Planning capacity in Primary Health Care under the utilization of case-mix

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Abstract

Primary health care (PHC) represents the first contact between the health care system and the citizens. Over the past years it has been noticed that demand for primary care is increasing. The population is growing older and the prevalence of chronic conditions is increasing. However, the resources provided by the Portuguese National Health System (NHS) are not enough to satisfy the demand, being verified a decrease in primary care accessibility. Patients experience long periods of time to get an appointment with their family physician. The main goal of this study is to show the importance of planning the capacity of PHC under the concept of case-mix, by developing a tool in Excel. The methods applied were based on (Ozen & Balasubramanian 2013) and were adapted to be used by the Portuguese NHS. This tool provides information about the overflow frequency (probability of demand exceeding the available capacity) of every physician in the unit, and allows several scenarios. To test the tool, data from a hypothetical PHC unit were used. The results demonstrated that it is crucial to consider case-mix while planning the physician panels so as to improve the balance between supply and demand and reduce appointment waiting time.

Key words: Primary health care, planning capacity, case-mix, physician panel, overflow frequency.

1. Introduction

Health care systems with an organized primary health care (PHC) are recognized for obtaining better results in terms of satisfaction, higher equity, health gains and better health conditions (Miguel & Sá 2010).

PHC is responsible for stablishing the first contact between the health system and the citizens and for providing a long term delivery of care, with continuity and support to individuals and families. The relationship of continuity is crucial for the development of trust between physicians and patients, and represents one of the main advantages of PHC (Amado & Santos 2009).

Access to health services is considered a prerequisite for the development of a high quality health care system (Kontopantelis et al. 2010). Health services are accessible if they are geographic and temporal available and if their costs and socio-cultural environments are acceptable (Haggerty et al. 2011).

In order to overcome the challenges in the Portuguese National Health System (NHS) and to satisfy the population needs', a national reform of the PHC was initiated in 2005. The main focus of the reform was to improve access to care and quality in health care delivery, meanwhile reducing unnecessary visits in the hospitals and emergency department, ensuring a more efficient control of costs (Leone et al. 2014).

In spite of being verified a lot of improvements after the implementation of the reform, it has still a long way to go. In (Entidade Reguladora da Saúde 2009) the major areas of dissatisfaction in concerning the PHC were identified, by realizing a survey to patients. The results clearly indicated that the waiting time was the main area corresponding to a higher dissatisfaction by patients.

The lack of access to care is also related to the excessive load of work experienced by physicians. One of the specialities related to burn out is the physician's in PHC. The burn out of physicians is described by a loss of enthusiasm in their work and feelings of not being able to achieve their personal goals. If physicians are unsatisfied, it demonstrates that the health system is not maintaining a high quality delivery care (Bodenheimer & Sinsky 2014).

Physicians' professional satisfaction is related to patients' satisfaction with their care. Nevertheless, if physicians are satisfied with their work, it is more likely that patients will get more satisfied with their health system (Buchbinder et al. 2001).

Therefore, in order to improve patients' quality of care, not only is access to primary care an area which should be addressed by the NHS, but also increasing PHC capacity, so that physicians improve the quality of their work and avoid dealing with burnout.

This study aims to develop an Excel tool which provides a variety of scenarios related with capacity planning of PHC using case-mix. By using this tool, PHC units will be able to increase their capacity and respond to their demand.

Section 2 provides a literature review of different alternatives to increase PHC capacity. Section 3 summarizes the methods used in this study and section 4 presents the application of the methods by using data from the hypothetical PHC unit. Section 5 presents the results obtained and discusses the results. Section 6 presents the main conclusions of this study.

2. Literature review

The unbalance between demand for primary care and the available capacity of physicians creates consequences in the access of care. Demand is increasing and capacity, on the other hand, is decreasing when comparing to other specialities, since there are fewer physician in PHC. If there are less physicians, panel sizes will increase even more, which will lead to less access to care, less quality of care and higher workload for physicians (Ghorob & Bodenheimer 2012).

