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Study of the Relationship between Patients' Recovery and Indoor Daylight Environment of Patient Rooms in Healthcare Facilities

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This study focuses on the relationship between daylight and patients' outcomes in healthcare facilities. It investigates how daylight affects on patient recovery, by the evaluating and analyzing of daylight levels in patient rooms in comparison to their periods of recovery time. Patient hospitalization data were taken at one general hospital in Seoul, South Korea and one in Bryan, Texas, U.S.A.; physical, environmental and daylighting conditions were assessed at each building site. The gathered data was analyzed using the SPSS statistical package to find the trends in patients' recovery time and hospital wards.

Selected hospital wards were classified based on their location, orientations, types of patients, and diseases. Other variables considered in the study were: the differences in the solar, lighting, and physical environment properties of the two site locations (Seoul and Bryan), and how these affect patient hospitalization time in both locations. The focus of the study is mainly on the relationship between patient hospitalization times and daylight levels of each of the selected patient rooms. Results of this study also identify the types of diseases that are more responsive to high daylight levels in patient rooms. This information can be used as a basis for the development of guidelines for patient rooms in healthcare facilities in order to achieve more effective healing environments. Likewise, these results may be applied to medical treatment facilities, recreational facilities and general hospitals as well.

1. Introduction

Increasing energy costs during the last few decades has led to the improved construction and retrofitting of contemporary buildings for enhanced energy saving effects. As one of the energy saving architecture design strategies, reducing admitted amount of daylight in an indoor area is cost effective and widely practiced for diminishing energy consumption. Because of this efficient strategy, many researchers and engineers have concentrated on intercepting sun rays into indoor environments and using heavily tinted glasses, sun shading devices, and other tools for blocking natural light (Lisa Heschong 2002).

The majority of research on energy savings concentrates on how to avoid hot sunrays in residential environments by showing the contrasting energy usages before and after implementation. Consequently, such strategies are regarded as very efficient, though they might loose chances to have beneficial effects to occupant health conditions. In other word, daylight was just a target to block for reducing energy load. Some recent studies in architectural engineering indicate that daylight through windows has beneficial impacts on occupants' physical condition in buildings and insist we should make use of daylight actively for human health. Wilson (1972) compared the incidence of post-operative delirium in surgical patients treated for at least 72 hours in an ICU (Intensive Care Unit) without windows with patients in an intensive care unit possessing windows. Over twice as many episodes of organic delirium were seen in the intensive care unit without windows. Wilson concluded that the presence of windows was highly desirable for the prevention of sensory deprivation. Richard Kuler (1992) stated that health and behavior of children in classrooms have significant differences in their concentration, stress and growth hormones between environments with and without windows. Those conclusions gained further support by Lisa Heschong (2002) who pointed that students in classrooms with the most window area or daylight were found to have 7% to 18% higher scores on the standardized tests than those with the least window area or daylight. The correlation of how occupants react positively to daylight has been well substantiated.

However, there are few researches to show architectural efforts that address the orientation of windows and buildings related with the amount of inside daylight with the thought of architectural components. Especially, the importance of indoor environments in healthcare facilities is critical to patients' condition. Especially, in healthcare facilities, few patient rooms have windows and those that do have almost the same size windows and volume of spaces with different orientations.

Thus, this study begins with the assumption that as facility orientation determines indoor daylight levels it will also affect the physical conditions of patients in the area. This study focuses on how daylight and patients' hospitalization time correlate with each other in healthcare facilities: the purpose being to assess the effects of natural daylight on the hospitalization time in patient recoveries.

2. Methodology

This study examines how daylight affects patients' hospitalization times in two healthcare facilities. To minimize outside variances in patient recovery rates this study was performed with the following assumptions to maintain its objectivity:

- Patient's able to leave a hospital are regarded as recovered.
- Unexpected leaving patients have the same frequency in each category.
- Variables other than indoor daylight are not considered.
- The qualities of environmental factors other than daylight are regarded as almost the same.
- The medical treatment quality of each nurse and doctor has no statistical bearing.

Because various physical conditions such as illuminance level, orientation, and surface material reflectance can affect the indoor environment of patient rooms this study also uses on-site observations and measurements for illuminance level and daylight condition of patient rooms. In the measurement, a randomly sampled patient room from each orientation in each ward was selected. Illuminance levels in sampled patient rooms were measured at a height of 0.85m above the floor in grids 0.5m by 0.5m. Measurements were taken at almost 25 points in each room using a Minolta T-1H light meter.

