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Research article

Investigations into the impact of nursing unit layout on critical care nurses

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HIGHLIGHTS

- Nurses' satisfaction with their work environment is critical for delivering high-quality healthcare services.
- Hospitals that want to improve the job performance of their nurses must establish a supportive work environment for them.
- Hospitals should encourage nurses to take an active role in making decisions about their work environment.
- The findings from this study will contribute to the existing literature from a cross-cultural perspective.

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Keywords:
Critical care units
Architectural layout
Spaces arrangement
Movement pattern
Behavioral mapping

ABSTRACT

Background: Nurses' work environment has apparent implications for maximizing their productivity, satisfaction, and improving patient care.
Objectives: This study aimed to explore the influence of three nursing unit spatial layouts on critical care nurses' satisfaction and walking behavior at a university hospital.
Methods: The research used a comparative design by administering a standardized questionnaire, recording walking steps and distances using pedometers, and tracking nurses' walking behavior. Thirty-six critical care nurses working on the morning shift consented to participate in the research.
Results: The study results showed a relationship between the spatial layout of intensive care units (ICUs) and nurses' satisfaction and walking behavior. Questionnaire results indicated statistically significant variations in nurses' satisfaction with the location of the nursing station, the arrangement of patients' rooms, the availability of family space, and the unit's auditory privacy. Nurses in ICU1 were more satisfied with the nursing station's placement and the availability of family space inside patient rooms, while nurses in ICU2 were more satisfied with the patient bed arrangement and the unit's aural privacy than nurses in other units. The pedometer readings and movement maps revealed significant differences in nurses' walking patterns across the three ICUs. The steps, distances, and movement diagrams demonstrated that ICU1 with private rooms outperformed the other units owing to the nurse station's placement and accessibility to patients and support rooms.
Conclusion: This study concludes that the ICU design impacts nurses' satisfaction and behavior. The optimum placement of nursing stations, patients' beds, and supporting room reduces walking distance and thus increases nurses' satisfaction and performance.

1. Introduction

Healthcare institutions must attract qualified personnel to provide optimal treatment, cost savings, and improved patient outcomes via high-quality care (McAlearney et al., 2011). Patient care in the critical care setting is dynamic, and care delivery is contingent on the clinical knowledge, judgment, and reasoning of skilled nurses working in intensive care units (ICUs). Critical care nurses (CCNs) are responsible for managing the nursing care of chronically ill patients and assisting patients whose lives are in danger by means of monitoring, follow-up, threat management, and other invasive procedures (Marshall et al., 2017; Rashid, 2007). CCNs are the medical team's most mobile members, liaising between physicians, specialists, patients, and families. CCNs facilitate, supervise, and evaluate the medical team's activities while also responding to a variety of nursing interventions and needs, including equipment, materials, supplies, and tools, medical records and other

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informational needs; and communication with adjacent units or with other units and support departments (Rashid, 2007; Strachan et al., 2018; Ulrich et al., 2014).

Critical care nurses' work requires them to travel between and across various areas within the ICU that support specific critical care or resource functions, such as (supplies). The time spent by nurses in walking contributes to increased fatigue, workload, and stress, which may affect their job satisfaction (Copeland and Chambers, 2017; Fay et al., 2017) and might negatively impact the time spent on patient care. Hendrich et al. (2008) found that 6.6% of nurses' work time was a nonvalue-added task. The literature has suggested that one non-productive use of nurses' time is unnecessary walking, such as searching for equipment and transporting garbage and soiled linens over long distances (Fay et al., 2017; Grunden and Hagood, 2012). Thus, the nursing station, equipment area, storage units, and medication locations are critical to the CCNs' efficient and effective workflow. The layout and configuration of certain areas can influence the distance and frequency with which CCNs need to travel, making planning critical to both the overall performance of CCNs and the potential impact on patients and the medical team (Copeland and Chambers, 2017; Fay et al., 2017; Hua et al., 2012; Yi and Seo, 2012; Zadeh et al., 2018).