The continuity between patient and physician is often in contradiction with access to care (Balasubramanian et al. 2011). To overcome this challenge, new planning and scheduling systems have been developed, such as the case of advanced access. This method allows the patient to schedule an appointment in the same day. For a successful implementation of this technique it is necessary to balance demand and available capacity (Qu et al. 2007).

Panel size provides an average of how many patients can be admitted in PHC units. When panel size is too high, the waiting times can increase exponentially (Hulshof et al. 2012). Continuity and access to care rely on the panel size and on the case-mix, which refers to the type of patients in the panel. Consequently, a physician's panel associated with healthier patients will have less appointments and a lower workload, when comparing to a physician's panel associated with unhealthier patients (Ozen & Balasubramanian 2013).

Accordingly to (Bodenheimer & Pham 2010) there are several strategies to increase physicians' capacity. These include sharing physicians' health care delivery with other professionals of the PHC unit, providing appointments over the phone or by e-mail and creating more positions (like panel managers and medical assistants) in the PHC unit. It is important to understand that the appointments shared and realized over the phone or e-mail, would be related to preventive and chronic care.

Another way of increasing capacity is to improve the efficiency of the scheduling system adopted in the PHC unit (Wiesche et al. 2016). Usually these systems are simulated through the use of queuing models to improve the system's efficiency and to take into consideration more realistic aspects (Cayirli & Veral 2003). (Zander 2016) developed a queueing model in which considers no-shows (patients who don't show for their appointments) and the possibility to reschedule their appointment.

Panel size is an important measure for capacity planning, as it has been mentioned above. (Green et al. 2013) demonstrates how access to care and how the implementation of new operational methods influence in panel size. (Green et al. 2007) relates the overflow frequency with panel size. The overflow frequency calculates the probability of demand exceeding the available physician's capacity. (Altshuler et al. 2012) studies how sharing physicians' tasks with other professionals influences in panel size.

According to (Liu et al. 2013) case-mix refers to the type of patients which belong to the PHC unit. Since every patient is different from another, the delivery of care should also be different and the frequency which they need care is also different. (Balasubramanian et al. 2010) uses a computational simulation model to prove that redesigning panels using case- mix improves access and continuity of care. (Ozen 2014) uses queueing models to study the relation between panel size, physicians' capacity, access and continuity of care. (Stahl et al. 2014) uses three algorithms to transfer patients between panels in order to obtain panels with the same level of case-mix.

3. Methods

The methods used in this study were adapted from (Ozen & Balasubramanian 2013), in order to be applied in the Portuguese NHS. Some extensions to those methods were also developed. Figure 1 summarizes the methods used in this study.

First of all, it was necessary to decide which case-mix to consider. The classification of patients in this study included by age (adults) and by comorbidities, which we were not able to collect, since it is not possible to collect such data in Portugal. Therefore, a new classification of patients was developed in this study, which is by the number of problems patients have (which will be defined in section 3.1).

Balasubramanian 2013) and heuristic 3 was developed in this study.

The methods were applied in an interactive Excel tool which allows any unit of PHC to infer about the overflow frequency, real capacity and utilization of their physicians. This tool can also be used to obtain an estimative of the waiting time to get an appointment with a certain physician.

