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Faculteit Geneeskunde en Levenswetenschappen

master in systeem- en procesinnovatie in de gezondheidszorg

Masterthesis

Evolution of patient safety culture during the COVID pandemic

Niki Sciarrino

Scriptie ingediend tot het behalen van de graad van master in systeem- en procesinnovatie in de gezondheidszorg

PROMOTOR :

Prof. dr. Ward SCHROOTEN

2024
2025

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CONTENT TABLE

PREFACE

This thesis finalizes my Master's program and captures both academic and personal progress. In the course of this thesis, I have enhanced my knowledge and skills in coding, data science, and their relevance in a clinical setting. Coming from a biomedical background, this thesis offered me an exceptional opportunity to combine both clinical insight and data analysis. A complex health challenge, such as COVID, has highlighted the critical role of data-driven decisions. Therefore, many aspects during the pandemic remain in development. My motivation for this project is to be part of scientific knowledge about the pandemic for healthcare organizations. Accordingly, I am very thankful for everyone who supported me during this project. Specifically, I would like to thank my supervisor, Prof. dr. Ward Schrooten, for his guidance, knowledge, and support.

ABSTRACT

Introduction

Patient safety culture (PSC) is a crucial element in health care quality, as it prevents medical errors and increases the quality of patient health. The Hospital Survey on Patient Safety Culture (HSOPSC) is a validated tool for evaluating PSC. This became more relevant during the COVID pandemic, where healthcare systems were disrupted globally and elevated pressure on healthcare organisations and workers. Therefore, this study aims to evaluate the PSC in hospitals before, during, and after COVID.

Methods

A retrospective, observational study design, including HSOPSC survey data from 194 general and psychiatric hospitals in Belgium, was used. Staff and hospital characteristics were evaluated, and the positive response rate of the participants was measured over the 12 HSOPSC dimensions. To assess the COVID impact on PSC, an interrupted time series (ITS) analysis was conducted using a subset of the data with hospitals completing the HSOPSC before, during, or after COVID.

Results

Most of the dimensions regarding teamwork, organizational learning, communication, and management support improved before the pandemic. However, during the pandemic, declines were observed in management support, handoffs, and safety perception, with 5% or more drops in positive responses for several dimensions. After the pandemic, organizational learning and teamwork within departments showed a declining trend. Furthermore, positive responses to dimensions concerning non-punitive response, handover, teamwork across departments, staffing, and outcome measures remained low.

Conclusion

While most dimensions showed improvements before the pandemic, several dimensions remained low across all periods. Dimensions regarding teamwork, handoffs, safety perception, and management support declined during or after the pandemic. This study reflects the fragility of healthcare institutions in times of crisis and suggests the need for resilient and durable systems for future improvement and research.

KEYWORDS: Patient safety culture, COVID, quality, health care, hospital.

INTRODUCTION

Patient safety (PS) is a crucial process to improve patient care and involves the interception of medical errors within healthcare organisations (1). Preventing medical errors increases the patient's quality of life, as such medical errors often lead to patient harm, illness, disability, and even death (2). These medical errors are induced by a variety of processes, such as medication errors, surgical errors, diagnostic errors, sepsis, and unsafe injection practices (3). However, many of those medical faults are preventable by utilizing the correct procedures and systems (4). Globally, patient harm occurs in roughly one in ten patients in health care organisations, and around three million deaths occur due to hazardous care (5). One in 20 patients is confronted with preventable harm, accounting for about 50% of the overall patient harm (6). Therefore, patient harm caused by medical errors is a significant concern in health care (7). Moreover, sources of patient harm also include failure of health care systems, actions of professionals, or a combination of those elements (6).

Previous studies indicated the relationship between the health organization culture and the organization's outcome, including patient satisfaction and adverse effects. Improved clinical outcomes, elevated staff morale, and patient trust are generally related to a positive organizational culture (8, 9). Patient safety culture (PSC) evaluates health care organisations to create a more assured and reliable system. The assessment of PSC has been enhanced worldwide in the health care industry for the improvement of PS (2). It includes the norms, values, attitudes, and behaviors that may promote PS (10). To accomplish this, many factors are investigated, such as communication, leadership, resources, and education of the health care workers (11).

Using PSCs reveals the risks and safety issues in health care organisations. The analysis of those challenges contributes to an engagement of multidisciplinary work, provides solutions, and promotes a healthy work environment (11, 12). Organisations can monitor the efficacy of the interventions over a time period, offering an overview of practices and challenges. PSC is measured by various techniques, including hospital surveys and questionnaires. In November 2004, the Agency for Healthcare Research and Quality (AHRQ) originated the Hospital Survey on Patient Safety Culture (HSOPSC). This survey is the most commonly used indicator for PSC and is also used in Belgium (13-16). It involves 12 dimensions with 42 subitems, including 10 safety dimensions and 2 outcome dimensions. Additionally, HSOPSC is a useful tool for the analysis of PSC over a longer period of time (17). However, more research is required to determine the predictive value of the dimensions on the HSOPSC outcomes (13).

In 2019, SARS-COV-2 emerged in our population and spread rapidly worldwide (18). The pneumonia-causing virus was identified as a pandemic and was therefore named COVID-19 by the World Health Organisation (WHO) (19). Many different measurements were applied to avoid further spreading of the virus, including quarantine and teleworking. Whereas health workers were held at the frontline to minimize transmission of the virus (20). Consequently, the pandemic has caused many alterations in the healthcare system nowadays. Accordingly, adaptation was crucial due to the severity and urgency of the pandemic (21). As a result of the rapid increase in hospitalisations, health care workers were exposed to elevated workload, new clinical environments, retraction of routine procedures, and treatment of patients suffering from the new disease (20). The immense and immediate inflow of hospitalizations led to shortages in infrastructure and materials, contributing to alterations in health care quality. The pressure on hospitals and health care workers was sudden and unmatched, urging staff to experience exhaustion, burnout, and emotional discomfort. Hospitals were operating above their capacity to control the elevated inflow of patients (18, 22). Health care workers were expected to make decisions about prioritizing patients for health care or intensive care under time pressure. Accordingly, they were responsible for the patient's safety and avoiding any outbreaks, their well-being and health (23, 24).

The pandemic also delayed non-COVID-19 treatments due to the priority of infrastructure and materials for COVID-19 patients. Therefore, patients suffering from chronic diseases, such as cardiovascular disease, cancer, or diabetes, were affected by this disruption. The overall disease burden increased for those patients (25). Little was known about COVID-19, leading to limited resources about the safety of health care workers and the patients themselves (21). Guidelines and

protocols considering safety issues were absent during the pandemic. Moreover, information about the virus itself was missing (26). Continuous adaptation to those conditions was necessary and challenging due to the inflow of information about guidelines (22).

In Belgium, the first COVID case was discovered in March 2020 (27). 17,1% of the hospitalized COVID patients needed intensive care, and 46% of the patients required higher-than-average care, increasing the nursing workload. The mortality rate of COVID patients in hospitals was 17% in 2020 (28). Compared with other European countries, high rates of COVID cases and mortality were identified in Belgium. The greater impact of COVID was due to the complex health care system and disintegrated political structure (29). The health care system is decentralized at regional and federal levels (30). Accordingly, despite the efforts for a united coordination, miscommunication and misunderstanding emerged between levels. Furthermore, the high prevalence of elderly populations amplified the proliferation of the virus and elevated mortality rates, with 85% of patients in intensive care ranging from 50-80 years old (28, 31). This vulnerable demographic, in combination with the organizational issues, was additionally confronted with the absence of a robust crisis management plan, which caused uncertainty and delay in the health care systems (29).