The evidence-based design literature established connections between the physical environment and the experience of healthcare providers (Ulrich et al., 2014). The available research on this connection focuses on the dynamics of movement patterns at the hospital level in general (Choi, 2011; Yi and Seo, 2012), as well as within specialized units such as critical care units (Cai and Zimring, 2012; Ossmann et al., 2019; Zadeh et al., 2012), medical-nursing units (Pachilova and Sailer, 2020; Xuan et al., 2020), operating rooms (Bayramzadeh et al., 2018), and the emergency department (Rismanchian and Lee, 2017). At the unit level, research indicates that excessive and unnecessary movement caused by lengthy travel routes can result in fatigue, cause delayed task completion, or impair overall performance (Zadeh et al., 2012). Inadequate spatial organization and proximity between different areas within the unit are associated with decreased patient safety (Ossmann et al., 2019) and efficiency, increased travel distance and time, and harmful communication between medical team members (Copeland and Chambers, 2017; Fay et al., 2017; Zadeh et al., 2012). These are critical factors to consider when determining the level of job satisfaction among nurses. Indeed, one survey found that more than half of nurses contemplated or planned to quit nursing in search of a less stressful, physically demanding career (Nogueira et al., 2018). Additionally, operational inefficiencies lead to nurses' poor evaluations of their work surroundings and have a detrimental impact on job satisfaction and retention (Faraji et al., 2017; Lee et al., 2017). Job satisfaction has a significant impact on nurses' intentions to remain in nursing roles and in the profession (Masum et al., 2016). Due to the present nursing shortage and the accompanying expenses of nurse turnover, hospital executives must understand nurses' satisfaction. However, little is known about the significance of the physical work environment in influencing job satisfaction, either directly or indirectly via its effect on interpersonal interactions, stress, or the quality of patient care. The goal of efficient nursing unit design should be to provide an atmosphere that enables caregivers to complete a job (Pelletier and Thompson, 1960). There have been a few efforts to establish analytic and quantitative tools for hospital planning (Jaco, 1972). Pelletier and Thompson (1960) devised a technique for assessing the efficacy of different nursing-unit designs by calculating the traffic between certain places. This resulted in study on certain building styles that were suggested for staffing efficiency, decreased traveling distances for staff, and increased opportunities for patient observation, among other benefits (Trites et al., 1970; Verderber and Fine, 2000). Radial corridor hospitals were popular in the 1960s (Jaco, 1972; Pachilova and Sailer, 2020). Verderber and Fine (2000) also identified a variety of issues that have marked the transition of health care in their broad examination of the development of efficient health care architecture. These include (a) large scale vs. small scale, (b) linearity vs. compactness, (c) low-rise vs. mid- or high-rise architecture, and (d) centralized vs. decentralized organization (Verderber and Fine, 2000). This study suggests that hospital design does have an influence on staff behavior, depending on the social, psychological, medical, and administrative uses of such wards. Thus it is critical to examine the planning configuration of the healthcare environment as ICUs since it may result in unnecessary nurses' movement and the creation of obstacles to movement flow inside the ICU, causing workflow disruptions, dissatisfaction and other consequences.

Jordan is a Middle Eastern nation that is small, resource-constrained, and middle-income, with an estimated total population of 11.06 million (Department of Statistics, 2021). Jordan's health system is a complicated mixture of public and private sectors. There are 31 public hospitals, 15 military hospitals, two teaching hospitals (associated with universities), and 69 private hospitals (Ministry of Health, 2021). Over the last fifty years, Jordan's nursing profession has made significant strides toward role adequacy. There are around 25,108 registered Jordanian nurses (RNs) between 2017 and 2020, with approximately 48% nurses employed in Jordan and the remainder jobless or relocating to other nations (Jordanian Nursing Council, 2020). Around half of Jordan's nurses are female, and the overall number of nurses grows by around 1, 500 per year. The ratio of nurses to patients varies across public and private hospitals, as well as between critical care and general wards. In private hospitals, the ratio is 1:1; and in public hospitals, it is 1:2 (Jordanian Nursing Council, 2020).