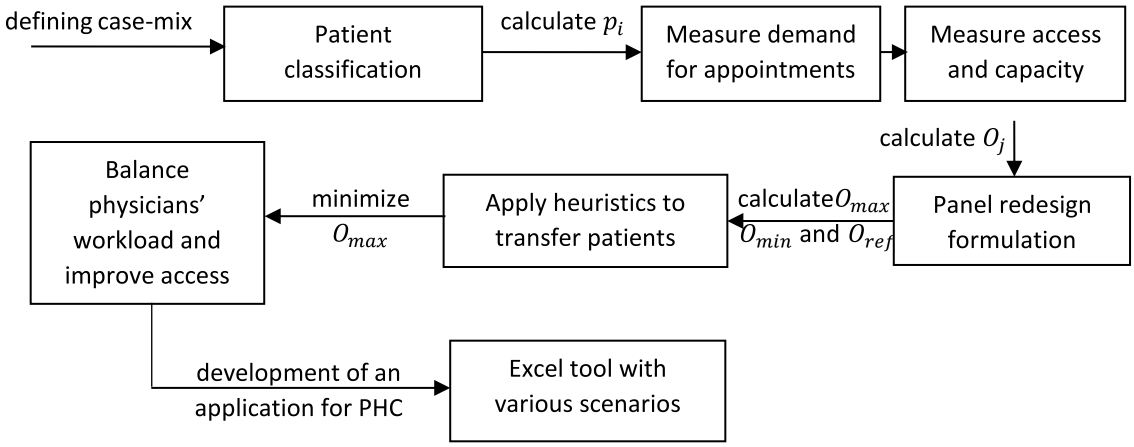

Figure 1- Summary of the methods applied in this study

The following step consisted on measuring the demand for appointments, by calculating p_i which refers to the probability of a patient from category i scheduling an appointment.

It was also necessary to measure access to care and capacity. These measures were obtained by calculating the utilization, real capacity, expected overflow (it was not possible to calculate in this study, see section 3.3) and overflow frequency (O_j).

With these measures defined it was possible to formulate panel redesign. Panel redesign consists on minimizing the maximum overflow frequency by transferring patients from the physician's panel with maximum overflow to the physician's panel with minimum overflow, until reaching reference overflow frequency (O_{ref}).

For patients' transference three heuristics were used. Heuristic 1 and 2 were developed in (Ozen &

3.1. Patient classification

Patients were classified by age, considering only adults and by the number of problems they have.

- **Age**

Figure 2 represents the categories used to classify patients according to their age.

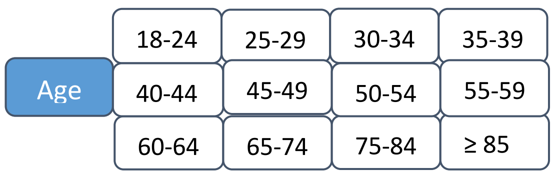

Figure 2- Categories applied in patient classification according to their age

- **Problems**

As it was mentioned in section 3, it is not possible to collect data in Portugal related to the number of patients according to the number of comorbidities they have. So, in this study a new classification was developed. Patients are classified by the sum of problems they have by category of age and the ratio of problems is also calculated by category for every panel. These problems are related with patients' illnesses. This ratio can be calculated by:

$$R_{ij} = \frac{Pr_{ij}}{n_{ij}} \quad (1)$$

For category i and physician j.

$Pr_{ij} - Number\ of\ problems\ from\ category\ i\ and\ physician\ j$

$n_{ij} - Number\ of\ patients\ from\ category\ i\ and\ physician\ j$

- **Children and pregnant women**

Both children and pregnant women were not included in the model. Since there is an estimative of appointments to both children and pregnant it is possible to obtain an estimate of its total number. It is provided in this study an Excel spreadsheet which allows to estimate the number of appointments regarding both groups.

3.2. Measuring demand

In order to estimate the demand, it is calculated the probability of a patient from category i to schedule an appointment on a given day (p_i). This value takes into account the characteristics of each category. For unhealthier and older patients this value will be higher, when comparing to healthier and younger patients. This probability is calculated by:

$$p_i = \frac{A_i}{N_i * T} \quad (2)$$

$A_i - Total\ of\ appointments\ for\ patients\ in\ category\ i$

$N_i - Total\ of\ patients\ in\ category\ i$

$T - Number\ of\ work\ days\ in\ a\ year$

The demand of each patient can be represented by a Bernoulli random variable with p_i probability of scheduling an appointment, while the demand from each category can be represented by a Binomial random variable with n_{ij} patients and p_i probability of scheduling an appointment. The demand for a physician's j panel is given by the sum of the demand from each category and is well approximated by a normal distribution.