The data of patient hospitalization times were obtained from St. Joseph Hospital in Bryan, Texas, U.S.A. and Yonsei Medical Center, Seoul, South Korea. The collected data were categorized according to their wards: pediatrics, post partum, oncology, telemetry, orthopedics, surgery, and medical ward. Hospitalization times were compared within wards based on variance in daylight levels. Selected hospital wards were classified based on their location, orientation, and diseases. Other aspects considered in the study were: solar position, weather properties, daylight levels, and other physical environment properties of the two site locations (Seoul, South Korea and Bryan, Texas). The two health facilities have very different climates, building types, medical systems, and treatment process and these may all affect light levels and therefore recovery times. Statistical analysis, weather conditions, and miscellaneous properties of each facility were investigated.

3. Data Analysis

3.1 Location and facility Properties Analysis

During the summer season, all facilities control the interior temperature with mechanical air conditioning systems and occupants usually shut any curtains or blinds on the windows. Additionally, the intensity of sunrays in winter is so mild it is inappropriate for analyzing the impact of daylight on occupants. Because the fall season imparts climatically mild environmental conditions to people, occupants usually open the blinds and admit daylight into the indoor environments. For that reason, this research was done with the data taken from the fall season.

Table. 1. *Comparisons of location, solar condition, weather and facility properties in St. Joseph Hospital (Bryan, Texas, U.S.A.) and Yonsei Medical Center (Seoul, South Korea)*

	ST. JOSEPH HOSPITAL		YONSEI MEDICAL CENTERR	
Location	Bryan, Texas, U.S.A.		Seoul, South Korea	
Latitude	30.6 ˚ N		37.5 ˚ N	
Longitude	96.4 ˚ W		126.9 ˚ W	
Solar position (South Altitude)	Oct. 1	57.1 ˚	Sep. 1	61.1 ˚
	Nov. 1	45.8 ˚	Oct. 1	49.5 ˚
	Dec. 1	38.3 ˚	Nov. 1	38.3 ˚
External Average Temperature	October	30˚C (7˚C)	September	30˚C (13˚C)
	November	27˚C (0˚C)	October	26˚C (3˚C)
	December	23˚C (-5˚C)	November	18˚C (-5˚C)

According to Table 1, even though both cities are in different locations, Seoul and Bryan have common climate properties during the fall season. The outside temperature and solar condition of Seoul in September, October, and November are almost same with those of Bryan in October, November, and December. Solar positions were almost identical to each other in both cities.

