The Effect of Indoor Daylight Levels on Patients Admitted to General Surgery

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Research

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Abstract

Background

Indoor daylight levels can directly affect people's physical and psychological state. However, the effect of indoor daylight levels on patient's clinical recovery process remains controversial.

Aim

To evaluate the effect of indoor daylight levels on hospital costs and average length of stay (LOS) of a large patient population in general surgery wards.

Methods

Data were collected retrospectively and analysed of patients in the Second Affiliated Hospital of Zhejiang University, School of Medicine between January 2015 and August 2020. We measured light levels in the patient rooms of general surgery and assessed their association with patients' total hospital costs and LOS.

Results

A total of 2,998 patients were included in this study with 1,478 each assigned to two light level groups after matching. Overall comparison of hospital total costs and LOS among patients according to light levels did not show a significant difference. Subgroup analysis showed when exposed to higher intensity of indoor daylight, illiterate patients had lower total hospital costs and shorter LOS as compared to those exposed to lower intensity.

Conclusions

Indoor daylight levels were not associated with the hospital costs and LOS of patients in the wards of general surgery, except for those who were illiterate. It might be essential to design guidelines for healthcare facilities to enhance indoor environmental benefits of daylight for some specific population.

Introduction

Human health is undoubtedly one of the most important considerations for all kinds of environmental designs. Most of the research related to the impact of environment elements on occupants has been oriented toward offices and schools rather than focusing on healthcare facilities; however, the in-patient room is a special indoor environment, requiring both extensive experimental and field research efforts to enhance and the treatment of diseases and accelerate the recovery of patients[1]. As an important environmental factor, light levels will directly affect people's physical and psychological state under certain conditions. It has been proved that it can elicit immediate physiological changes in body temperature, heart rate, hormones, cognition, mood and even gene expression, which are intensively related to the clinical recovery[2-5].

Previous studies have found that increased daylight exposure in wards can have some positive effects, such as accelerating the discharge of patients with depression[6] and myocardial infarction[7] and reducing the mortality of some cancers such as ovarian cancer, breast cancer and colon cancer[8]. However, others have shown that ambient daylight levels in an intensive care unit (ICU) room did not improve outcomes for critically ill patients, including hospital length of stay, intravenous sedative or analgesic use and the development of ICU-acquired delirium[9-12]. Thus, the effect of indoor daylight levels on patient's clinical recovery process remains controversial. In addition, studies on the relationship between light levels and surgery outcomes have been limited to spinal surgery[13] or cardiac surgery[14], etc. and the sample size of these studies was generally small. There has not been an independent study on patients who undergo general surgeries.

Therefore, the purpose of this research was to evaluate the effect of indoor daylight levels on hospitalization, particularly hospital costs and LOS, of a large patient population in general surgery wards. To do this, we measured light levels in the patient rooms of general surgery and assessed their association with patients' total hospital costs and LOS. Every patient was assigned to a bed upon admission on the basis of availability, without regard to whether there was a window by the side, therefore creating a natural randomized experiment.

Methods

Study Population and Data Collection

The study protocol was approved by the Institutional Review Board of the Second Affiliated Hospital of Zhejiang University, School of Medicine, China. A retrospective cohort study was conducted to assess hospital outcomes between patients that was exposed to high light side (window) and patients that was exposed to low light side (door). Adult patients (aged 18 years and older) who had been admitted to Department of General Surgery between 1 January 2015 and 28 August 2020 were enrolled. We collected patient data including general characteristics (sex, age and BMI at admission), clinical characteristics (taking surgery or not, diagnostic categories, comorbidities), and demographic characteristics including lifestyle factors (smoking and drinking), residential district (urban or rural), and educational levels. Total costs (Chinese Yuan, CNY ¥) and length of days during stay in hospital were collected as primary outcomes.

Hospital Building and Patient Units

Located in Hangzhou, Zhejiang, China, SANZU has two campuses with a total of 3200 beds and provides nearly 190,000 inpatient services and 150,000 surgeries every year. The hospital building in Jiefang campus has 9 floors and each floor has 17 inpatient units. As shown on the **Figure 1**, all units are facing south to allow plenty of sunlight to enter the space. The general surgical wards are located on the 6th floor and comprises of three types rooms: ten 7-bed rooms, four 4-bed rooms and three 2-bed room. In each room, the patient beds near the door (north) are assigned to the low light side group and beds near the window (south) are assigned to the high light side group.

Measurement of Daylight Intensity

Daylight levels were measured using the light meter (AS813 Smart Sensor; Arco Electronics Ltd., Hong Kong, China). The light meter was placed on the back wall over the patient's head and positioned toward the window of hospital unit. We selected one typical clear, sunny day and one typical overcast day around autumnal equinox to measure levels of daylight. Measurements were taken 8 times a day every hour from 6:00 AM to 6:00 PM at each side (window and door) and at three types of the patient units. Each measurement was repeated 5 times and then averaged to obtain a reliable estimate of the light intensity (lux). These reliable estimates were then averaged again across room types to obtain the overall daylight intensity estimates.

Subgroup Definitions

Given the large sample size, we conducted subgroup analyses to assess for an interaction between patients (sex, age, BMI, comorbidity, hospital characteristics and patients' demographics) and to assess the association between daylight levels and outcomes.

Age was categorized into four groups according to the median and interquartile range values in all participants (<51 years, 51-59 years, 60-67 years, and ≥68 years).

Body-mass index (BMI) was calculated as weight in kilograms divided by the square of the height in meters (kg/m^2) and was categorized into four groups according to cut-off values indicated in The BMI criteria adopted by Chinese Adults Overweight and Obesity Prevention and Control Guidelines: underweight (<18.5 kg/m^2), normal range (18.5-24 kg/m^2), overweight (24-30 kg/m^2), and obese (≥30 kg/m^2)[15].

Length of Stay (LOS) was categorized into four groups: 1-6 days, 7-13 days, 14-29 days, and ≥30 days).

Diagnosis was categorized into six groups: Benign tumor, Malignant tumor, Inflammation, Hernia, Intestinal obstruction, and Others.

District was divided into two groups: rural area and urban area.

Education level was categorized into five groups: Illiterate, Primary school, Middle school, High school, and University degree.

In order to observe the differences between the groups more carefully, we further subdivided subgroups into plural subgroups, that is, the intersection of any two subgroups generate a set of new smaller subgroups. A total of 616 plural subgroups were generated for further comparisons.