Due to the extensive impact of COVID on health care workers and the organization of health care institutions, it is crucial to evaluate how the pandemic affected the PSC in hospitals. Moreover, the findings from this study could provide information for better comprehension and awareness of future unexpected challenges and how they affect PSC. Evaluating PSC in health crises could reinforce health care organisations' resilience and thus provide constant, safe, and quality health care in the future. The aim of this study is to evaluate the impact of COVID on PSC in general and psychiatric hospitals. Therefore, the HSOPSC was utilized for a long-term period from 2005-2024, providing an interesting perspective on alterations throughout the COVID period.

METHODS

Design

This retrospective observational study was applied using the Patient Safety Culture benchmark data. A total of 194 Belgian hospitals were included in this study. 109 Dutch-speaking (Flanders), 55 French-speaking (Wallonia), and 15 both Dutch and French-speaking hospitals (Brussels) were involved. General and psychiatric hospitals were selected and received a paper-based or online survey. In total, 369563 surveys were distributed and 177806 were returned for this study, yielding a response rate of 48,11 %. Specifically, physicians accounted for a response rate of 29,23%, and the other health care workers (such as nurses, technicians and pharmacologists, etc) accounted for 51,42% of the response rate. The surveys were allocated anonymously to the hospital staff.

Measurements

The HSOPSC survey is a validated measurement tool that includes 42 items across the ten dimensions and 2 outcome measures, and analysis was anticipated using the Likert scale, differentiating between 1 (Strongly disagree) and 5 (Strongly agree) (**Supplementary Table 1**) (16, 32). The survey consists of a few questions about the work area, contact with patients, and position. The study was conducted over a time period of 2005-2024.

Funding and ethics

The HSOPSC was managed anonymously to ensure the privacy of the participants. Researchers acquired permits from the hospitals for the analysis of the HSOPSC measurements. The participating hospitals obtained an unique code for the comparison with other institutions, to ensure confidentiality. Ethical approval was acquired from the Central Ethics Committee of Hasselt University.

Limburg Sterk Merk and the Federal Public Service of Health, Food Chain Safety, and Environment of Belgium provided the funding for this study. The study was part of a Quality and Patient Safety program. The data could be shared voluntarily in a national database organized by the University of

Hasselt. This survey became important due to the transition to pay-for-performance, as it was included in the ISQUA accreditation.

Descriptive analysis

Descriptive analysis was used to obtain an overview of the participating hospitals and staff. The number and percentages of the participating hospitals are measured by status, type, region, province, and number of measurements. For the staff, direct contact, work environment, function, and experience are indicated. The proportion of direct contact was calculated by dividing the number of direct or indirect contact by the total number in each time period, multiplied by 100. Furthermore, direct contact between staff and patients, and also the type of hospital, are shown per time period (2005-2008; 2009-2014; 2015-2019; 2020-2021; 2022-2024).

Statistical analysis

To obtain a general overview of the 12 dimensions over the time periods, a distribution of the positive responses was analysed using boxplots. The percentage of positive responses was calculated by dividing the sum of positive responses by the sum of total responses, multiplied by 100. A score of 4 or 5 out of 5 is considered a positive response. The data was observed using a threshold of 5% as practically different. This data also obtained the average score, and dimensions scoring below 50% were classified as low-scoring performances (16).

Moreover, an interrupted time series analysis (ITS) was constructed to assess the impact of COVID on the PSC in general and psychiatric hospitals. For this analysis, a subset of the data was taken. For hospitals completing the survey pre- and during COVID or pre- and post-COVID (or all three categories), the mean percentage of positive responses was estimated (**Figure 1; Supplementary Table 3**). The COVID pandemic (2020-2021) was defined as the intervention in this study, where the 5 sequential periods were used to evaluate the data. Using the following equation, a linear regression model was estimated for each dimension separately: $Y = \beta_0 + \beta_1 * time + \beta_2 * covid + \beta_3 * timesince + \varepsilon$

A time series plot was obtained for each dimension and outcome measurement. For the assessment of autocorrelation in the regression models, a Durbin-Watson test was utilized. A p-value of 0.05 is considered statistically significant. All statistical analyses and graphs were constructed using RStudio (version 2024.12.1).

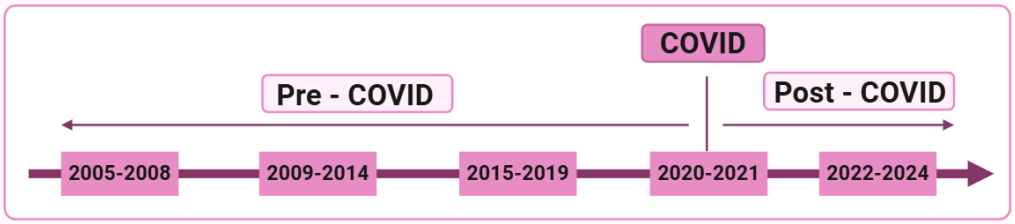


Figure 1: Periods and timeline related to the COVID pandemic. The five periods are categorized into the three phases: Pre-COVID, COVID, and Post-COVID. These phases are utilized for the ITS subset analysis.

RESULTS

Hospitals characteristics

For the descriptive analysis, the status, geographical information, and type and number of measurements were evaluated from the data (**Table 1**). This descriptive analysis was performed with the whole dataset to obtain a general overview. Firstly, the largest number of participating hospitals was private (**Table 1**). Moreover, general hospitals accounted for a larger number than psychiatric hospitals (**Table 1**).

Additionally, 60,9% of hospitals from the Dutch-speaking part of Belgium (Flanders) participated in the study, whereas Brussels was the smallest participating group (**Table 1**). For the provinces of

Belgium, the distribution of the hospitals was diverse, with "Oost-Vlaanderen as the highest number of participating hospitals. The province with the smallest participating hospital group was "Luxemburg" (**Table 1**). Furthermore, an analysis of the measurement frequency was performed, ranging between 1 and 5, where most hospitals completed three measurements (n = 62). The distribution of general and psychiatric hospitals over the five time periods is also shown in **Table 1**.

Table 1: Hospital characteristics. The number and percentage of participating hospitals by status, region, province, type, measurements, and type per period.

Status				**N**	**%**
Privat				110	61,5
Public				69	38,5
Region					
Flanders (Dutch-speaking)				109	60,9
Wallonia (French-speaking)				55	30,7
Brussels (both Dutch and French speaking)				15	8,4
Province					
Oost-Vlaanderen				30	16,8
Antwerpen				23	12,8
Limburg				20	11,2
West-Vlaanderen				23	12,8
Luik				15	8,4
Waals-Brabant				5	2,8
Brussel				15	8,4
Henegouwen				25	14,0
Vlaams-Brabant				13	7,3
Namen				6	3,4
Luxemburg				4	2,2
Type					
GH				110	61,5
PH				69	38,5
Number of Measurements				**Number of Hospitals**	
1				37	
2				38	
3				62	
4				34	
5				8	
Type	**2005-2008**	**2009-2014**	**2015-2019**	**2020-2021**	**2022-2024**
GH	89	94	91	5	13
PH	42	51	73	9	8

GH, General hospital; PH, Psychiatric hospital.

Hospital staff characteristics

Next, in **Table 2**, the staff characteristics of the participating hospitals are shown. The majority of staff have direct contact with patients across all periods. The proportion of direct contact peaked in 2020-2021 (89,8%), whereas the percentage of indirect contact with patients remained low in all periods (**Table 2**).

Participants were distributed across many hospital departments. The proportion of respondents in Medicine and Surgery wards was the highest. Whereas the lowest proportion of participants specified their work environment in Pediatrics, Emergency departments, Psychiatry, and Pharmacy (**Table 2**).

Table 2: Hospital staff description. The distribution of staff based on direct and indirect contact with patients, work environment, function description, and experience.