ST. JOSEPH HOSPITAL	YONSEI MEDICAL CENTER

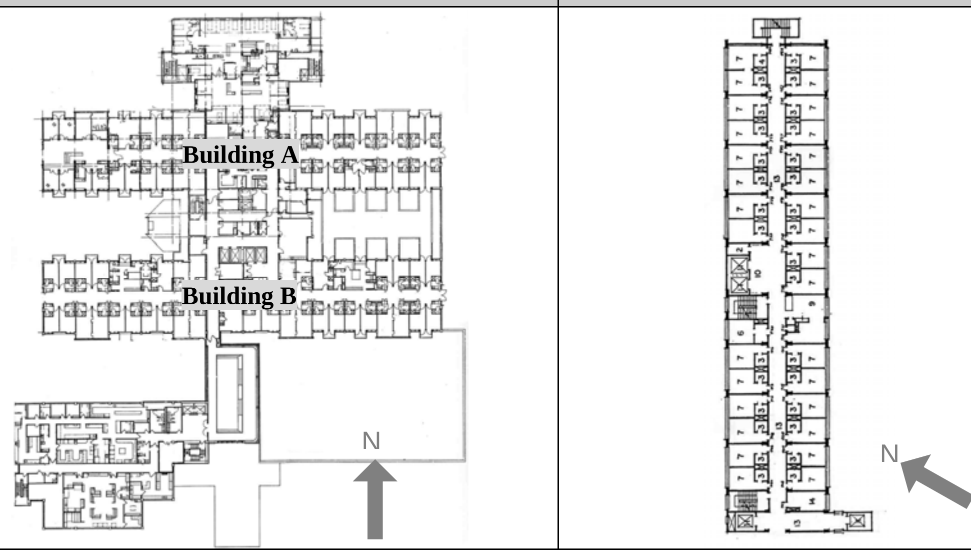


Fig. 1. *Facility Plans of St. Joseph Hospital and Yonsei Medical Center*

St. Joseph Hospital is situated in a quiet suburb of Bryan in the southern part of Texas. The climate in this region is very hot in summer and mild in fall with mostly clear sky conditions. It has about 120 beds for patients, is three-story building. This hospital has two main patient buildings that are connected by a small intermediary structure. Because the daylight condition would be different in each building, this hospital is categorized into Building A and B sections. Half of the patient rooms face South and the other half face North. The patient building of Yonsei Medical Center is an annex of patient buildings. It is located next to Yonsei University campus where is a few kilometers apart from the center of Seoul. The climate during the season fall is mostly mild compared to the other seasons. This building was newly built in 1968, and remodeled in 1983. It has 300 patient beds, and it is a ten-story building. Fifty percent of the patient rooms face southeast and the rest face northwest.

A patient room in St. Joseph Hospital has a relatively small window compared to Yonsei Medical Center. In a patient room in St. Joseph Hospital, a window is 2.53m^2, floor space is 10.24m^2, the exterior wall is 7.36m^2, and the height is 2.3m. A patient room in Yonsei Medical Center has a 4.62m^2 window, 13.2m^2 floor, 7.76m^2 exterior wall, and is 2.35m high.

	ST. JOSEPH HOSPITAL	YONSEI MEDICAL CENTER
Inside View	 < A north-facing room in Building B >	 < A southwest-facing room >
Outside View		

Fig. 2. *Inside and outside views of St. Joseph Hospital and Yonsei Medical Center*

In St. Joseph Hospital, pediatric, post partum, and telemetry wards are in Building A, and orthopedics, surgery, oncology, and medical wards are in Building B. Yonsei Medical Center has eight wards: respiratory, otorhinolaryngology, internal, surgery, oncology, pediatrics, epilepsy, and psychiatric wards. Among them, this study collected the data from the oncology, internal, surgery, and respiratory wards.

Table. 2. *Facility properties of St. Joseph Hospital and of Yonsei Medical Center*

	ST. JOSEPH HOSPITAL	YONSEI MEDICAL CENTER
Orientation	South	South-East (30° east of south)
Window Size	1.1 m × 2.3m	2.7m × 1.4m
Area of Wall (ext.)	3.2m × 2.3m	3.3m × 2.35m
Area of Floor	3.2m × 3.2m	4.0m × 3.3m
Glass Transmission of window	55 %	73 %
Window / Wall ration	34.4 %	59.6 %
Window / Floor area	24.7 %	35.0 %
Number of Floors	3	11

3.2 Analysis of Daylight level in patient rooms

The light levels of the rooms were measured with an illuminance meter with electric light off. Direct and reflected daylight admitted into patient rooms was taken into consideration for the measurement. In Fig.1, Building B blocks some direct and reflected sunrays that would be admitted into Building A. Thus, these south-facing rooms have lower indoor daylight levels than the north-facing rooms in Building A. This phenomenon occurs also in the 2nd and 3rd floors. Fig. 3 shows that the north-facing patient rooms in Building A and the south-facing patient rooms in Building B admit daylight deeper than the other rooms.

Daylight measurement in St. Joseph Hospital was conducted in an overcast sky condition at 3:00 PM, April 27, 2004. The outside illuminance level was approximately 30,000 lx. In Yonsei Medical Center, the measurement was performed at 2:00 PM, May 24, 2003. The outside illuminance level was 40,000lx with overcast sky condition.

Fig. 3. *Daylight Factor in patient rooms at St. Joseph hospital (April 27, 2004)*