3.3. Measuring access and capacity

To measure access to care, the measures of utilization, expected overflow and overflow frequency were considered. To measure capacity the real capacity of each physician is calculated.

- **Utilization**

Utilization is given by the total demand of each panel, divided by the available capacity of physician j in each day.

$$Utilization_j = \frac{p * L_j}{C_j} \quad (3)$$

$L_j - Physician's\ j\ panel\ size$

$C_j - Available\ capacity\ of\ physician's\ j,\ given\ by\ the\ number\ of\ appointments\ per\ day\ with\ duration\ of\ 20\ minutes$

With p equals to the probability of requesting an appointment from all categories of patients.

$$p = \frac{A}{N * T} \quad (4)$$

$N - Number\ of\ patients\ from\ the\ PHC\ unit$

$A - Total\ appointments\ from\ all\ patients$

$from\ the\ PHC\ unit\ during\ a\ period\ T$

- **Expected overflow**

Expected overflow indicates the average quantity of appointments which were not accomplished by each physician in each day. This measure is not calculated in this study, since there is not available data to calculate it.

- **Overflow frequency**

Overflow frequency (O_j) is the probability of demand exceeding the available capacity of each physician j per day.

$$O_j = 1 - \Phi\left(\frac{C_j - \mu_j}{\sigma_j}\right) \quad (5)$$

$\mu_j - Average\ of\ visits\ from\ patients\ of$

$physician's\ j\ panel$

$\sigma_j - Standard\ deviation\ of\ visits\ from$

$patients\ of\ physician's\ j\ panel$

$\Phi - Normal\ distribution\ percentil$

- **Real capacity**

Real capacity indicates the necessary capacity for each physician to fulfil its demand. This value refers to the number of appointments with duration of 20 minutes.

$$Real\ capacity_j = L_j * p + a * L_j * p \quad (6)$$

$a - Positive\ parameter$

This value ensures that capacity exceeds the average demand of each panel, covering demand's variability. In this study, a equals 10% as in (Ozen & Balasubramanian 2013).

3.4. Panel redesign formulation

In order to redesign the physician panels, the maximum overflow frequency is minimized and at the same time the physicians' workload is balanced, ensuring that the demand for each panel is balanced with the available capacity of each physician.

The overflow frequency is a non-linear objective function. The optimization of this function can be achieved by the application of heuristics, which provide an approximation of the obtained solutions from the solutions which would be reached by its exact approximation.

To minimize the maximum overflow frequency, patients from the physician's panel with maximum overflow frequency are transferred to physician's panel with minimum overflow frequency.

The number of patients transferred from category i to physician's j panel is represented by x_{ij}. This variable assumes only integer values and non-negative values, and is assumed that any patient can be transferred:

$$\sum_{j=1}^{J} x_{ij} = N_i, \forall i = 1, \dots, M \quad (7)$$

$J - Sum\ of\ all\ physicians$

$M - Sum\ of\ all\ categories$

This model assumes that patients schedule appointments independently from each other, representing the total demand for category i from physician's j panel as a binomial random variable with a mean given by $x_{ij} * p_i$ and variance by $x_{ij} * p_i(1 - p_i)$.

The total demand for all the physician's j panel has a mean and variance given by:

$$\mu_j = \sum_{i=1}^{M} p_i * x_{ij} \quad (8)$$

$$\sigma_j = \sqrt{\sum_{i=1}^{M} p_i * (1 - p_i) * x_{ij}} \quad (9)$$

With $0 < p_i < 1$.

As panels' sizes are sufficiently high, the total demand is obtained by the sum of Bernoulli random variables and it can be well approximated by the normal distribution. The Z value for a physician j is given by:

$$Z_j = \frac{C_j - \mu_j}{\sigma_j} \quad (10)$$

And the overflow frequency for each physician j by:

$$O_j = 1 - \Phi(Z_j) \quad (11)$$

Patients' transference consists on optimally dividing the mean and variance of all panels for each physician's panel. The values of x_{ij} quantify the value of that division. The values of O_j, μ_j and σ_j depend on the values of x_{ij}, increasing/decreasing it they increase/decrease for $i = 1 \ldots M$.