Direct contact with patients	**2005-2008 N (%)**	**2009-2014 N (%)**	**2015-2019 N (%)**	**2020-2021 N (%)**	**2022-2024 N (%)**
Yes	47878 (85,8)	52138 (87,7)	52470 (88,5)	3204 (89,8)	4536 (87,7)
No	4815 (8,6)	5217 (8,8)	5390 (9,1)	311 (8,7)	393 (7,6)
N/A	3124 (5,6)	2073 (3,5)	1444 (2,4)	52 (1,5)	242 (4,7)
Work environment				**N**	**%**
Many different hospital units				11562	6,3
Medicine wards				16269	8,9
Surgery wards				15782	8,6
Operation theatre				8981	4,9
Gynaecology/obstetrics				6498	3,5
Pediatrics				5672	3,1
Intensive care				8122	4,4
Emergency department				5646	3,1
Rehabilitation				6240	3,4
Geriatrics				8576	4,7
Psychiatry				4183	2,3
Laboratory/Radiology				15499	8,5
Pharmacy				3060	1,7
Others				18790	10,3
N/A				24504	13,4
Function description					
Nurse				91193	49,8
Head nurse				8154	4,4
Nurse aid				11787	6,4
Physician				12747	7,0
Physician – Head of dept.				9677	5,3
Physician in training				1681	0,9
Pharmacist				1276	0,7
Pharmacist technician				1617	0,9
Management				5253	2,9
Technician (Lab, Radiology)				7010	3,8
Physical, Occupational, … Therapist				11389	6,2
Other				10598	5,8
N/A				10519	5,7
Work experience in hospital					
Less than 1 year				9960	5,4
1 to 5 years				41206	22,5
6 to 10 years				30507	16,6
11 to 15 years				23694	12,9
16 to 20 years				20924	11,4
21 years or more				53067	29
N/A				3930	2,1

N/A, Not applicable.

Regarding professional function, almost half of the participants were nurses (49,8%). The lowest proportion of professions worked in pharmacy (**Table 2**). As for working experience, 29% of participants have more than 21 years of experience, with the smallest proportion of participants

included new staff (less than one year of experience) (**Table 2**). These observations reflect an experienced workforce with a distribution across many departments and knowledge.

Concerning the work experience within the department, the findings reflect the observations for the work experience across departments (**Supplementary Table 2**). Most of the health care workers work 20 to 39 hours per week on average, whereas only 0,6% worked more than 80 hours per week on average (**Supplementary Table 2**). Lastly, the majority of the staff is currently more than 21 years active in current job (**Supplementary Table 2**).

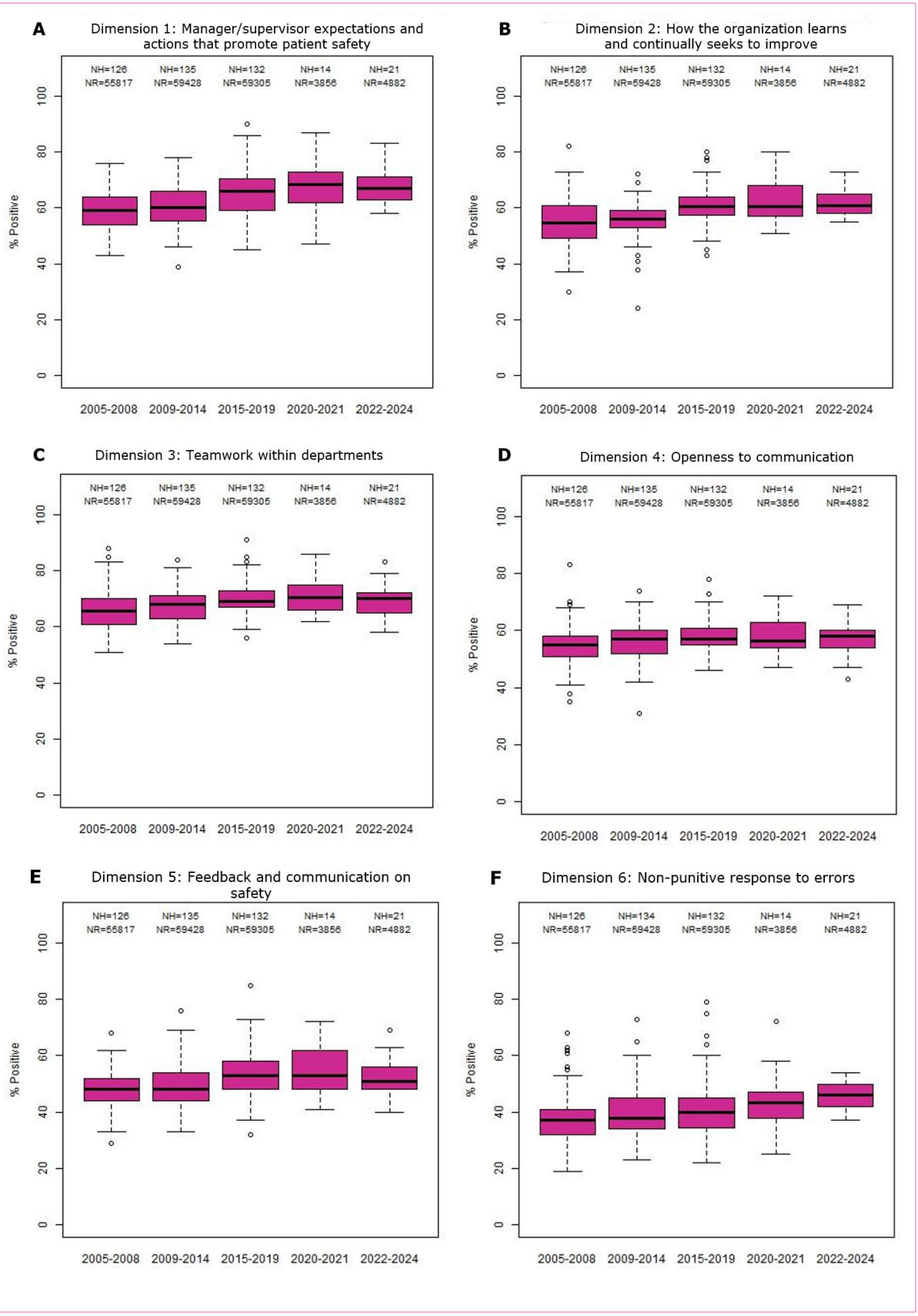
Positive response rate over time

The boxplots display the distribution of the percentage of positive responses of the participating hospitals over the five periods (**Figure 2**). **Table 4** shows the exact values of the boxplots for each dimension and each period. To observe this data, a threshold of 5% or more was utilized as a practically relevant (16, 33). The change in positive responses before, during, and after COVID was evaluated to assess the impact of the pandemic.

During the pandemic, a decline of 5% was observed in the dimensions regarding "manager/supervisor expectations and actions that promote PS", "how the organization learns and continually seeks to improve", "openness to communication", "hospital management support for PS", "teamwork across hospital departments", and "handover and transitions" (Dimensions 1, 2, 4, 8-10; **Figure 2A-B, D, H-J, respectively; Table 3**). Additionally, the 2 outcome measures concerning "global perceptions about safety" and "frequency of 'event' reporting" showed a decline of 5% (**Figure 2K-L, respectively; Table 3**).

After the pandemic, management support showed a 5% or more recovery in positive responses (Dimension 8; **Figure 2H**; **Table 3**). Next, outcome measure event reporting reflected a decline (Outcome 2; **Figure 2L; Table 3**), whereas organizational learning and "feedback and communication on safety" had a decline of 4 and 4,67%, right below the threshold (Dimension 2 and 5; **Figure 2B and E; Table 3**).

Lastly, the average score of positive responses was evaluated over all periods for all dimensions and outcomes. Dimensions with an average score below 50% were categorized as low-scoring performances. The boxplots reflect the dimensions 6-10, and the two outcome measures scored an average percentage below 50% over all periods, suggesting lower performance in these areas and possible targets for improvement (**Figure 2F-L; Supplementary Table 4**).