Patients Matching

Variables such as patient age could potentially confound the relationship between daylights and outcomes, so we conducted a matched analysis. Patients were 1:1 matched so that one member of each pair had one patient on the high light side (window) and one patient on the low light side (door). The criteria for matching were sex, age and admitting unit. We performed nearest neighbor matching algorithms using the MatchIt package in R.

Statistical analysis

We compared descriptive characteristics and hospital outcomes between patient groups exposed to different light sides after matching. For continuous variables (total costs and length of days of hospitalization) were performed using the T-test (or the non-parametric Wilcoxon Rank Sum test for two groups in the case of continuous data with non-homogenous variances). Meanwhile, nominal variables (e.g. sex, age groups) were analyzed using the chi-square test. Statistical significance was considered at the level of P<0.05 based on a two tailed comparison. All statistical calculations were performed by R software version 4.0.2.

Results

Basic Characteristics

A total of 2,998 patients' stays were included in this study. After matching, 1,478 patients were assigned to the low light side group, as well as 1,478 patients were assigned to the high light side group (**Table 1**). At baseline, most variables did not show a significant difference between these two groups, with the exception of district. There were more patients from the urban area in the high light side group than in the low light side group (69.4% vs 65.6%, *p*=0.028).

Daylight Intensity

Average light intensity across daily hours in the high light group was significantly higher than that in the low light group both in sunny day and overcast day. (sunny day: low light group = 39.7 ± 28.2 lux; low light group = 756.9 ± 489.1 lux; *p*<0.001; overcast day: low light group = 10.7 ± 7.1 lux; low light group = 296.6 ± 183.8 lux; *p*<0.001; mean ± SD; **Figure 2a-b**; **Supplemental Table 1**)

Hospital Costs and Length of Stay

Overall comparison of hospital total costs among patients according to light sides did not show a significant difference (CNY ¥14182.0 *vs* ¥13724.0, *p*=0.229). By dividing the patients into subgroups according to their characteristics, we found that in most subgroups, the values of median hospital total costs in the low light side group were higher than that in the high light side group. Particularly in the illiterate subgroup (education level=1), the difference in median hospital total costs was statistically significant (CNY ¥15210.3 *vs* ¥13070.0, *p* =0.018) (**Table 2**). **Table 3** compares the median LOS between the low light side group and the high light side group. Overall, there was no statistically significant difference among patients in these two groups (6 *vs* 6 days, p=0.579). However, in the illiterate subgroup, statistically higher LOS were observed for participants in the low light side group (10 vs 7 days, p=0.011). **Figure 3a-b** were the heat maps visualizing the p-values obtained by comparing hospital total costs and LOS between the high light side group and the low light side group in the plural subgroups. There were more significant differences in hospital total costs in the plural subgroups of the illiterate subgroup (**Figure 3a**). The most significant differences were found in three plural subgroups: age ≥68 years old (number of patients: 61 *vs* 59, p=0.001), normal range BMI (number of patients: 81 *vs* 68, p=0.002) and non-surgery (number of patients: 20 *vs* 26, p=0.006). We also found more significant differences in LOS in the plural subgroups of the illiterate subgroup (**Figure 3b**). The most significant differences were shown in three plural subgroups: age ≥68 years old (number of patients: 61 *vs* 59, p=0.003), normal range of BMI (number of patients: 81 *vs* 68, p=0.009), and diagnosis of benign tumors (number of patients: 81 *vs* 63, p=0.005). Detailed p values could be found in **Supplemental Table 2** and **Supplemental Table 3**.

Discussion

In this study, we found no significant association between light exposure and patients' hospital costs and length of stay in the wards of general surgery, regardless of their general characteristics (sex, age and BMI at admission), clinical characteristics (taking surgery or not, diagnostic categories, comorbidities), and demographic characteristics including lifestyle factors (smoking and drinking), residential district (urban or rural), etc. However, subgroup analysis showed that patients with the lowest education level were prone to be more easily affected by light levels, especially when they were old-aged (≥68 years old) or within normal BMI range (18.5-24 kg/m^2). When exposed to higher intensity of indoor daylight, they had lower total hospital costs and shorter LOS as compared to those exposed to lower intensity.

So far, numerous studies have been carried out to clarify the potential importance of different aspects of the environment for health and healing, such as indoor air quality and noise[16-19]. As one of the most intuitive environmental factor, it is well-known that light may exert a significant impact on patients' physical and psychological well-being in various direct or indirect ways[20]. However, in this research, the absence of association with total hospital costs and LOS may reflect differences in daylight levels that were not physiologically sufficient for statistically significance. What is interesting is that this work also demonstrated that in contrast with patients with higher education levels, illiterate ones did get affected by indoor daylight levels. Undoubtedly, the education levels of patients are often perceived as an adequate index for their socioeconomic status, apart from their income and occupation[21]. It has been proved that individuals with lower socioeconomic status tend to suffer from higher risks of psychiatric problems including depression, anxiety disorders and post-traumatic stress disorder[22-25]. And lower levels of knowledge were reported to be associated with significantly higher health care costs, due to bad medication adherence[26]. Besides, according to the results of subgroup analysis, the most undereducated patients who were also old-aged (≥68 years old) and within normal BMI range (18.5-24 kg/m^2) were more sensitive to light intensity, which was in line with a previous finding that among elderly group, there is inverse correlation between anxiety and obesity[27]. And the lack of sample size of the subgroup might explain the statistical insignificance in underweighted (BMI<18.5 kg/m^2) illiterate patients. Therefore, given the immobility of these characteristics, medical staff should collect information about education level, BMI as well as age at admission and enhance indoor environmental benefits to accelerate the recovery process. What's more, the association between light levels and outcomes in this specific population also suggested that it was necessary to develop regulations of light in architectural and engineering guidelines of health facilities and a recommended standard of a minimum light intensity might be essential.

Unlike our study, a previous research showed a significant relationship between indoor daylight environments and a patient's average length of stay in department of surgery (p<0.048) and gynecology(p<0.015) in a hospital[1]. Another work by Joarder et al. developed a multiple linear regression to describe the relationship of daylight illuminance and LOS of patients who underwent coronary artery bypass graft[14]. Yet, the former study found no significant results in department of internal medicine and otolaryngology. In addition, unlike these researches, our study included a much larger sample size with detailed clinical information and demographic characteristics, which may account for the different results. Generally, our findings are consistent with those researches investigating the effect of indoor daylight levels on the recovery of patients in ICU. Wunsch et al. found that the presence of a window in an ICU room was not beneficial for critically ill patients with subarachnoid hemorrhage (SAH)[10]. Likewise, Smonig et al. pointed out that exposure to natural light did not help improve delirium burden[11]. And Verceles et al. indicated that room orientation with different ambient light levels did not exert a significant impact on critical care outcomes or differences in sedative/analgesic/neuroleptic use[12]. However, due to limited sample size, these researches didn't take into account the patients' demographic information. Moreover, it is noteworthy that patients in ICU are often in sedation and analgesia, which might make external stimuli less potent than it would be for patients in ordinary hospital wards. Even awake patients with brain injury or some other diseases may have photophobia, which might disturb the light exposure they receive.

