contributes to an unprecedented increase in the workload. Specifically, contact management activity (with an average of total weekly hours of 741) where PH professionals occupy a unique position in response to COVID-19. Moreover, there was a limitation of the material resources essential to perform COVID-19 activities. Nevertheless, this deficit predates the pandemic (formally, a structural need was verified).

The functional and organizational changes generated by the PHUs during the COVID-19 pandemic showed high diversity, with responses consistent between the PHUs, which suggests an essential adaptive capacity and autonomy in the reorganization of the PHUs. Several changes had a transient nature, possibly because they responded to temporary needs, and others remain, suggesting their usefulness and effectiveness. Regarding the innovative initiatives implemented in the PHUs, in such a short and demanding time during the COVID-19 pandemic, it showed high diversity, with a group of consistent responses among the PHUs, which suggests robustness in the validity of the implementations. The need to increase efficiency in processes and activities, as well as reduce the workload, were the common reasons that led to their implementation. In addition to the mobilization capacity of the PH professionals, it was notable their innovative capacity. The innovative implementations in the PHUs required competencies outside the health area (such as computing/data management).

A strong hypothesis arises from the real impact of the pandemic COVID-19 in the PHUs, evidently in the numerous changes.

In response planning, even at the local level, it is crucial that decision-makers primarily understand the pandemic as a public health problem and not as a hospital (or intensive care) issue. After the emergency phase, the role of hospitals for COVID-19 patients' treatment diminishes. Strong evidence emerges of the possibility of incorporating the lessons learned into a model to inform future revisions of the plan from DGS.

Limitations and Future Work

The present study is inevitably affected by the participation adhesion of PHU coordinators. One of the main limitations of this study is the small number of completed questionnaires, which strongly limited the statistical power of the study and the generalizability of the study findings for all Portuguese PHUs. In addition, the time of application of the questionnaire was not ideal because it corresponded to a period of elevated workload in the PHUs, and simultaneously coincided, in part, with the summer vacations.

It is imperative to continue the individualized awareness of PHUs' coordinators to increase their participation in the study, making possible a nationwide analysis. Furthermore, as previously mentioned, the development of data analysis in the R software has the enormous advantage of updating the results almost automatically. In the future, it would be interesting to perform inferential statistics to compare groups regarding relevant characteristics (e.g., health region, urban vs. non-urban setting).

The present work is not free from some limitations, mainly related to the reported data quality. The analysed data are considered estimates, as several units do not record the requested information (such as available resources). Additionally, as a resource deficit occurred throughout the pandemic response, forecasting needs is considered problematic. The evolution of the disease and its unpredictability make this prediction even more challenging (periods of great calm contrasted with others of great difficulty in responding). Furthermore, a semi-structured interview could be performed with the coordinators to clarify their answers to the questionnaire.

The present study also contributed to identifying innovative functional and organizational changes that occurred in the analysed PHUs. However, because different innovative initiatives were identified, the data analysis required the definition of different categories. Thus, it would improve the study findings quality if the analysis was sent to the respective unit to verify the answers' consistency and completeness. In addition, some topics in the questionnaire were not analysed, due to inconsistency and

incompleteness of the data. In future studies, it is important to add these missing topics as well validate the data related to the innovative changes and initiatives implemented.

The number of active health professionals needed by the unit was adjusted to each unit's population. However, this standardization is not ideal. As the COVID-19 activities workload depends directly on the number of cases of COVID-19 disease, the values should have been adjusted to the number of confirmed cases in each region (i.e., that each unit had to respond to). Since that information is not publicly available over the different periods under analysis, we requested DGS and SPMS as part of the data from the platform Trace COVID-19. Currently, DGS/SPMS are still working on the data authorization process. Assuming the data becomes available, standardization adjusted to the number of confirmed cases will be a crucial analysis.

It is important to emphasize that one of the objectives of creating the research network is to continue this project. This will promote research at local, regional, and national levels to identify good practices and foster evidence-based public health.

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