When the physicians' capacity is different, the value of overflow frequency of reference (O_{ref}) is used as an approximation of the optimum value.

$$O_{ref} = 1 - \Phi(Z_{ref}) \quad (12)$$

$$Z_{ref} = \frac{Z_{CP}}{\sqrt{J}} \quad (13)$$

$$Z_{CP} = \frac{C - \mu_{total}}{\sqrt{\sigma_{total}^2}} \quad (14)$$

$Z_{CP} - Z\ value\ of\ combining\ physicians, with$

$no\ concept\ of\ continuity$

$$O_{CP} \leq O_{opt} \leq O_{ref} \quad (15)$$

3.5. Heuristics

In this study three heuristics were applied. All of them transfer patients from physician's panel with maximum overflow frequency to the physician's panel with minimum overflow frequency.

Heuristic 1 transfers only patients from categories with lowest visits, low p_i values. It only changes to next category when there aren't more patients in the category for the physician's panel with maximum overflow.

Heuristic 2 transfers patients from all categories.

Heuristic 3 transfers patients according to the category with highest value of problems.

4. Case study

These methods were applied in an interactive Excel tool, which simulates various scenarios, including redesigning panels, designing panels, adding physicians and sharing physician's responsibilities with nurses.

The user only has to insert the number of physicians, the number of patients for each physician's panel by age, the number of problems for each physician's panel by age, physicians' capacity, number of visits per patient per category, number of total visits per category and number of workdays, of the unit.

The data provided includes panels' distribution, panels' size, real capacity, utilization and overflow frequency for all the physicians.

The data applied in the Excel tool was randomly generated based in the governmental guidelines for building patient lists and having knowledge on the different information systems available to manage consultations. The hypothetical unit in study was conceived as having initially 6 physicians, the number of work days for adults considered was 177 and the duration of appointments equal to 20 minutes. The results obtained only refer to adults.

Tables 1 to 4 refer to the values obtained for the initial design. Table 1 presents panel size and capacity per physician, table 2 the overflow frequency per physician and the reference overflow frequency, table 3 real capacity and utilization per physician, table 4 the initial ratio of problems of each panel.

Table 1- Panel size and capacity of each physician

Physician	Panel size	Capacity
Physician 1	1260	14
Physician 2	1495	20
Physician 3	1474	16
Physician 4	1491	20
Physician 5	1525	16
Physician 6	1506	20

Table 2- Overflow frequency and reference overflow frequency obtained initially

Physican	Overflow frequency%	Reference overflow frequency%
Physician 1	97.4	
Physician 2	54.1	
Physician 3	82.9	
Physician 4	57.3	
Physician 5	97.2	
Physician 6	68.7	83.1

Table 3- Real capacity and utilization of each physician

Physician	Real capacity	Utilization%
Physician 1	21	133
Physician 2	25	114
Physician 3	25	138
Physician 4	25	114
Physician 5	25	145
Physician 6	25	115

Table 4- Initial ratio of problems per panel

Physician	Ratio of problems per panel
Physician 1	5.44
Physician 2	2.98
Physician 3	3.13
Physician 4	2.25
Physician 5	4.75
Physician 6	4.26

The data collected presented some limitations. It was realized an estimative of the number of visits per year and patient for each category by considering the average value of visits for each patient equal to 3.4 (Direcção Geral da Saúde 2012).