To the best of our knowledge, this is the first study to assess the potential effect of indoor daylight levels on the recovery of patients admitted to department of general surgery with such a large sample size. Despite the fact that it was not a randomized controlled trial, patients were naturally randomly assigned to window-side versus door-side beds in the general surgery wards, which resulted in a perfect balance of almost all baseline characteristics of patients from the two different groups. Thus, there was less chance of the results or conclusions of this study to be affected by potential unmeasured confounding factors. Nonetheless, given the single-center design and observational nature of this study, there are inevitably some limitations that need to be addressed. First, due to limited access to details of hospital cost, we did not figure out how indoor daylight levels affected different kinds of cost, such as nursing cost and surgical cost. Second, this study was not able to include more individualized factors such as social and cultural differences, daylight preferences, preferred activity, etc. Third, not only is the indoor daylight intensity able to influence the physiological condition of patients, but also the window view itself can generate positive physiological effects[28-30]. Our study cannot rule out the fact the possibility that the window view might play a more important role in affecting illiterate patients' recovery. Therefore, future investigations are desired in this direction.

Conclusion

In this retrospective study, we investigated associations between indoor daylight levels with hospital costs and LOS of patients admitted to general surgery. No significant difference was found between low light group and high light group. However, these data do support the beneficial effects of presence of natural light from a window on outcomes in illiterate patients. Further investigations need to be done to find out the underlying physiological and social psychological mechanism. This study could shed some light on developing design guidelines for healthcare facilities to enhance indoor environmental benefits that will accelerate the recovery of some specific population.

Abbreviations

LOS: Length of stay; BMI: Body Mass Index; ICU: Intensive Care Unit.

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional Review Board of the Second Affiliated Hospital of Zhejiang University, School of Medicine, China.

Consent for publication

Not applicable.

Availability of data and materials

The datasets and R code of this study are available from the corresponding author (yulianwu@zju.edu.cn), upon reasonable request.

Competing interests

The authors declare no conflict of interest.

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Authors' contributions:

XL: Conceptualization, Writing-original draft, Formal analysis. JL: Investigation, Validation. AS: Investigation, Validation. NW: Investigation. LZh: Data curation. ZY: Formal analysis, Visualization. MZ: Formal analysis. FY: Data curation. ZP: Data curation. YW: Writing-review & editing, Supervision, Project administration, Funding acquisition.

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Tables

Table 1 Basic characteristics of patients on low light and high light sides of the hospital unit.

Variables [a]		Light Sides		p-value [c]
		Low (n=1478)	High (n=1478)	
Sex				0.574
	1 [Male]	889 (60.1) [b]	873 (59.1)	
	2 [Female]	589 (39.9)	605 (40.9)	
Age				0.616
	1 [<51 years]	341 (23.1)	358 (24.2)	
	2 [51-59 years]	358 (24.2)	361 (24.4)	
	3 [60-67 years]	365 (24.7)	376 (25.4)	
	4 [≥68 years]	414 (28.0)	383 (25.9)	
BMI				0.213
	1 [<18.5]	208 (14.1)	239 (16.2)	
	2 [18.5-24]	967 (65.4)	918 (62.1)	
	3 [24-28]	255 (17.3)	263 (17.8)	
	4 [≥28]	48 (3.2)	58 (3.9)	
Length of Stay (LOS)				0.378
	1 [1-6 days]	753 (50.9)	753 (50.9)	
	2 [7-13 days]	386 (26.1)	405 (27.4)	
	3 [14-29 days]	261 (17.7)	261 (17.7)	
	4 [≥30 days]	78 (5.3)	59 (4.0)	
Surgery				0.509
	0 [No]	269 (18.2)	284 (19.2)	
	1 [Yes]	1209 (81.8)	1194 (80.8)	
Diagnosis				0.944
	1 [Benign tumor]	955 (64.6)	976 (66.0)	
	2 [Malignant tumor]	99 (6.7)	98 (6.6)	
	3 [Inflammation]	244 (16.5)	239 (16.2)	
	4 [Hernia]	30 (2.0)	25 (1.7)	
	5 [Intestinal obstruction]	62 (4.2)	55 (3.7)	

	6 [Others]	88 (6.0)	85 (5.8)	
Hypertension				0.937
	0 [No]	1007 (68.1)	1004 (67.9)	
	1 [Yes]	471 (31.9)	474 (32.1)	
Diabetes				0.268
	0 [No]	1281 (86.7)	1302 (88.1)	
	1 [Yes]	197 (13.3)	176 (11.9)	
Smoking				0.405
	0 [No]	900 (60.9)	923 (62.4)	
	1 [Yes]	578 (39.1)	555 (37.6)	
Drinking				0.676
	0 [No]	917 (62.0)	929 (62.9)	
	1 [Yes]	561 (38.0)	549 (37.1)	
District				0.028
	0 [Rural]	509 (34.4)	452 (30.6)	
	1 [Urban]	969 (65.6)	1026 (69.4)	
Education level				0.086
	1 [Illiterate]	131 (8.9)	114 (7.7)	
	2 [Primary school]	509 (34.4)	455 (30.8)	
	3 [Middle school]	426 (28.8)	482 (32.6)	
	4 [High school]	219 (14.8)	234 (15.8)	
	5 [University degree]	193 (13.1)	193 (13.1)	

[a] Variable names are presented as categorical label [name].

[b] Variables are listed as columnwise No. (percentage).

[c] *p* value is determined by a chi-squared test between low and high light sides.

Table 2 Total costs of patients by light sides of the hospital unit.