A
Dimension 1: Manager/supervisor expectations and actions that promote patient safety
B
Dimension 2: How the organization learns and continually seeks to improve
C
Dimension 3: Teamwork within departments
D
Dimension 4: Openness to communication
E
Dimension 5: Feedback and communication on safety
F
Dimension 6: Non-punitive response to errors
NH=126 NR=55817
NH=135 NR=59428
NH=134 NR=59428
NH=132 NR=59305
NH=14 NR=3856
NH=21 NR=4882
% Positive
0
20
40
60
80
100
2005-2008
2009-2014
2015-2019
2020-2021
2022-2024

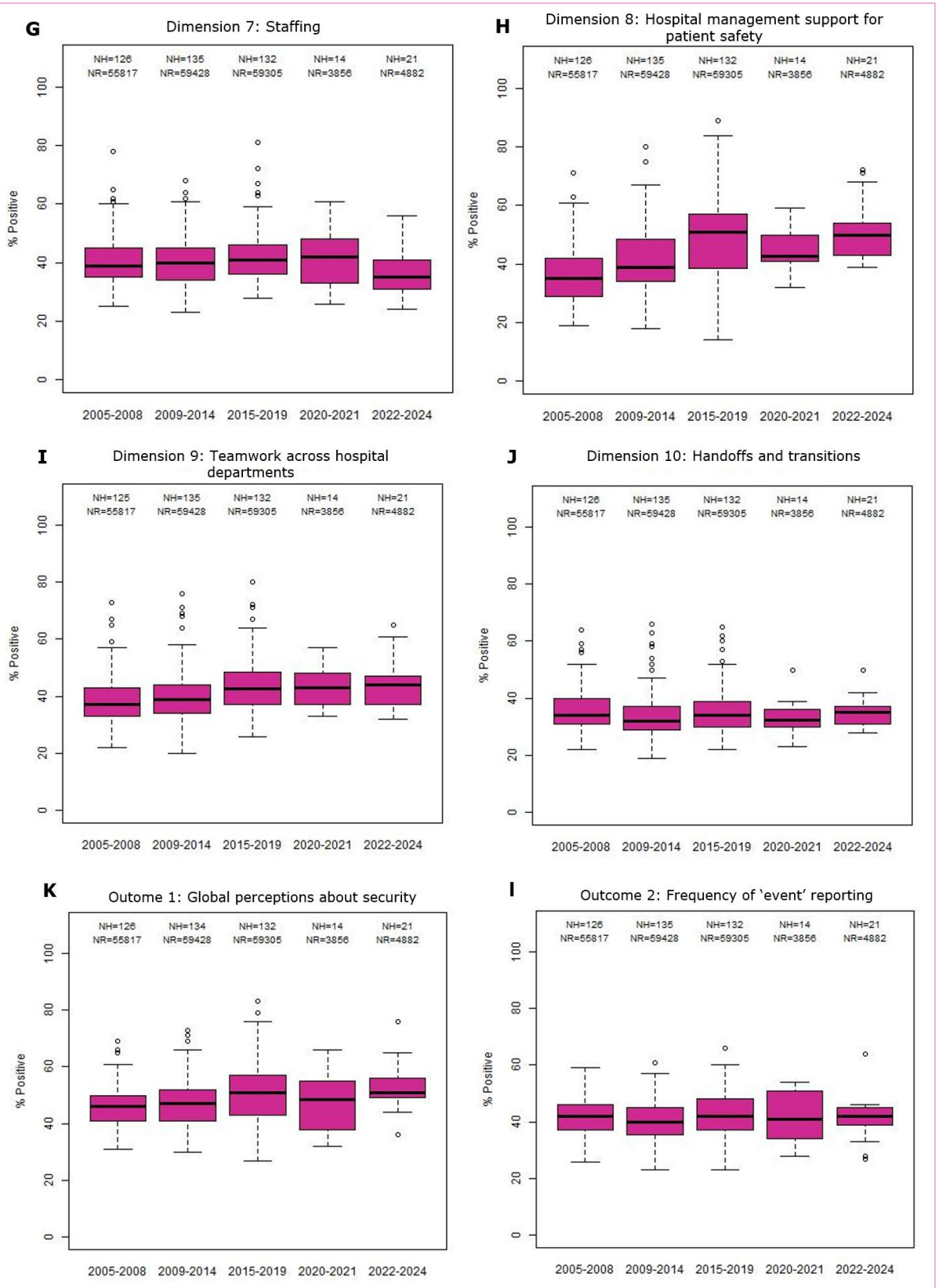


Figure 2: Boxplots with the percentage of positive responses for each period. For each dimension and outcome measure, the number of participating hospitals and respondents per period: 2005-2008, 2009-2014, 2015-2019, 2020-2021, 2022-2024 was given. *NH, Number of Hospitals*; *NR, Number of respondents*.

Table 3: Percentage of positive responses of participating hospitals. For each dimension and outcome, the percentage of positive responses is given for every period. Percentages were calculated by dividing the number of positive responses by the total number of positive responses multiplied by 100. The differences between the periods before, during, and after COVID were calculated.

	2005-2008 (1)	2009-2014 (2)	2015-2019 (3)	2020-2021 (4)	2022-2024 (5)	Δ3-4	Δ4-5
Dimension 1	57	61,33	70	62,67	63	**- 7,33**	+ 0,33
Dimension 2	59	64,33	74,50	66	62	**- 8,50**	- 4
Dimension 3	64	69	74,50	70	70,67	- 4,50	+ 0,67
Dimension 4	49,50	54,67	60,50	54	54	**- 6,50**	0
Dimension 5	45,50	50,67	59	55	50,33	**-** 4	- 4,67
Dimension 6	35	37,33	37	37,67	40,67	+ 0,67	+ 3
Dimension 7	48,50	46,67	44,50	42,67	45,67	- 1,83	+ 3
Dimension 8	38,50	44	57,50	43,67	51	**- 13,83**	**+ 7,33**
Dimension 9	37,50	38,67	49,50	40,33	40	**- 9,17**	- 0,33
Dimension 10	31,50	33	35,50	29,33	30,67	**- 6,17**	+ 1,34
Outcome 1	44,50	47	52	44,67	45,33	**- 7,33**	+ 0,66
Outcome 2	37	39,33	47	41	35,67	**- 6**	**- 5,33**