Nurse turnover reached 36.6 percent in Jordan, and this figure is anticipated to rise (Hayajneh et al., 2009). Jordanian nurses have poor working circumstances, including stress, unhappiness, and an unsupportive work environment, which contributes to their high turnover rate (Alnuaimi et al., 2020; Hayajneh et al., 2009; Suliman and Aljezawi, 2018). Additionally, Jordan today confronts unique issues that are distinct from those faced by any other bordering nation. Jordan is experiencing a massive population increase as a result of the inflow of refugees, putting great strain on the health care system and raising concerns about the type of health care services given (Suliman et al., 2021).

Thus, depending on the kind of institution in which nurses work, the environment of the Jordanian healthcare system may provide various obstacles. While the links between hospital work environments and nurse outcomes have been extensively studied in North American, Asian, and European settings, we know very little about them in Jordan. Due to Jordan's continued rising demand for healthcare, it is critical to study the effect of the work environment on nurses' job satisfaction. After searching the different academic databases, there have been no previous studies that evaluated the designs and environments of ICUs and their effect on nurses' satisfaction in Jordan. This study aims to investigate the effect of the ICU design and environment on critical care nurses in three intensive care units at King Abdullah University Hospital (KAUH) at Al-Ramtha, Jordan. The ICUs at KAUH are designed in two distinct styles: private rooms and open wards. One of the objectives of this study was to provide the design practitioners with evidence-based insights into the ICU design by exploring the contribution of ICU layout and its effect on nurses' satisfaction and movement pattern during healthcare activities. Working in intensive care units and understanding their complicated dynamics requires an in-depth understanding of the functionally distinct areas and their relationships. Furthermore, this study will serve as a springboard for providing scientific evidence for the policymakers in Jordanian hospitals to pay more attention to ICU designs and environments and concentrate their efforts on improving Jordan's healthcare environment and consequently improving the nurses' satisfaction, quality of nursing care, and patients' outcomes.

2. Materials and methods

2.1. Design and setting

This study used an observational and survey-based design. The study was conducted in three separate intensive care units (ICU1, ICU2, and

ICU3) at KAUH, a major university hospital in northern Jordan (Figure 1). ICU1 is distinguished by its private room arrangement. ICU2 and ICU3 are two intensive care units that have an open ward layout.

The study was quantitative and comparative in nature, with no participation of a control group. This study employed three main tools for data collection (1) a short survey used to ascertain nurses' satisfaction with the layout of the ICUs. (2) A pedometer was used to collect data on walking distances, and (3) an observational study referred to as behavioral tracking was conducted using an indoor positioning system, or IPS.

2.2. Ethical considerations

The research team obtained approval of the study protocol by the Institutional Review Board (IRB) committee in Jordan University of Science and Technology (JUST), approval number 154/2019, before conducting the study.

2.3. Sampling and participants

The accessible sample was all staff nurses on the morning shift (8 working hours). The nurses who agreed to participate in the study were informed and given an explanation of the purpose of the study and a description of data collection procedures. Participation in the research was voluntary and anonymous, and each nurse had the opportunity to withdraw at any time. Inclusion criteria used in this study were a nursing license, full-time employment in an acute care ward at the hospital for at least six months, and age between 20 and 60 years. Exclusion criteria included student nurses and nurse assistants.

No strategy was implemented to ensure that nurses participated in the study. The recommended sample size of this study was calculated using G*Power 3.1.9.7 (Faul et al., 2020) based on power analysis for a partial one-way ANOVA-F test. The effect size reported in previous studies reached 0.86 ((Berkland et al., 2017; Latour et al., 2010; O'Connell, 2015). The priori sample size calculation, given $\alpha = .05$, power $= .80$, and $d = .55$ estimated that 12 subjects were needed in each group (Cohen, 1988). This study has a small sample size. However, descriptive and ANOVA tests were used to identify possible trends and significant differences in nurses' satisfaction with ICUs' design features. The significance level for assessing trends was established at $p < .05$.