Variables[a]		N	Light Sides		p-value [d]
			Low(CNY ¥) [b]	High(CNY ¥)	
Overall		1478/1478	14182.0 (7692.0-25796.0)	13724.0 (7808.0-23838.0)	0.229
Sex					
	1 [Male]	889/873	14494.9 (7809.2-24874.0)	14322.0 (8115.0-25798.0)	0.966
	2 [Female]	589/605	13947.6 (7440.5-27504.0)	13050.0 (7607.0-21426.0)	0.069
Age					
	1 [<51 years]	341/358	13247.5 (7955.8-23348.9)	12672.0 (7810.0-18770.0)	0.272
	2 [51-59 years]	358/361	13953.4 (7585.0-24415.4)	13842.0 (7597.0-21240.0)	0.532
	3 [60-67 years]	365/376	13610.0 (7234.2-21366.9)	14495.0 (8228.0-23199.0)	0.094
	4 [≥68 years]	414/383	16281.7 (8501.0-36644.3)	15143.0 (7691.0-35494.0)	0.496
BMI					
	1 [<18.5]	208/239	11986.2 (6204.5-19008.2)	11483.0 (6531.0-18565.0)	0.374
	2 [18.5-24]	967/918	14269.3 (7910.0-26474.1)	13749.0 (7815.0-22198.0)	0.229
	3 [24-28]	255/263	15638.5 (8749.4-26372.1)	15183.0 (8977.0-30893.0)	0.901
	4 [≥28]	48/58	18403.5 (10904.2-25688.6)	17457.0 (8269.0-30022.0)	0.571
Length of Stay (LOS) [c]					
	1 [1-6 days]	753/753	9154.2 (5274.6-14086.1)	9101.0 (5409.0-13642.0)	0.627
	2 [7-13 days]	386/405	15991.3 (11506.9-24273.6)	15479.0 (10966.0-22747.0)	0.500
	3 [14-29 days]	261/261	41760.9 (27625.0-57664.1)	42646.0 (29394.0-59278.0)	0.991

	4 [≥30 days]	78/59	85389.3 (66518.6-117553.7)	83964.0 (64563.0-100000.0)	0.748
Surgery					
	0 [No]	269/284	12153.4 (5762.8-18499.6)	10468.0 (6033.0-16580.0)	0.360
	1 [Yes]	1209/1194	14685.4 (8361.3-28337.9)	14514.0 (8345.0-28189.0)	0.485
Diagnosis					
	1 [Benign tumor]	955/976	14042.7 (7372.4-23920.0)	13845.0 (8012.0-23803.0)	0.386
	2 [Malignant tumor]	99/98	13959.3 (7165.3-25773.9)	10112.0 (5688.0-23902.0)	0.561
	3 [Inflammation]	244/239	13837.9 (10139.0-25526.3)	13814.0 (8535.0-22096.0)	0.831
	4 [Hernia]	30/25	14692.1 (11539.6-17006.9)	13952.0 (12230.0-17129.0)	0.290
	5 [Intestinal obstruction]	62/55	19341.6 (9240.2-35478.9)	16378.0 (7473.0-37040.0)	0.569
	6 [Others]	88/85	19639.4 (7430.1-36179.6)	12320.0 (6067.0-29873.0)	0.079
Hypertension					
	0 [No]	1007/1004	13610.0 (7283.9-25530.2)	13135.0 (7556.0-21242.0)	0.174
	1 [Yes]	471/474	15186.2 (8792.6-26905.5)	15062.0 (8314.0-29577.0)	0.765
Diabetes					
	0 [No]	1281/1302	14042.7 (7492.3-25801.0)	13695.0 (7815.0-22598.0)	0.090
	1 [Yes]	197/176	14856.0 (7962.4-25781.5)	13922.0 (7612.0-31176.0)	1.000
Smoking					
	0 [No]	900/923	14101.5 (7490.4-26998.3)	13764.0 (7800.0-22828.0)	0.098
	1 [Yes]	578/555	14369.1 (7974.5-23980.2)	13649.0 (7944.0-25555.0)	0.817
Drinking					

	0 [No]	917/929	13837.0 (7046.1-23940.7)	13571.0 (7668.0-22814.0)	0.625
	1 [Yes]	561/549	14870.2 (9332.6-28315.1)	13950.0 (8164.0-25703.0)	0.193
District					
	0 [Rural]	509/452	13864.3 (7313.0-25953.7)	12227.0 (6537.0-20951.0)	0.051
	1 [Urban]	969/1026	14344.7 (7962.4-25522.5)	14180.0 (8386.0-25579.0)	0.714
Education level					
	1 [Illiterate]	131/114	15210.3 (8108.2-48915.6)	13070.0 (6831.0-29089.0)	**0.018**
	2 [Primary school]	509/455	14269.3 (7501.3-25467.9)	13814.0 (7817.0-22620.0)	0.548
	3 [Middle school]	426/482	14095.7 (7579.5-22886.4)	12954.0 (7361.0-23115.0)	0.184
	4 [High school]	219/234	14797.1 (7478.4-23053.0)	15673.0 (9360.0-25099.0)	0.693
	5 [University degree]	193/193	13247.5 (9037.5-26890.8)	13764.0 (8402.0-23448.0)	0.940

[a] Variable names are presented as categorical label [definition].

[b] CNY: Chinese Yuan.

[c] listed as median (Q1-Q3).

[d] *p* values are determined by T-test or Wilcoxon Rank Sum test. *p* value for overall comparison is determined by paired T-test.

Table 3 Length of Days (LOS) of patients by light sides of the hospital unit.

Variables[a]		N	Light Sides		p-value [c]
			Low(days)	High(days)	
Overall		1478/1478	6 (3-13)	6 (3-12)	0.579[#]
Sex					
	1 [Male]	889/873	6 (3-12)	6 (3-13)	0.329
	2 [Female]	589/605	7 (4-14)	7 (4-12)	0.063
Age					
	1 [<51 years]	341/358	6 (3-11)	6 (3-11)	0.392
	2 [51-59 years]	358/361	7 (3-12)	6 (3-11)	0.121
	3 [60-67 years]	365/376	5 (2-10)	6 (3-13)	0.067
	4 [≥68 years]	414/383	7 (4-16)	8 (4-15)	0.645
BMI					
	1 [<18.5]	208/239	5 (2-12)	5 (2-11)	0.244
	2 [18.5-24]	967/918	6 (3-13)	6 (3-12)	0.636
	3 [24-28]	255/263	7 (4-12)	7 (4-14)	0.350
	4 [≥28]	48/58	9 (6-14)	7 (4-15)	0.956
Length of Stay (LOS) [b]					
	1 [1-6 days]	753/753	3 (2-5)	3 (2-5)	0.702
	2 [7-13 days]	386/405	9 (7-11)	9 (7-11)	0.723
	3 [14-29 days]	261/261	18 (15-21)	18 (15-22)	0.483
	4 [≥30 days]	78/59	36 (33-45)	38 (34-50)	0.220
Surgery					
	0 [No]	269/284	6 (3-11)	6 (3-9)	0.340
	1 [Yes]	1209/1194	6 (3-13)	7 (3-13)	0.810
Diagnosis					
	1 [Benign tumor]	955/976	5 (2-12)	5 (2-11)	0.622
	2 [Malignant tumor]	99/98	8 (6-12)	7 (5-14)	0.451
	3 [Inflammation]	244/239	8 (5-13)	7 (5-13)	0.908