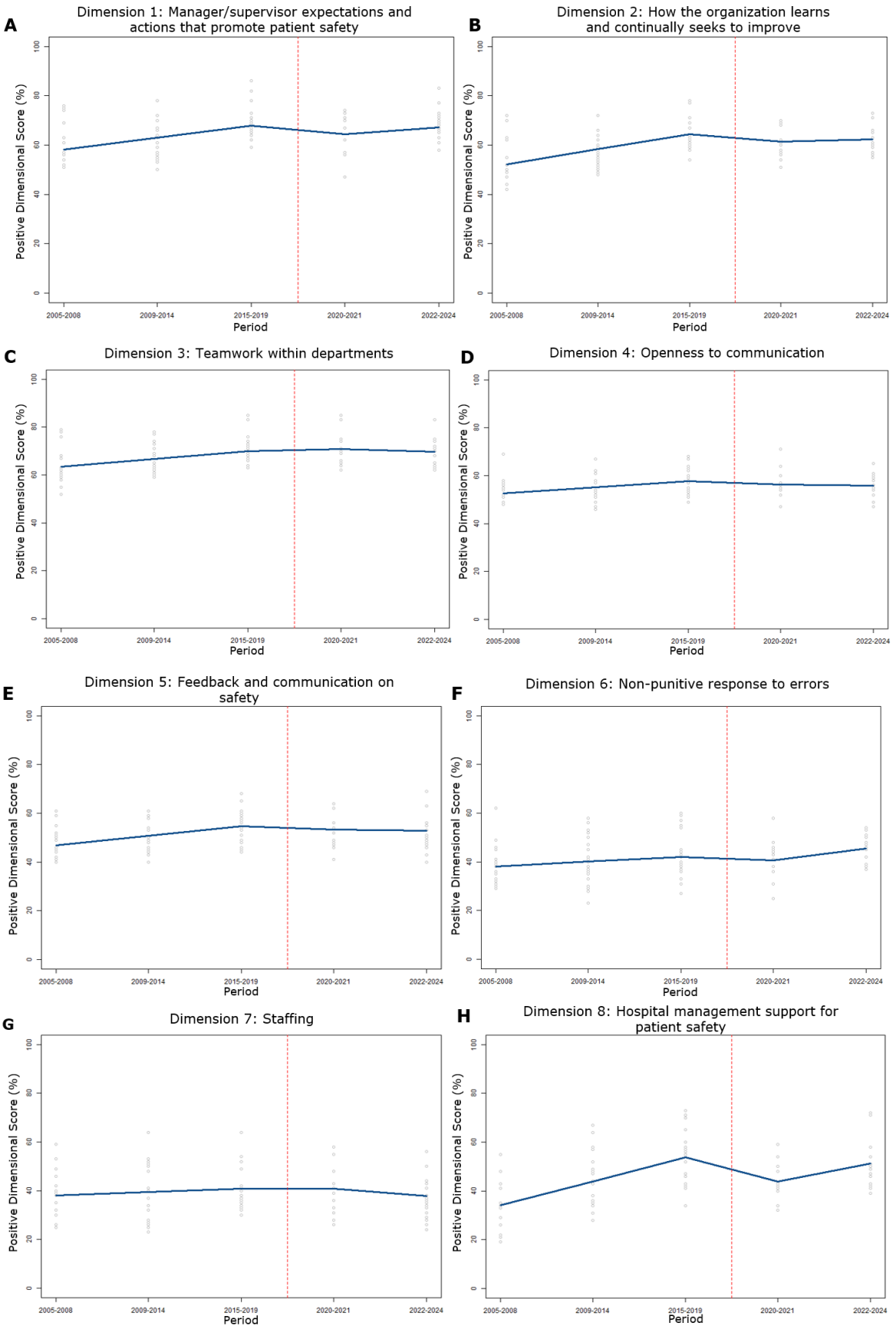
Interrupted time series analysis during COVID

For the analysis of the effect of COVID on PSC during and after the pandemic, an ITS analysis was conducted. A subset of the data was taken to perform this analysis. Firstly, the five periods were categorized into 3 phases (**Figure 1**). Then, a subset was taken where every unique hospital did one measurement before COVID, during COVID, and after COVID. However, at first, only three hospitals completed the surveys in all three phases (**Supplementary Table 3**). Due to this low sample size, another approach was taken. By including the hospitals with one measurement before COVID and one measurement during or after COVID, the sample size could be increased. This subset also included the three hospitals with measurements across all three phases. **Supplementary Table 3** shows the sample size for the subsets used for the ITS analysis.

The ITS analysis was conducted by evaluating the percentage of positive responses of the subset of hospitals for the different dimensions over the time periods (**Figure 3**). The period before COVID indicated a significant increased trend for manager expectations, organizational learning, overall teamwork, communication, feedback, and safety perception (Dimension 1-5, 9, O1; **"Time" in Table 4, Figure 3A-E, H-I, K**). The largest slope change before COVID was observed for management support (Dimension 8; **Table 4, Figure 3H**).

The changes associated with the immediate intervention were significant for management support (Dimension 8), where COVID caused a strong significant decrease in positive responses (**Figure 3H; "Covid" in Table 4**). Furthermore, handover (Dimension 10) and safety perception (Outcome 1) exhibited a strong, significant intervention effect (**Figure 3J and K, "Covid" in Table 4**).

After the intervention, dimensions 2, 3, and 5 ($p = 0{,}089175$) regarding organization learning, teamwork, and feedback and communication on safety showed a significant negative slope change (**Figure 3B, C, E; Table 4).** The new trend after the pandemic was calculated to evaluate the slope after COVID. The pre-COVID slope (**"Time" in Table 4**) was added with the trend change after COVID (**"Timesince" in Table 4**) to obtain the final slope after COVID. For the dimensions 2, 3, and 5, the resulting final slopes were +0,88%,-1,27%, and -0,40%, respectively (**Table 4**). This suggests that organizational learning has a recovering trend, whereas teamwork and feedback and communication on safety still reflect a declining trend compared to pre-COVID.


A
Dimension 1: Manager/supervisor expectations and actions that promote patient safety
B
Dimension 2: How the organization learns and continually seeks to improve
C
Dimension 3: Teamwork within departments
D
Dimension 4: Openness to communication
E
Dimension 5: Feedback and communication on safety
F
Dimension 6: Non-punitive response to errors
G
Dimension 7: Staffing
H
Dimension 8: Hospital management support for patient safety
Positive Dimensional Score (%)
Period
2005-2008
2009-2014
2015-2019
2020-2021
2022-2024

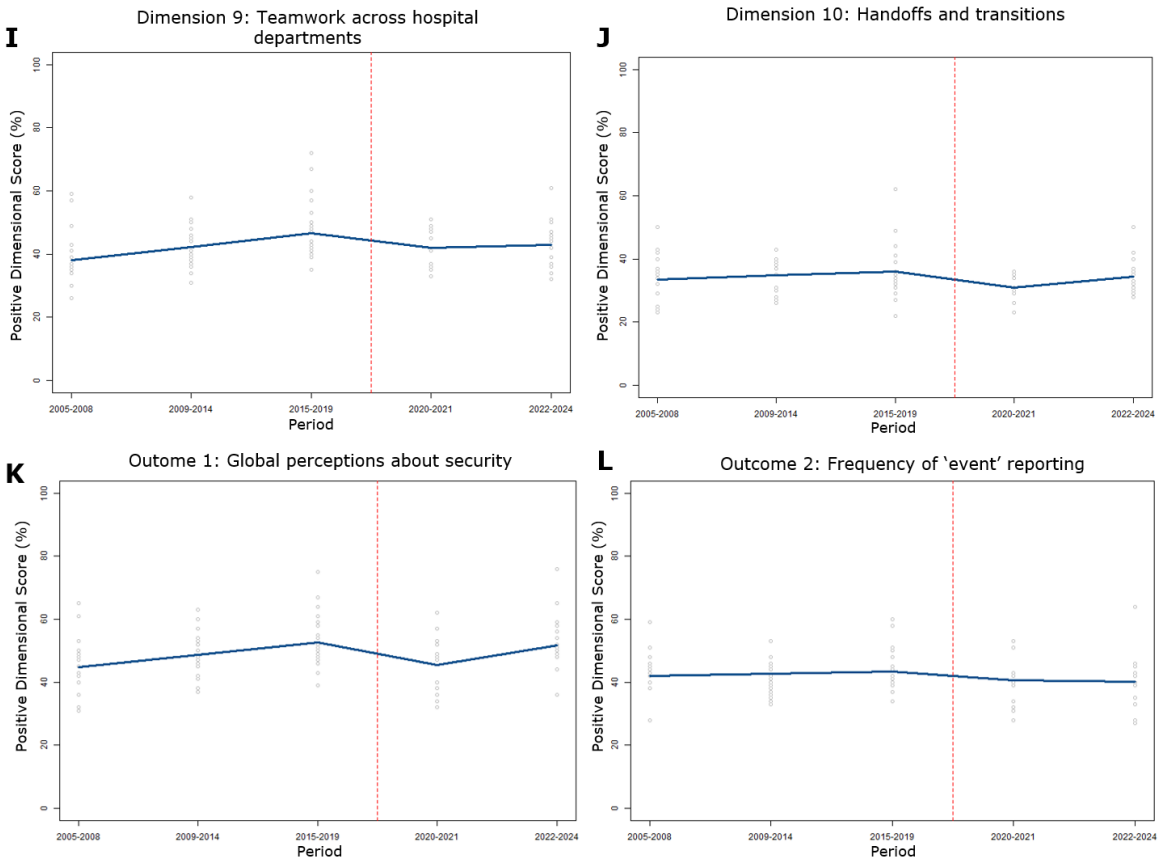


Figure 3 : Visualisation of the Interrupted time series analysis. The plots represent the ten dimensions (**A-J**) and two outcome measures (**K,L**). The mean percentage of positive responses using the HSOPSC for the subset of hospitals is visualised over the five periods: 2005-2008 (n = 18), 2009-2014 (n = 23), 2015-2019 (n = 23), 2020-2021 (n = 12), and 2022-2024 (n = 17), sample size is given for each dimension and outcome seperately. The estimated trends were obtained by the regression analysis (blue line) with the COVID pandemic (2020-2021) as the intervention (red vertical line). The grey dots indicate individual hospitals.