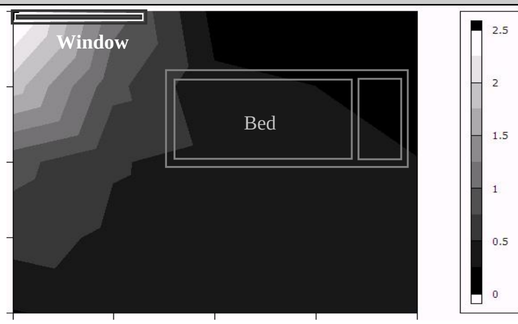
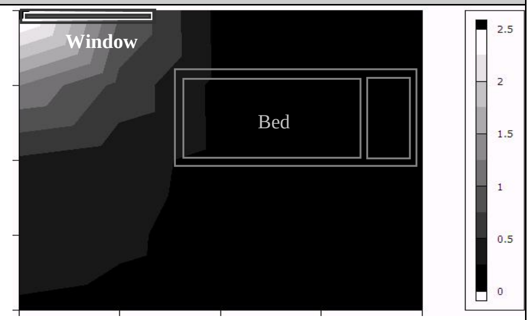
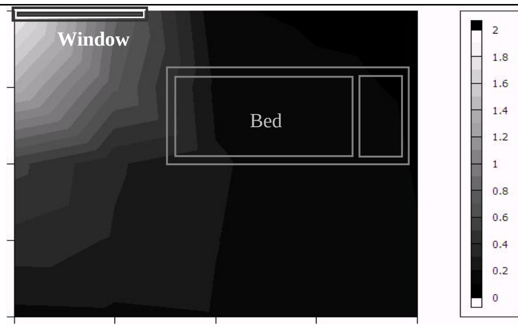
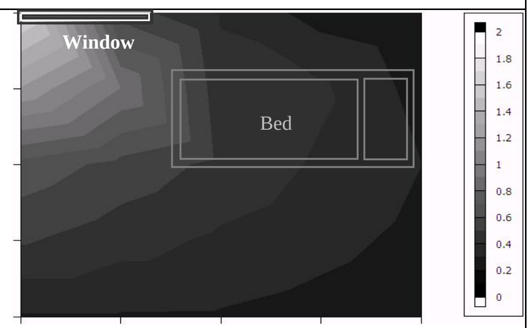
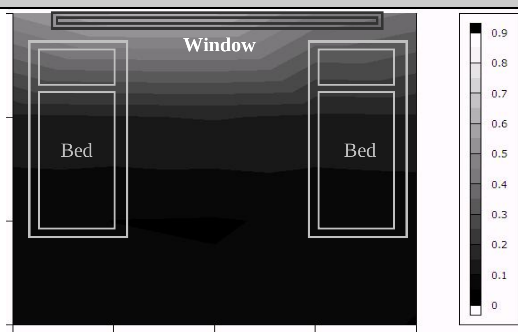
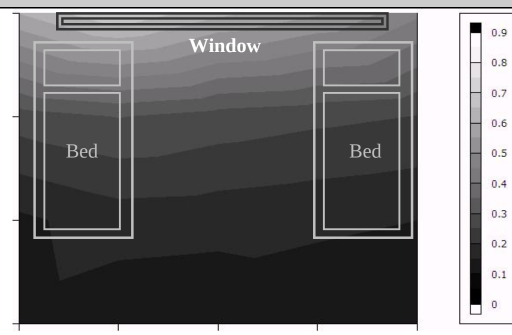
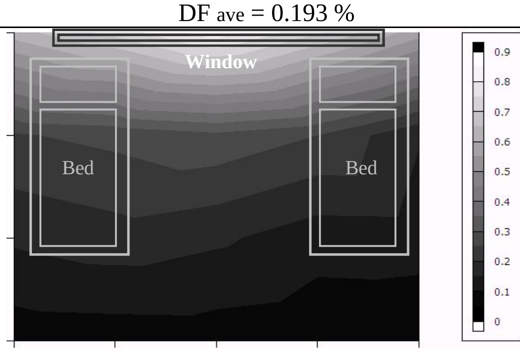
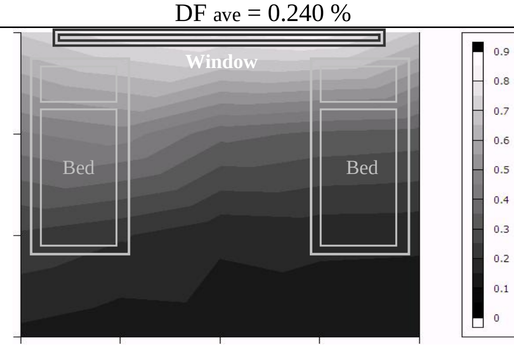
	DAYLIGHT FACTOR (DF)	
	NORTH-FACING PATIENT ROOM	**SOUTH-FACING PATIENT ROOM**
Building A	 DF ave = 0.537 %	 DF ave = 0.382 %
Building B	 DF ave = 0.347 %	 DF ave = 0.477 %

Fig. 4. *Daylight Factor in patient rooms at Yonsei Medical Center (May 24, 2004)*

	DAYLIGHT FACTOR (DF)	
	NORTH-FACING PATIENT ROOM	**SOUTH-FACING PATIENT ROOM**
5th Floor	 DF ave = 0.193 %	 DF ave = 0.240 %
11th Floor	 DF ave = 0.288 %	 DF ave = 0.365 %

As depicted in Fig.4, the Daylight Factor is lower in the lower floors and higher in the top floors (11th floor). This occurs because the surrounding tall buildings block the view to the sun and sky. Thus, this building can generally only have daylight after 9:00 AM during the fall season. The daylight in the southeast-facing patient rooms is more introduced than in the northwest-facing patient rooms.