	4 [Hernia]	30/25	7 (5-10)	7 (6-10)	0.423
	5 [Intestinal obstruction]	62/55	9 (6-18)	9 (6-15)	0.552
	6 [Others]	88/85	10 (7-18)	9 (6-15)	0.384
Hypertension					
	0 [No]	1007/1004	6 (3-12)	6 (3-11)	0.723
	1 [Yes]	471/474	7 (3-13)	7 (3-14)	0.635
Diabetes					
	0 [No]	1281/1302	6 (3-13)	6 (3-12)	0.280
	1 [Yes]	197/176	6 (2-11)	7 (3-14)	0.153
Smoking					
	0 [No]	900/923	7 (4-13)	7 (4-12)	0.214
	1 [Yes]	578/555	5 (2-12)	6 (2-12)	0.517
Drinking					
	0 [No]	917/929	6 (3-12)	7 (3-12)	0.856
	1 [Yes]	561/549	6 (3-13)	6 (3-13)	0.273
District					
	0 [Rural]	509/452	6 (3-13)	6 (3-11)	0.212
	1 [Urban]	969/1026	6 (3-13)	7 (3-12)	0.743
Education level					
	1 [Illiterate]	131/114	10 (5-19)	7 (4-14)	**0.011**
	2 [Primary school]	509/455	6 (2-12)	7 (3-13)	0.188
	3 [Middle school]	426/482	6 (3-10)	6 (3-11)	0.212
	4 [High school]	219/234	6 (3-13)	7 (4-12)	0.857
	5 [University degree]	193/193	7 (4-12)	7 (4-13)	0.503

[a] Variable names are presented as categorical label [definition].

[b] LOS is listed as median (Q1-Q3).

[c] *p* values are determined by T-test or Wilcoxon Rank Sum test. *p* value for overall comparison is determined by paired T-test.

Figures

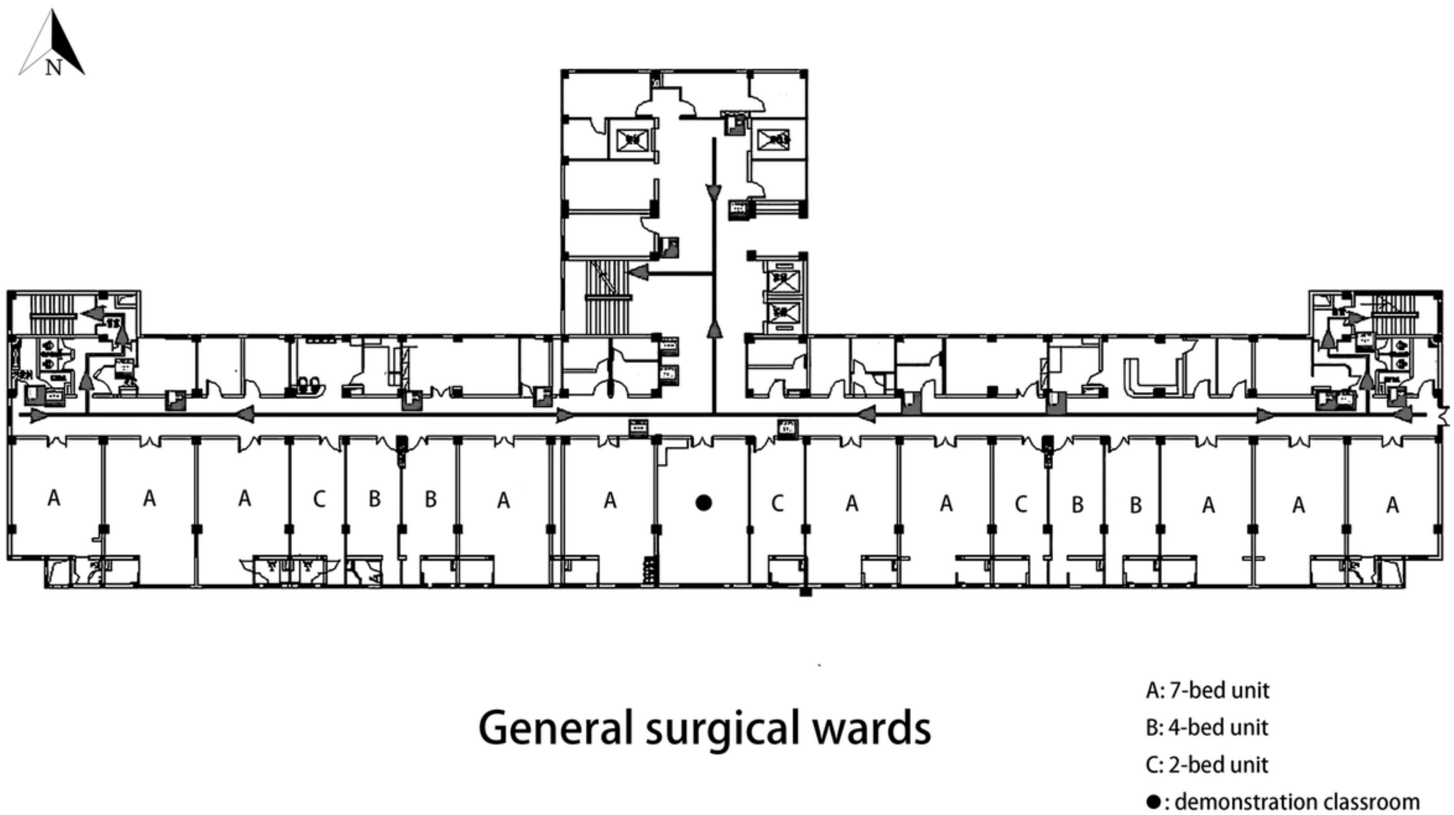


Figure 1

Layouts of the patient units in the general surgical wards.