The slope change for non-punitive response, staffing, and event reporting was not significantly different, indicating a more stable evolution (Dimensions 6,7, and Outcome 2; **Figure 3F, G, L**). However, these dimensions have a low positive response (<50%) overall and therefore indicate low improvement over a long time period.

Subsequently, although the slope changes for dimensions 6, 10, and outcome 1 were not significant, they reflect a positive trend after the pandemic, also observed in the boxplots (**"Timesince" in Table 4; Table 3**). Other dimensions, such as dimensions 1 and 8, also tend to reflect a recovery after COVID. However, the scores remained lower than the improvement before COVID and were not significant (**Figure 3A, H**; **Table 4**).

In summary, these findings show similarity with the descriptive boxplots, where before the pandemic, the Belgian hospitals increased positive scores over time for many dimensions and outcomes. However, COVID caused disruptions in management support, handover, and safety perception. The period after COVID reflects declines in organizational learning, feedback and communication on safety. Some dimensions tend to reflect a slight recovery after COVID, but further analysis with additional time periods is necessary to confirm these results.

Table 4: Interrupted time series analysis of the ten dimensions and two outcomes. The estimate, standard errors, t-values, and p-values for each dimension and outcome are given. Within the estimates, the intercept is given, followed by the Time (Pre-COVID), COVID (the intervention), and Timesince (change Post-COVID). A p-value of 0,05 was considered significantly different. *p < 0,05, **p < 0,001, ***p <0,0001.

		Estimate	Std error	T value	P value
Dimension 1: Manager/supervisor expectations and actions that promote patient safety	Intercept	53,104	2,360	22,505	**< 2e-16*** **
	Time	4,936	1,064	4,638	**1,05e-05*** **
	Covid	-6,029	4,208	-1,433	0,155
	Timesince	-2,353	2,652	-0,887	0,377
Dimension 2: How the organization learns and continually seeks to improve	Intercept	46,086	2,265	20,348	**< 2e-16*** **
	Time	6,101	1,022	5,972	**3,44e-08*** **
	Covid	-3,807	4,039	-0,942	0,3482
	Timesince	-5,218	2,546	-2,050	**0,0429*** *
Dimension 3: Teamwork within departments	Intercept	60,392	1,975	30,572	**< 2e-16*** **
	Time	3,164	0,891	3,552	**0,000581*** *
	Covid	2,248	3,523	0,638	0,524771
	Timesince	-4,431	2,220	-1,996	**0,048616*** *
Dimension 4: Openness to communication	Intercept	50,2167	1,6959	29,611	**< 2e-16*** **
	Time	2,5076	0,7649	3,278	**0,00143*** *
	Covid	-0,7894	3,0242	-0,261	0,79459
	Timesince	-3,0576	1,9060	-1,604	0,11176
Dimension 5: Feedback and communication on safety	Intercept	42,827	2,261	18,940	**< 2e-16*** **
	Time	3,961	1,020	3,884	**0,000183*** *
	Covid	-1,110	4,032	-0,275	0,783581
	Timesince	-4,361	2,541	-1,716	0,089175
Dimension 6: Non-punitive response to errors	Intercept	35,942	2,757	13,036	**< 2e-16*** **
	Time	2,042	1,244	1,642	0,104
	Covid	-6,317	4,917	-1,285	0,202
	Timesince	2,808	3,099	0,906	0,367
Dimension 7: Staffing	Intercept	36,691	3,283	11,175	**< 2e-16*** **
	Time	1,374	1,481	0,927	0,356
	Covid	3,305	5,855	0,564	0,574
	Timesince	-4,557	3,690	-1,235	0,220
Dimension 8: Hospital management support for patient safety	Intercept	24,279	3,114	7,796	**5,64e-12*** **
	Time	9,811	1,405	6,985	**2,99e-10*** **
	Covid	-17,362	5,554	-3,126	**0,00231*** *
	Timesince	-2,361	3,500	-0,675	0,50148
Dimension 9: Teamwork across hospital departments	Intercept	33,698	2,523	13,358	**< 2e-16*** **
	Time	4,282	1,138	3,763	**0,00028*** *
	Covid	-5,577	4,498	-1,240	0,21789
	Timesince	-3,315	2,835	-1,169	0,24497
Dimension 10: Handoffs and transitions	Intercept	32,183	2,057	15,643	**< 2e-16*** **
	Time	1,292	0,928	1,393	0,1667
	Covid	-8,577	3,669	-2,338	**0,0213*** *
	Timesince	2,091	2,312	0,904	0,3680
Outcome 1: Global perceptions about security	Intercept	40,752	2,875	14,173	**< 2e-16*** **
	Time	3,950	1,297	3,046	**0,00295*** *
	Covid	-13,468	5,127	-2,627	**0,00995*** *
	Timesince	2,383	3,231	0,738	0,46245
Outcome 2: Frequency of 'event' reporting	Intercept	41,3429	2,3288	17,753	**< 2e-16*** **
	Time	0,6779	1,0504	0,645	0,520
	Covid	-2,5600	4,1528	-0,616	0,539
	Timesince	-0,9613	2,6173	-0,367	0,714

Std Error, Standard Error.

DISCUSSION

This research aimed to evaluate PSC before, during, and after the COVID pandemic in psychiatric and general hospitals in Belgium. To measure PSC, HSOPSC surveys were utilized. The study provides an exceptional opportunity to evaluate PSC over a long-term period, from 2005 to 2024, which included a global health crisis causing acute stress to the healthcare system.

First, the largest proportion of participants were nurses, accounting for over half of the respondents. The percentage of physicians, however, was much lower, as observed in other studies (15, 34). In addition, the number of respondents with direct patient contact was higher than indirect contact, even in the COVID pandemic. Previous studies have concluded that direct health care workers often have a more accurate and precise perspective on PSC (35).

Autocorrelation was evaluated using the Durbin-Watson test to assess the independence of residuals. Whereas positive correlation was found in dimensions 2 and 7, no corrections were applied. This positive correlation could be due to the work environment and culture, where perceptions are affected by shared work or organization (36). Since the COVID pandemic disturbed the PSC and the completion of the survey, the sample size from 2020-2021 remained small. Due to the increased workload and pressure in this period, fewer surveys were completed (37, 38). As for the 2022-2024 period, this small sample size could also influence the autocorrelation measurement due to the short period of time and the adaptation after the pandemic (39).

An interesting perspective was the measurement of positive responses in all dimensions over the five periods, using an ITS analysis with COVID as the intervention. As mentioned, a subset of the data was used where hospitals completed one measurement before the pandemic, and one during and/or after the pandemic. This was done to obtain a larger sample size, as one measurement in each phase resulted in a very small sample size (n = 3). Manager expectations, organizational learning, teamwork, communication, feedback, manager support, and safety perception showed an increased slope before the pandemic (Dimensions 1-5, 8-9, and Outcome 1). The findings in this study are aligned with existing literature, where teamwork and proactive leadership enhance patient safety culture (40-43). The importance of leadership commitment in patient safety and health care quality was highlighted in the drastic increase of +9.81 % in management support (43, 44). As observed in other studies, communication is crucial to enhance PS outcomes such as reduction of adverse events, satisfaction, and shorter length of stay (41, 45).