3.3 Statistical Analysis of the data of patient hospitalization times

Patient hospitalization time data were collected from seven wards in St. Joseph Hospital during the three months from October 2003 to January 2004 for over eight thousand patients. The patient data for Yonsei were collected during the autumn season from 4 wards in the annex patient building for roughly nine thousand patients. The number of patients whose hospitalization time data was recorded is about 1,100 in each ward of St. Joseph Hospital, and about 2300 in each ward of Yonsei Medical Center. Patients leaving the ward due to death were excluded from the data sets.

The fall season data of patient hospitalization times were collected and categorized by orientation and ward. Even though each patient's condition is not same, patient data from the same ward in each hospital was consolidated into a single group for the analysis. The data of temporary patients (those staying for less than 48 hours) and those patients with extremely long hospitalization times were excluded in this analysis. In Yonsei Medical Center, those with less than 72 hours of data were excluded for maintaining effective statistical sensitivity. Because the independent data samples in each category follow neither normal distribution nor binominal distribution, treatment of data was carried out by a nonparametric method (distribution free method) with 95% confidence. The sample size ranges from 120 to 250 in each orientation of each ward.

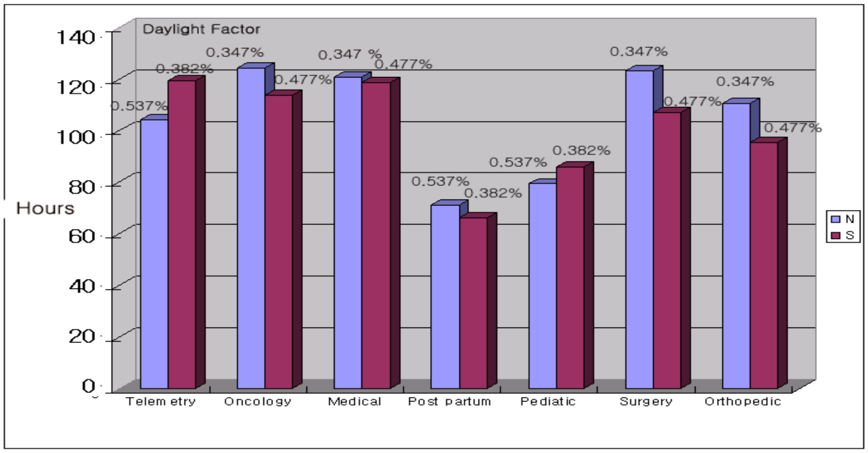


Fig. 5. Comparison of patient hospitalization times between North facing rooms and South facing rooms in St. Joseph Hospital

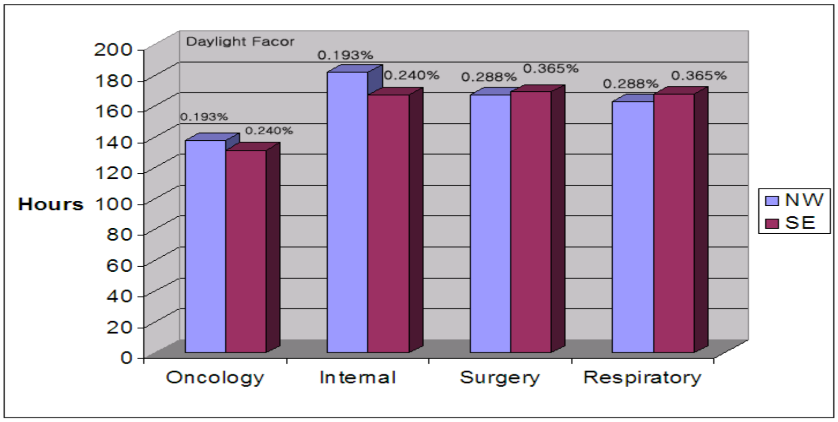


Fig. 6. Comparison of patient hospitalization times between Northwest facing rooms and Southwest facing rooms in Yonsei Medical Center

Figure 5 shows the hospitalization time in each orientation of each ward. There are statistical significances in the average hospitalization times in each orientation of the telemetry, oncology, surgery, and orthopedic wards. Others wards have no statistical differences in the data. Patients in post-partum usually experienced longer temporary stays after giving birth than others. The majority of patients left the hospital within three days, making the average number of hours smaller than those of other wards. Likewise, because children in the pediatric ward experience fewer complications than elderly and adult patients, the average hospitalization times differ from the other wards.