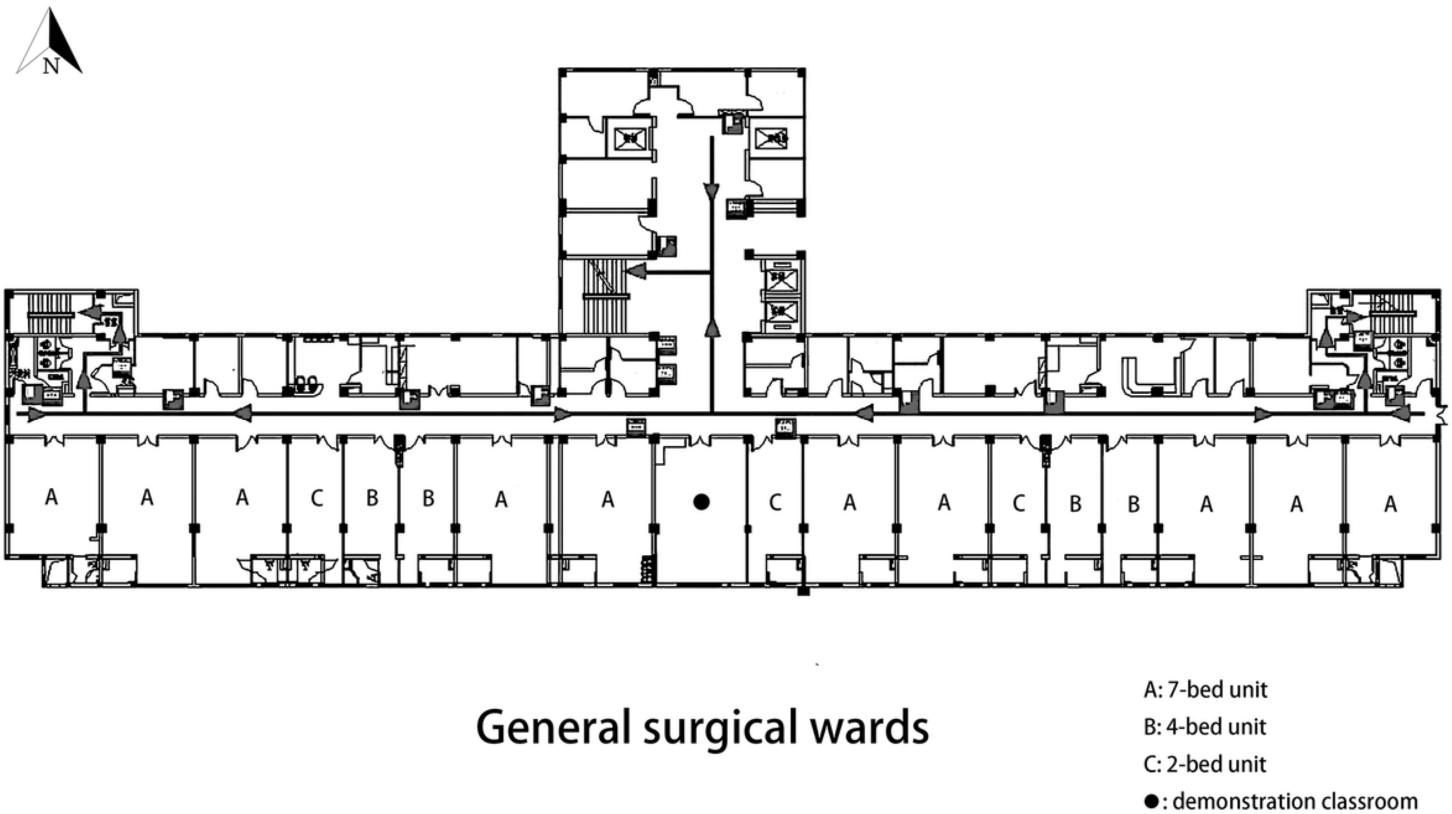


Figure 1

Layouts of the patient units in the general surgical wards.