The findings considering the immediate effect of the pandemic were mostly seen in management support (Dimension 8), which had a significant decrease of -17,36%. This suggests a reduced perception of managerial support during crisis situations, supported by other studies (46, 47). This decline highlights the need for robust and resilient crisis management. Handover (Dimension 10), also dropped during the pandemic, reflecting the increased work pressure, new guidelines, and disrupted organizations (48). Similarly, the outcome measure 1 concerning safety perception declined during the pandemic, indicating global concerns about safety during the pandemic (49).

After the pandemic, some of the dimensions showed a reversed trend. Teamwork within departments, feedback and communication on safety, and organizational learning expressed a decline in the positive trend (Dimensions 2, 3, and 5). Due to the acute crisis, health care workers underwent increased pressures mentally and physically (50). In some international institutions, communication and teamwork improved during and after the pandemic (51, 52). Other studies have examined the teamwork culture during and after COVID and concluded worsening teamwork norms and declining patient safety (53, 54). On the contrary, manager expectations and support, non-punitive response, handover, and safety perception tend to show a positive recovery after COVID (Dimensions 1, 6, 8, 10, and Outcome 1). However, these positive slope changes were not significant, suggesting a potential for adjustment and recovery after the pandemic. Additional time periods are necessary to evaluate this recovery.

Non-punitive response, staffing, and event reporting showed a stable trend over time (Dimensions 6, 7, and Outcome 2). This could reflect that these dimensions can remain resilient during crises (55, 56). Although these dimensions show a stable evolution, the positive responses remain low (under

50%), which suggests possible targets for improvement. In other studies, these dimensions often perform poorly (57-59). Other dimensions having a slow evolution are teamwork across departments, management support, and handoffs (Dimensions 8-10). Organizational silos and perspectives often obstruct collaboration between departments, inconsistent handover protocols and leadership perception gaps remain barriers for improvement (58). Remarkably, one of the overall highest scoring dimensions is teamwork within departments (Dimension 3), which is confirmed by other studies (58, 60).

Positive response rates were also assessed for all dimensions and outcome measures shown in boxplots. A threshold of 5% was applied to reflect the practical (clinical) relevance rather than statistical significance, as recommended by the PSC user guide (16, 33). This perspective allows for evaluating actionable and operationally relevant aspects (61). When comparing before and during the pandemic, eight dimensions exhibited a practical decline of 5% or more (Dimension 1, 2, 4, 8, 9, 10, and both outcome measures). This emphasizes the sudden effect of the COVID pandemic (62). After the pandemic, event reporting exhibited a practical decline (Outcome 2), and management support reflected a positive recovery (Dimension 8). Comparing both methods, similar changes are seen in the ITS analysis; the pre-COVID phase shows improvement in many dimensions, while COVID disrupted dimensions such as management support, handoff, and safety perception (Dimensions 8, 10, and Outcome 1). The post-COVID phase also tends to reflect declines in organizational learning and feedback and communication (Dimensions 2 and 5). Non-punitive response, handover, and safety perception suggest a recovery in both methods (Dimensions 6, 10, and Outcome 1). To confirm these observations, additional time periods should be added.

This research provides a first insight into the evolution of PSC during and after a healthcare crisis. Data such as this could assist healthcare organisations in strengthening their structure, specifically in times of crisis, and evaluate the routinely collected PSC data to understand alterations over time. Moreover, monitoring PSC over a long-term period provides a tool for the development of interventions to improve PSC. On the other hand, this study emphasizes the significance of psychological safety for health care workers and the importance of maintaining a culture of openness among staff.

Despite its strengths, certain limitations should be taken into account. Although the HSOPSC is a valuable tool to evaluate the PSC, it relies on a self-reported survey that could include subjectivity and be affected by social appeal or recall bias (12, 32, 63). The perception of PSC can fluctuate depending on the work culture, department, scheme, and institution. Often, health care workers with a higher salary, who worked less than 11 hours a day, and spent most of the time in patient care, scored higher in PSC (12, 64, 65). Additionally, health care workers affected by the pandemic can change their thinking patterns due to the change of context and external elements other than COVID could influence the results (66-68). An important limitation is the uneven distribution of the survey and small sample size in some periods, specifically the COVID period itself. Only one post-COVID period is available, constraining a long-term analysis after the pandemic. In this study, the overall response rate was 48,11%, being lower than the recommended 60% for safety measurements (69). However, contextual factors should be taken into account. The accessibility was applied by distributing the surveys on paper and online. Whereas online questionnaires are fast, easy to distribute, and low-cost, technical issues such as links not working and email access during working hours appeared (70). Institutional constraints, such as staff shortages, high work pressure, and timing, could also lessen the readiness to complete a survey. Other factors, including time and survey length, also contribute to low response rates (71-73).

Future research should investigate the specific PSC dimensions or items within the dimensions and outcome measures that could be improved or remained stable during the pandemic. An analysis of PSC between the different types of hospitals during the pandemic could also be applied. Moreover, organizational structures and leadership styles that are maintained during the pandemic could be explored for future times of crisis. Using HSOPSC gives us qualitative data that helps us discover cultural and contextual factors within health care organizations. Besides, cross-country comparisons could declare structural and organizational differences in preparedness and flexibility.

CONCLUSION

This study examined PSC in Belgian hospitals from 2005 to 2024, using HSOPSC data to explore the COVID effect in all dimensions and outcomes. The fragility of patient safety culture was emphasized when exposed to acute external factors such as COVID-19. While many dimensions showed a positive incline before the pandemic, several declined during and after the crisis. Specifically, management support, teamwork within departments, organizational learning, handoffs, and safety perception showed a declining trend. The largest drop was observed in management support, emphasizing perceived reduced leadership presence in crises. Several dimensions, such as non-punitive response, handoffs, teamwork across departments, and event reporting, had an overall low positive response score, suggesting areas for growth. These findings provide opportunities for improvement and highlight the need for flexible and resilient health care organizations. Future research should examine the underlying mechanisms to promote sustained improvement and resilience in PSC in healthcare settings when exposed to acute external factors.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1: HSOPSC dimensions and items in English and Dutch.

	Dimension	NL	EN
D1	**EN**: Manager/supervisor expectations and actions that promote patient safety **NL**: *Manager/supervisorverwachtingen en acties die patiëntveiligheid bevorderen*	De 'supervisor' toont waardering wanneer er gewerkt wordt met de uitgewerkte procedures in verband met patiëntveiligheid.	My supervisor/manager says a good word when he/she sees a job done according to established patient safety procedures
		De 'supervisor' houdt ernstig rekening met suggesties van medewerkers/collega's om patiëntveiligheid te verbeteren.	My supervisor/manager seriously considers staff suggestions for improving patient safety
		Wanneer de werkdruk toeneemt verwacht de 'supervisor' dat er sneller gewerkt wordt, zelfs als daarvoor stappen in de procedures moeten overgeslagen worden.	Whenever pressure builds up, my supervisor/manager wants us to work faster, even if it means taking shortcuts
		De 'supervisor' ziet steeds terugkerende problemen op het vlak van patiëntveiligheid over het hoofd	My supervisor/manager overlooks patient safety problems that happen over and over