Figure 6 shows the patient hospitalization time in each orientation for each ward in Yonsei Medical Center. There are statistically significant differences in the average hospitalization times in each orientation of the oncology and internal wards. The average hospitalization times of each orientation in Surgery and respiratory wards can be said to have no statistical differences in the data.

4. Results

4.1 The impact of daylight on patient hospitalization times

The statistically significant results commonly show that patients in a room with higher daylight levels had shorter stays than those in rooms with lower daylight levels. In the case of St. Joseph Hospital, north-facing rooms had higher daylight factors than south-facing rooms in the telemetry ward. Inversely, for the oncology, surgery, and orthopedic wards, patients in south-facing rooms left the hospital earlier than in north-facing rooms.

The average times in the telemetry ward are 104.3 hours in the north-facing rooms and 119.2 hours in the south-facing rooms. Thus, patients of north-facing rooms' hospitalization times were 12.5% shorter than those who were in the south-facing patient rooms. Similarly, in the oncology, surgery, and orthopedic wards, patients staying in the south-facing patient rooms had larger amounts of daylight and were hospitalized 8.5%, 13.1%, and 13.6% shorter (respectively) than those in the north-facing patient rooms in each same ward.

In the case of Yonsei Medical Center, daylight factors are higher in southeast-facing patient rooms than in northwest-facing rooms. Among the wards, the oncology and internal wards have statistically significant average times as seen in Figure 4. Patients hospitalized in the southeast-facing rooms of oncology and internal wards left the hospital 4.5% and 8% earlier (respectively) than in the northwest-facing rooms. Therefore, the difference in indoor daylight levels in patient rooms may bring larger differences between patient hospitalization times.

Table. 3. *Percentage of significant hospitalization time differences between the two orientations of each ward*

	ST. JOSEPH HOSPITAL		YONSEI MEDICAL CENTERR	
Building A (North-facing room)	**Telemetry**	12.5 % shorter	**Oncology (SE-facing room)**	4.5 % shorter
Building B (South-facing room)	**Oncology**	8.5 % shorter	**Internal (SE-facing room)**	8 % shorter
	Surgery	13.1 % shorter		
	Orthopedic	13.6 % shorter		
No significant difference	Post partum, Pediatric, and Medical		Respiratory and Surgery	

As summarized in Table 3, among the seven wards in St. Joseph Hospital, four of them have significant differences in patient hospitalization times related to daylight levels in each patient room. Similarly, among those four wards, two of them have also significant differences in average hospitalization times depending on the amount of daylight levels.

Based on the analysis and results, this study shows that daylight, even reflected natural light, can have an impact on patient restoration times. The differences in hospitalization times between north and south-facing rooms are larger than those between northwest and southeast-facing rooms.

5. Conclusions

The results of this study indicate that four out of seven wards in St. Joseph Hospital and two out of four wards in Yonsei Medical Center show consistently positive associations of increased daylight levels with shorter hospitalization times. The rest of them have no significant differences in average hospitalization hours of each orientation. There are no wards where patients staying time is shorter in a room of low daylight levels than of high levels. This is evidenced in the fact that +60 % of patients in the patient rooms with high indoor daylight levels were hospitalized shorter than those with low levels. In general, this supports the insistence that there are invisible positive beneficial effects of daylight on patients' conditions that reduce patient hospitalization times.

This study shows that the amount of daylight can be influential to patient condition and restoration whether it is direct or reflected natural light. However, daylight is a very complex component that affects our indoor and outdoor environments. There are still unidentified factors linked with patients' conditions and healing process in the environment of patient rooms. Thus, further studies about components to help patients' condition, and more samples of patients' data, are necessary to support the positive impacts of daylight on patients in a healthcare facility. Additional studies done by surveying and monitoring patients' condition in different indoor daylight environments would be beneficial in explaining possible beneficial restorative conditions for patients.

This study provides information on the types of patients' illnesses that are influenced by daylight levels on their healing process. This yields beneficial design guidelines for patient rooms in healing environments in healthcare facilities. The results of this study would also be helpful in future studies related with daylight and architecture, and in the healthcare facility design of medical treatment facilities, recreational facilities, and related structures.

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