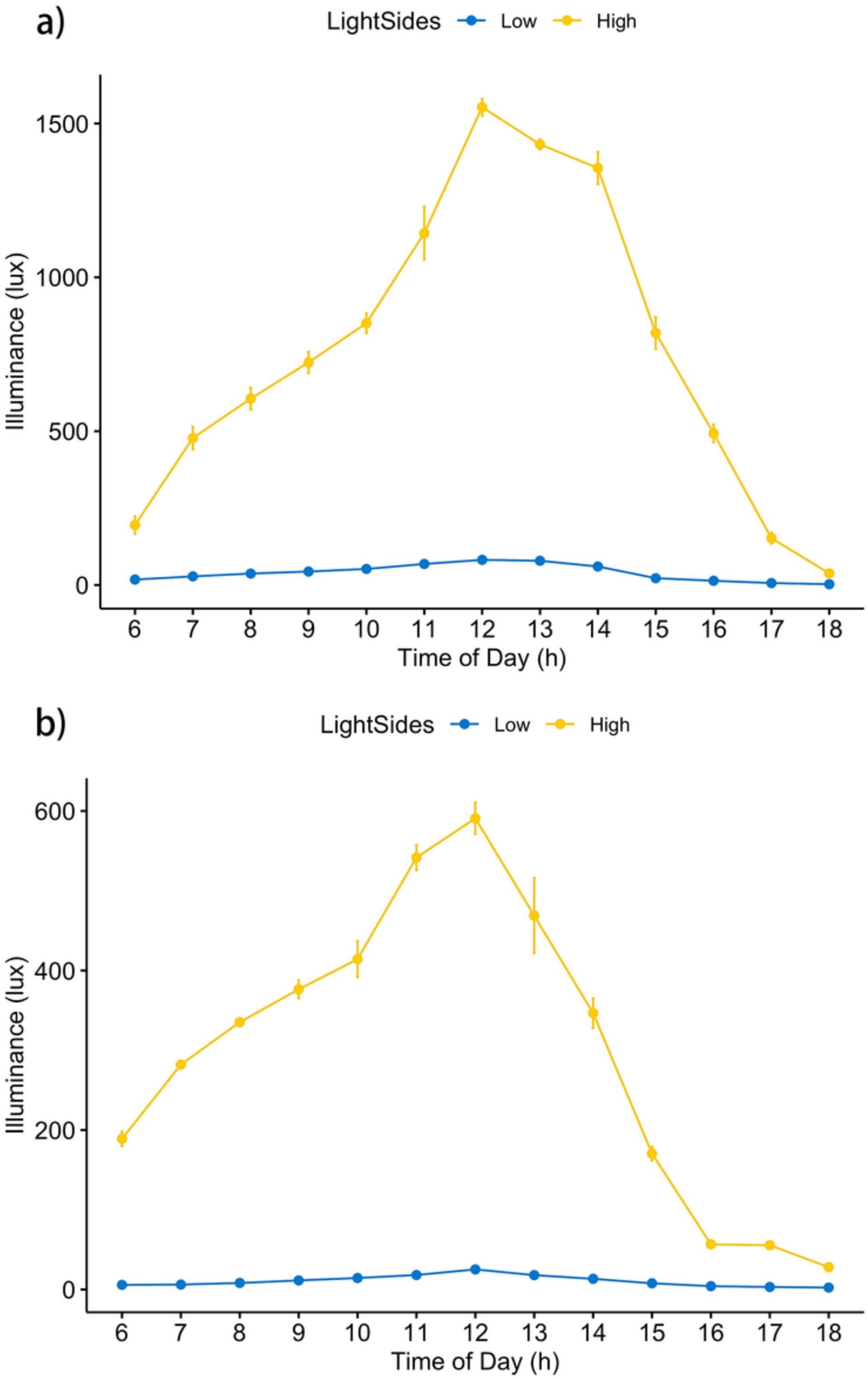
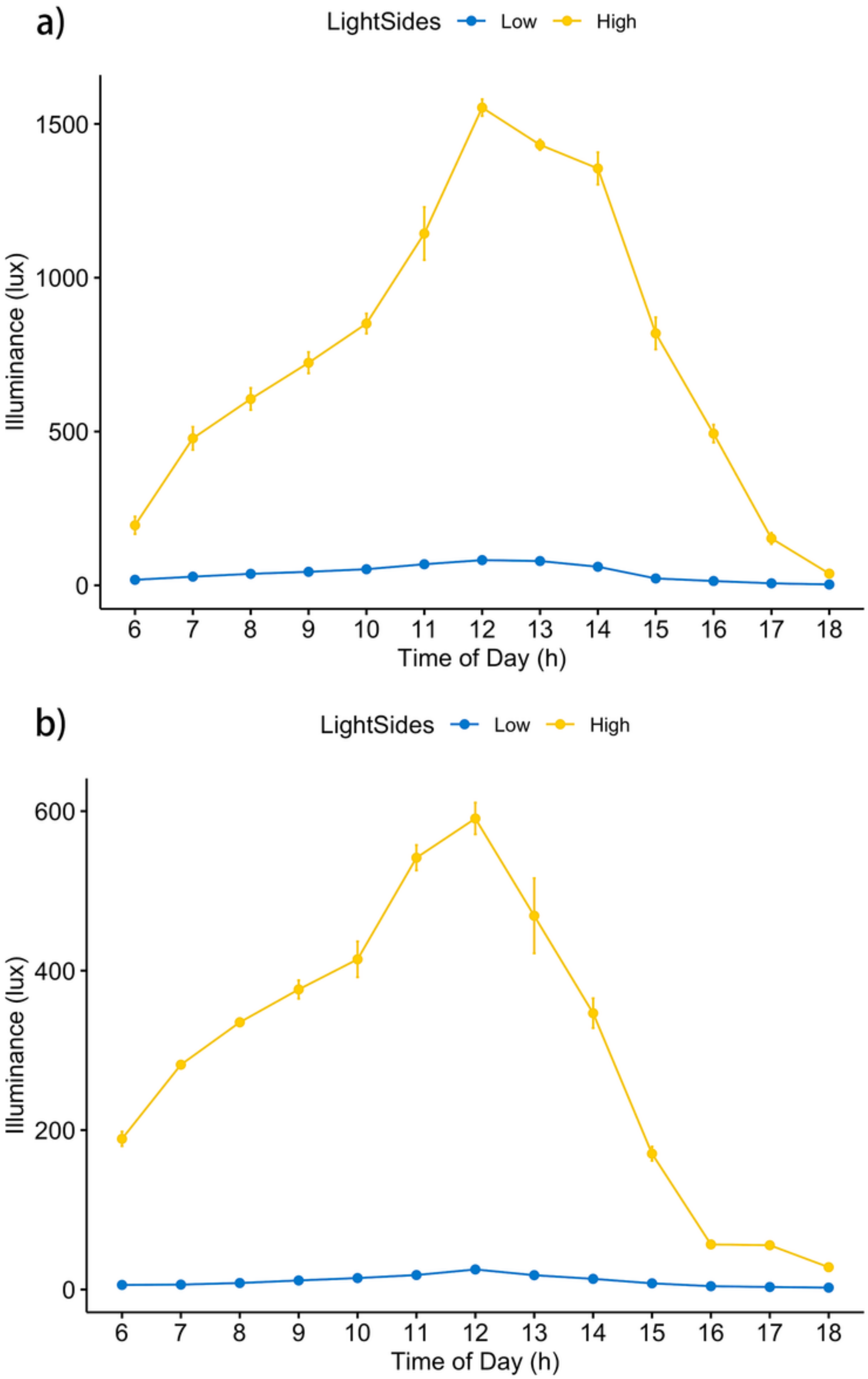


Figure 2

Light intensity by light sides of the hospital unit in two sky conditions. a) sunny day; b) overcast day.