2.4. Research tools

2.4.1. Survey

The level of satisfaction was measured through a self-administered questionnaire with closed-ended questions. The questionnaire consisted of two sections; the first section is demographic data contained questions in a multiple-choice format with information on gender, years of experience, nurse's position in the unit, and work-shift hours. The second section includes items that assess nurses' satisfaction with the ICU layout and its attributes and are constructed based on a scale developed by Rashid (2007). Only 25 items were selected as being applicable to this study. Each item in this set of questions used a 6-point Likert scale from 1; strongly disagree to 5; strongly agree and six not applicable. Islam and Rashid (2018) evaluated the scale's validity and reliability. Additionally, An internal consistency analysis was conducted for the scale and earned a Cronbach's α of .938, indicating satisfactory internal consistency for the scale components.

2.4.2. Walking distances

An Omron HJ-321 pedometer (Figure 2) was used to collect data on the number of steps taken, walking distances traveled, and calories burned. Prior to nurses starting their duty, the pedometer was set to zero.

Figure 1. The Layout of the three ICUs.

Number	Measurement	Pedometer A	Pedometer b	Pedometer C	Pedometer D	Pedometer E
1	Steps					
2	Distance					
3	Calories					
4	Time					

Figure 2. Omron HJ-321 pedometer.

Nurses were instructed to place the devices in the outfit pocket near the waist to obtain the most precise measurements possible, as illustrated in Figure 2. At the beginning of the study, each participant was asked to take ten steps to calibrate the pedometer according to the manufacturer's specifications and following the study's assumptions conducted by Hua et al. (2012). The researchers excluded distances traveled outside the unit, where they took the device from any nurse who came out of the unit, fixed it near the door, and then returned it to the nurse from the same location when the nurse returned to the unit. Each device was assigned a code. At the conclusion of the shift, the researchers placed the pedometer's data on a table.

2.4.3. Behavioral tracking

Behavior tracking was used to record nurses' circulation paths and locations inside the ICU interior environment. This was done via direct observation on-site and through the use of Ultra-wideband (UWB) technology-based Indoor Positioning Systems (IPS). Each participant's nurse was observed for 1 h, and his or her activities were recorded on the unit's plans—the IPS system assists in detecting the movement and position of persons inside the enclosed space. Recently, UWB technology has become the most common method for identifying each active element in space, with placement precision of a few centimeters anticipated. Among the many methods utilized for indoor localization, the Decawave (2020) commercial system was used (Figure 3). Decawave's UWB evaluation kit (MDEK1001) is very simple to install, requiring just the configuration of a network of beacons (anchors) and devices (tags) (Simedroni et al., 2020). The beacons are installed in the environment above walls and ceilings, while the tags are inserted into the nurses' pockets. Prior to the research, the system was tested and calibrated. Jordan University of Science and Technology's engineering projects team provided the AutoCAD plans. Prior to beginning the study, the researcher took a tour of the unit to verify that the drawn plans corresponded to the actual ones and documented the spaces use, the number of patient beds and their placement, and the location of different equipment and furniture surrounding the nursing station and patient beds.

2.5. Data analysis

Statistical data analysis was performed using SPSS25 (IBMCorp Ibm, 2017). The analysis included descriptive statistics and analysis of variance (ANOVA) to examine the mean differences between nurses' data in the three ICUs. Cronbach's coefficient (α) was used to measure the internal consistency of the survey tool.

3. Results

The sample included 36 nurses. Twelve were from ICU1, twelve were from ICU2, and twelve were from ICU3. There were 21 female participants. Around 14 individuals have zero to five years of experience, 14 have six to ten years of experience, seven have eleven to fifteen years of experience, and eight nurses have more than fifteen years of experience. Around thirty participants were nurses, and six were charge nurses.