D2	**EN**: How the organization learns and continually seeks to improve **NL**: De wijze waarop de organisatie leert en voortdurend tracht te verbeteren	Het ziekenhuis onderneemt acties om de patiëntveiligheid te verbeteren.	We are actively doing things to improve patient safety
		Fouten hebben al geleid tot positieve veranderingen.	Mistakes have led to positive changes here
		Als veranderingen ter verbetering van patiëntveiligheid worden doorgevoerd, dan wordt de effectiviteit ervan steeds geëvalueerd.	After we make changes to improve patient safety, we evaluate their effectiveness
D3	**EN**: Teamwork within departments **NL**: Teamwerk binnen afdelingen	Medewerkers en collega's steunen elkaar in de werkomgeving.	People support one another in this unit
		Wanneer er veel werk op korte tijd gedaan moet worden, wordt samengewerkt als een team.	When a lot of work needs to be done quickly, we work together as a team to get the work done
		In de werkomgeving behandelen medewerkers/collega's elkaar met respect	In this unit, people treat each other with respect
		Wanneer het zeer druk wordt, komen andere medewerkers/collega's helpen.	When one area in this unit gets really busy, others help out
D4	**EN**: Openness to communication **NL**: Openheid naar communicatie	Medewerkers/collega's kunnen vrijuit spreken wanneer ze iets zien dat de zorg voor de patiënt negatief beïnvloedt.	Staff will freely speak up if they see something that may negatively affect patient care
		Medewerkers/collega's kunnen beslissingen of acties van personen met een hogere hiërarchische positie kritisch, maar constructief, bespreekbaar maken.	Staff feel free to question the decisions or actions of those with more authority
		Medewerkers/collega's zijn bang om vragen te stellen wanneer er iets niet in orde lijkt.	Staff are afraid to ask questions when something does not seem right
D5	**EN**: Feedback and communication on safety **NL**: Feedback en communicatie over veiligheid	Er wordt feedback gegeven over veranderingen die gebeuren op basis van foutrapporteringen.	We are given feedback about changes put into place based on event reports

		Er wordt informatie gegeven over fouten die gebeuren binnen de werkomgeving.	We are informed about errors that happen in this unit
		In de werkomgeving worden fouten besproken om te voorkomen dat ze opnieuw gebeuren.	In this unit, we discuss ways to prevent errors from happening again
D6	**EN**: Non-punitive response to errors **NL**: Niet-bestraffende respons op fouten	Medewerkers/collega's hebben het gevoel dat fouten tegen hen gebruikt worden.	Staff feel like their mistakes are held against them
		Wanneer een fout gerapporteerd wordt, bestaat het gevoel dat men zich vooral op de persoon richt en niet op het probleem.	When an event is reported, it feels like the person is being written up, not the problem
		Medewerkers/collega's vrezen dat fouten die gemaakt worden in hun persoonlijk dossier bewaard blijven.	Staff worry that mistakes they make are kept in their personnel file
D7	**EN**: Staffing **NL**: Bestaffing	Er is voldoende bestaffing om de werkbelasting aan te kunnen.	We have enough staff to handle the workload
		Medewerkers/collega's werken meer uren dan goed is voor de zorgverlening aan de patiënt.	Staff in this unit work longer hours than is best for patient care
		Er worden teveel tijdelijke medewerkers ingeschakeld dan goed is voor de zorgverlening aan de patiënt.	We use more agency/temporary staff than is best for patient care
		Er wordt vaak gewerkt in een 'crisistoestand': er wordt geprobeerd te veel te doen en te snel.	We work in "crisis mode" trying to do too much, too quickly
D8	**EN**: Hospital management support for patient safety **NL**: Ziekenhuismanagementondersteuning voor patiëntveiligheid	Het ziekenhuismanagement zorgt voor een werkklimaat dat patiëntveiligheid bevordert.	Hospital management provides a work climate that promotes patient safety
		De acties van het ziekenhuismanagement illustreren dat patiëntveiligheid een topprioriteit is.	The actions of hospital management show that patient safety is a top priority

		Het ziekenhuismanagement lijkt enkel geïnteresseerd in patiëntveiligheid als er iets is misgelopen	Hospital management seems interested in patient safety only after an adverse event happens
D9	**EN**: Teamwork across hospital departments **NL**: Teamwerk doorheen ziekenhuisafdelingen	Ziekenhuisafdelingen werken niet zo gecoördineerd samen.	Hospital units do not coordinate well with each other
		Er is een goede samenwerking tussen afdelingen/diensten die vaak samenwerken.	There is good cooperation among hospital units that need to work together
		Het is vaak onaangenaam om samen te werken met medewerkers/collega's van andere afdelingen/diensten.	It is often unpleasant to work with staff from other hospital units
		Afdelingen/diensten werken goed samen om de best mogelijke zorgen aan de patiënten te kunnen bieden	Hospital units work well together to provide the best care for patients
D10	**EN**: Handover and transfer **NL**: Overdracht en transfer	Bij het transfereren van patiënten naar andere afdelingen worden zaken over het hoofd gezien.	Things "fall between the cracks" when transferring patients from one unit to another
		Er gaat vaak belangrijke informatie over de patiënt verloren bij het wisselen van werkposten.	Important patient care information is often lost during shift changes
		Er treden vaak problemen op bij het uitwisselen van informatie tussen afdelingen/diensten.	Problems often occur in the exchange of information across hospital units
		Het wisselen van werkposten is problematisch voor de patiënten in het ziekenhuis.	Shift changes are problematic for patients in this hospital
O1	**EN**: Global perceptions about security **NL**: Globale perceptie over veiligheid	Het is eerder toevallig dat er in de instelling geen ernstigere fouten gemaakt worden.	It is just by chance that more serious mistakes don't happen around here
		Patiëntveiligheid wordt nooit opgeofferd om meer werk gedaan te krijgen.	Patient safety is never sacrificed to get more work done

		Er zijn problemen in verband met patiëntveiligheid in de werkomgeving.	We have patient safety problems in this unit
		Procedures en systemen zijn goed uitgewerkt om fouten te vermijden.	Our procedures and systems are good at preventing errors from happening
O2	**EN**: Frequency of 'event' reporting **NL**: Frequentie van 'event'-rapportering	Er wordt een fout gemaakt, maar deze fout wordt opgemerkt en gecorrigeerd vooraleer de patiënt schade ondervindt. Hoe vaak wordt dit gemeld?	When a mistake is made, but is caught and corrected before affecting the patient, how often is this reported?
		Er wordt een fout gemaakt waarvan we weten dat deze fout de patiënt niet kan schaden. Hoe vaak wordt dit gemeld?	When a mistake is made, but has no potential to harm the patient, how often is this reported?
		Er wordt een fout gemaakt die de patiënt schade had kunnen berokkenen, maar hem uiteindelijk ongedeerd liet. Hoe vaak wordt dit gemeld?	When a mistake is made that could harm the patient, but does not, how often is this reported?

NL, Nederlands; EN, English; D1-10, Dimension 1-10; O1-2, Outcome 1-2.

Supplementary Table 2: **Staff characteristics.** The distribution of staff based on work experience in the department, hours per week on average, and the number of years in the current job**.**

Work experience in department	**N**	**%**
Less than 1 year	818	7,0
1 to 5 years	3361	28,9
6 to 10 years	2419	20,8
11 to 15 years	1688	14,5
16 to 20 years	1321	11,4
21 years or more	1940	16,7
N/A	68	0,6
Hours per week on average		
Less than 20h per week	515	4,4
20 to 39h per week	8113	69,8
40 to 59h per week	2605	22,4
60 to 79h per week	198	1,7
80h per week or more	68	0,6
N/A	116	1,0
Amount of years in current job		

Less than 1 year	423	3,6
1 to 5 years	2407	20,7
6 to 10 years	2174	18,7
11 to 15 years	1749	15,1
16 to 20 years	1564	13,5
21 years or more	3057	26,3
N/A	241	2,1

Supplementary Table 3: Overview of the sample size of the participating hospitals per period used for ITS.

	N
Pre - COVID	190
COVID	14
Post - COVID	24
Pre - COVID AND COVID	14
Pre – COVID AND Post – COVID	17
COVID AND Post – COVID	3
Pre – COVID AND COVID AND Post COVID	3

Supplementary Table 4: Average positive score for each dimension and outcome measure.

	Average positive score (%)
Dimension 1	62,80
Dimension 2	65,17
Dimension 3	69,63
Dimension 4	54,53
Dimension 5	52,10
Dimension 6	37,53
Dimension 7	45,60
Dimension 8	46,93
Dimension 9	41,20
Dimension 10	32
Outcome 1	46,70
Outcome 2	40