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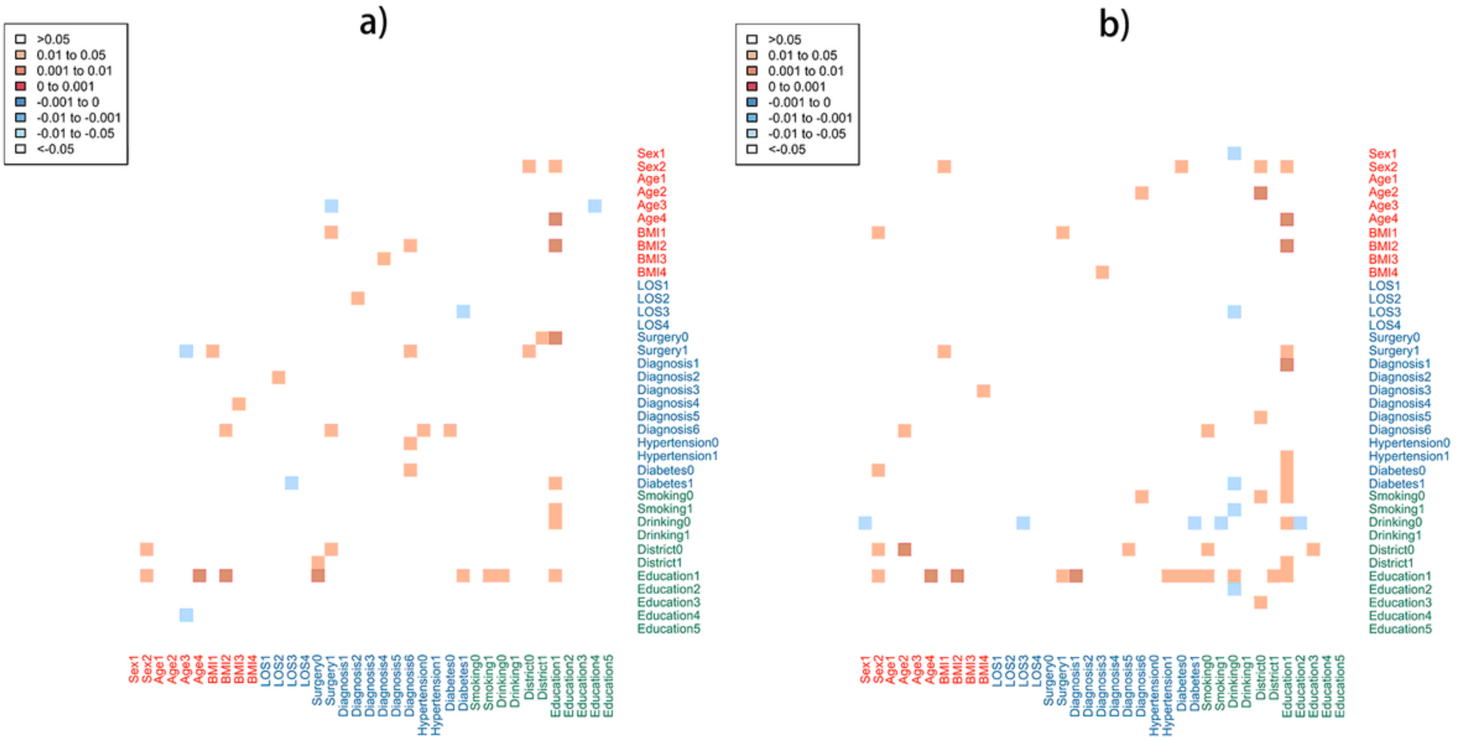

Figure 3

Heatmaps of p-values for hospital total costs (a) and LOS (b) between the high light side group and the low light side group by plural subgroups. Positive coefficients (p > 0) indicate a direct relationship between variables (Low light side > high light side); while negative coefficients (p < 0) indicate an inverse correlation (Low light side < high light side). No p values if sample size is less than 3 LOS: length of stay

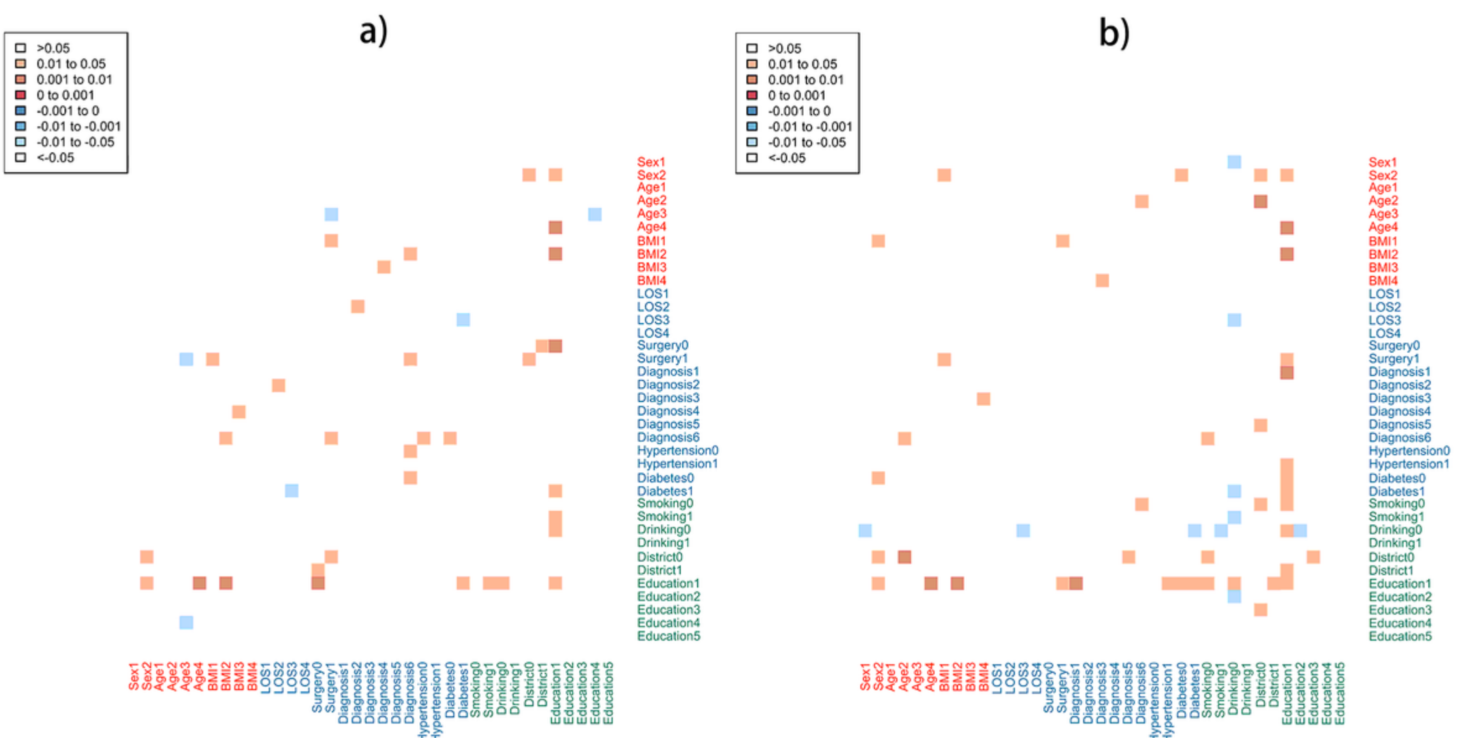

Figure 3

Heatmaps of p-values for hospital total costs (a) and LOS (b) between the high light side group and the low light side group by plural subgroups. Positive coefficients ($p > 0$) indicate a direct relationship between variables (Low light side > high light side); while negative coefficients ($p < 0$) indicate an inverse correlation (Low light side < high light side). No p values if sample size is less than 3 LOS: length of stay

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementalTables.xlsx
- SupplementalTables.xlsx