3.1. Survey results

The descriptive results (Figure 4 and Table 1) showed variations in nurses' responses at the three ICUs to different questions. In general, nurses in ICU2 are more satisfied with the design of their working space (C10; $M = 3.20$, $N = 36$) than nurses in ICU1($M = 3.10$, $N = 36$) and ICU3 ($M = 2.91$, $N = 36$). Nurses in ICU2 indicated that the environmental elements (temperature, light, and air velocity) contribute to their work performance in this unit since they have control over temperature and light penetration. The nurses on ICU2 express more satisfaction with the degree of privacy in the primary workstation, auditory privacy, and the availability of suitable work surfaces than other ICUs. Additionally, they believe that team members' closeness and the quantity of health care professionals in the workstation are suitable. Additionally, they are capable of monitoring patients from the nursing station.

On the other hand, nurses in the ICU1 (B11; $M = 3.08$, $N = 36$) expressed satisfaction with the overall design of the unit layout in comparison to the ICU2 ($M = 2.58$, $N = 36$) and ICU3 ($M = 2.92$, $N = 36$). The

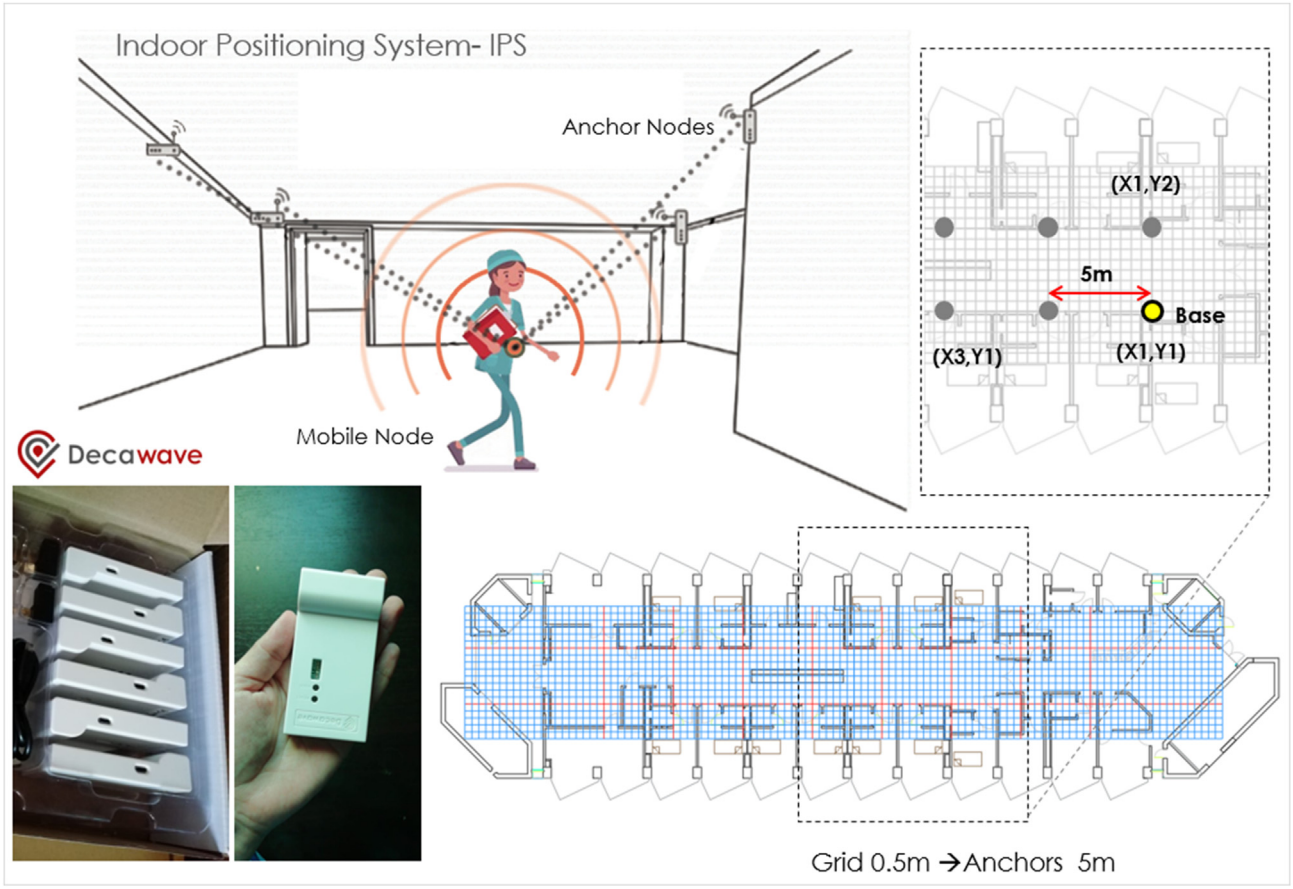

Figure 3. Indoor Positioning System Using Decawave's UWB evaluation kit.

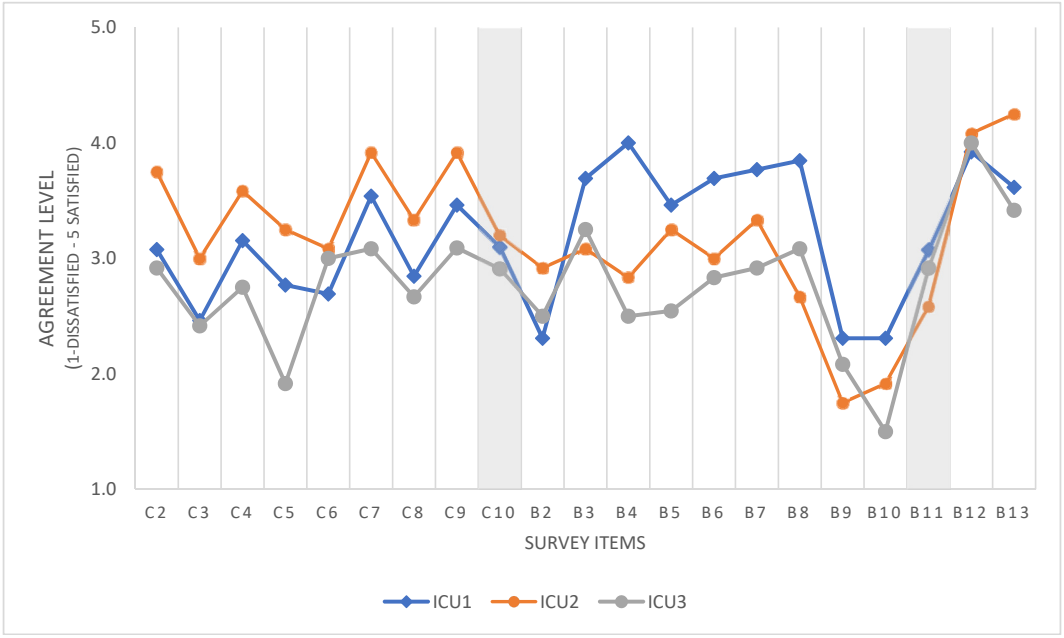

Figure 4. Mean values of all nurses' satisfaction with the ICUs design. A higher mean score is associated with a higher level of satisfaction.

nurses expressed satisfaction with the nursing station's placement, the number of patient beds, the layout of patient rooms around the nursing station, and the nursing station's closeness to patients, supplies, high-use care items, and medicine storage near the patient room. Additionally, the design promotes collaboration or cooperation, minimizes traffic, and maximizes space for the patient's family.

In general, nurses in ICU3 reported poorer satisfaction than nurses in other units, and they provide a lower rating to attributes relating to the

Table 1. Nurses' and charge nurses satisfaction with the ICUs design.