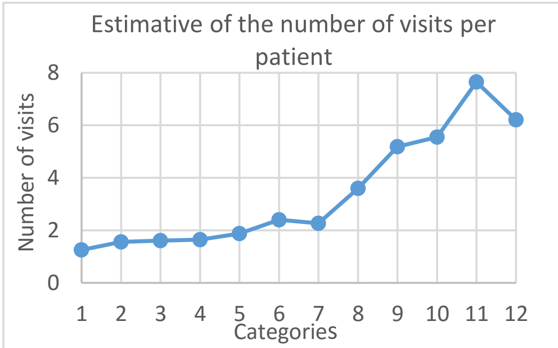

Figure 3- Estimative of the number of visits per patient

5. Results and discussion

As it was shown in table 2, the initial overflow frequency obtained for each physician in the unit is really high and shows significant differences between physicians. In order to decrease the overflow frequency, the scenario in which a physician is added to the PHC unit by applying heuristic 3 was simulated (tables 5 and 6). It is possible to observe that comparing to the overflow frequency values obtained initially, the values decrease and become similar. Although the maximum overflow obtained is still very high. Relatively to the ratio of problems for each physician panel obtained, the values decrease for most physician panels.

Table 5- Panel size and overflow frequency by adding one physician to the unit using heuristic 3

Physician	Panel size	Overflow frequency%
Physician 1	920	58.7
Physician 2	1464	58.8
Physician 3	1215	58.9
Physician 4	1501	58.9
Physician 5	1104	58.8
Physician 6	1337	58.7
Physician 7	1210	58.9

Table 6- Ratio of problems for each physician panel after adding one physician applying heuristic 3

Physician	Ratio of problems per panel
Physician 1	4.60
Physician 2	2.75
Physician 3	2.78
Physician 4	1.94
Physician 5	3.99
Physician 6	3.88
Physician 7	4.28

According to (Ozen & Balasubramanian 2013) the reference overflow frequency value should not exceed 30%. By simulating the scenario where is possible to insert the maximum overflow frequency, in order to obtain overflow frequency values lower than 30% it is necessary to add 3 physicians.

Comparing the results obtained in (Ozen & Balasubramanian 2013) for the test which analyses 4 physicians with different capacities, the overflow frequency of each physician is lower than the results obtained in this unit. The values are only comparable when 3 physicians are added to the unit. Proving that the current capacity in this unit is significantly low according to its demand.

For the scenario which allows sharing physicians' responsibilities with nurses, the categories considered were from 18 until 40 years old, with 50% sharing for each category. The reference overflow frequency obtained was equal to 63.7%. The results obtained by this example demonstrate the impact of delegating physicians' tasks to other professionals on increasing physician's capacity and decreasing physicians' overflow frequency. The reference overflow frequency obtained initially is 19.3% higher when comparing with this example.

By knowing physicians' capacity per month and calculating physician panels' demand each month, it is possible to calculate the number of appointments for each physician per month. Using this data, it is possible to estimate the waiting time for an appointment with a certain physician. The waiting time (in months) by physician when applying 5 scenarios is summarized in table 7. For each scenario was chosen the physician with highest waiting times. It was considered that demand is equal in each month and there was not any backlog from the previous year.

Table 7- Estimative of the time to obtain an appointment in months

Scenario	Physician	Mar	Jul	Dec
Initial	1	2	6	11
Redesign h3	1	2	4	7
Design h3	1	2	6	10
Add 1 physician h3	1	0	3	4
Add 3 physicians	6	0	3	4

The values increase along the year due to backlog. It is possible to observe that redesigning panels obtains better results than the initial design, proving that applying case-mix when planning panels improves access to care. Also, when capacity increases waiting time significantly decreases.

6. Conclusions

The main goal of this study was to plan PHC capacity under the concept of case-mix. The results obtained demonstrate that applying case-mix when designing and redesigning panels, provide better results in terms of access to a physician panel. The scenarios applied in the Excel tool demonstrated that increasing capacity, by adding physicians and/or sharing physicians' responsibilities with nurses, turns out in lower values of overflow frequency, increasing access to the physician panels.

It is possible to affirm that the objectives of this study were achieved and although the developed tool has still some limitations, it is possible to extend its use to other units.

For future work considerations, other scenarios could be developed in order to optimize patients' distribution to other professionals in PHC (not only to nurses) and models which are able to determine the ideal level of skill-mix to use in PHC.

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