Code	Items	Nurses (N[a] = 10) M[b]	Charge Nurses (N = 2) M	Nurses (N[a] = 10) M	Charge Nurses (N = 2) M	Nurses (N[a] = 10) M	Charge Nurses (N = 2) M
C2	Environmental features (temperature, light, Air velocity)	2.82	4.50	3.90	3.00	3.00	2.50
C3	The ability to control the temperature and light penetration	2.45	2.50	3.50	0.50	2.40	2.50
C4	Privacy in primary workspace	3.27	2.50	3.40	4.50	2.80	2.50
C5	Auditory privacy	2.82	2.50	3.00	4.50	1.70	3.00
C6	Sufficient work surfaces	2.73	2.50	3.40	1.50	3.00	3.00
C7	Proximity to the team members	3.45	4.00	4.10	3.00	3.00	3.50
C8	The number of healthcare providers in the workstation	2.91	2.50	3.80	1.00	2.60	3.00
C9	Ability to monitor patients from the station	3.36	4.00	4.00	3.50	3.00	3.50
C10	Satisfaction with the primary workspace design.	3.20	3.10	3.00	2.82	2.91	3.00
B2	Layout supports informal meetings.	2.18	3.00	3.40	0.50	2.60	2.00
B3	Layout supports teamwork or collaboration.	3.73	3.50	3.50	1.00	3.20	3.50
B4	The location of the nurse station	4.00	4.00	3.20	1.00	2.40	3.00
B5	The arrangement of patients' rooms around the nurse station	3.45	3.50	3.60	1.50	2.33	3.50
B6	Nurse station proximity to patients, supplies, and high-usage care items	3.64	4.00	3.40	1.00	2.80	3.00
B7	The layout reduces the traffic.	3.82	3.50	3.60	2.00	2.90	3.00
B8	The number of patients beds	3.73	4.50	2.90	1.50	3.10	3.00
B9	Storing medication near the patient room	2.09	3.50	2.00	0.50	1.90	3.00
B10	The availability of space for family	**2.27**	2.50	2.20	0.50	1.20	3.00
B11	Satisfaction with the overall unit layout	3.00	3.50	2.90	1.00	2.90	3.00
B12	Spending more time walking in the unit in relation to other activities.	4.00	3.50	3.90	5.00	4.10	3.50
B13	Walking takes away from the patient care time	3.64	3.50	4.20	4.50	3.80	1.50

Likert Scale: (1) strongly disagree to (5) strongly agree.
[a] N = sample size.
[b] M = Mean value.

intensive care unit's design. In terms of nurses' subjective perception of walking, the researcher provided two questions (B12 and B13). The descriptive results indicated that nurses' in the three ICUs feel that they spend more time walking in their unit in relation to other activities (ICU1; M = 3.92, ICU2; M = 4.08, and ICU3; M = 4.00), and Walking in the ICU takes away from the time they would otherwise have for patient care (ICU1; M = 3.62, ICU2; M = 4.25, and ICU3; M = 3.42).

Table 1 illustrates the mean values for nurses' responses in the three ICUs compared to the charge nurses' responses. The data, however, do not reveal a trend in which charge nurses' evaluations reflect those of nurses on certain items but not on others. Due to the restricted number of charge nurses on each unit, statistical comparisons are difficult.

Table 2 presents the Analysis of Variance test results. It is clear from the table that there is a statistically significant difference in nurses' responses to four questions: the location of the nursing station and its proximity to their patients and supplies ($F(2,28) = 5.219$, $p = 0.012$). The arrangement of patients' rooms around the nurse station ($F(2,28) = 3.474$, $p = 0.045$), the availability of space for patients families ($F(2,28) = 3.747$, $p = 0.036$), and others cannot hear conversations in the primary workplace ($F(2,28) = 4.414$, $p = 0.022$). The results indicated that nurses in the ICU1 are more satisfied with the nursing station's location than the other units. Tukey HSD test confirmed differences between ICU1, ICU2, and ICU3. The mean values indicated that nurses in ICU1(m = 4.00) recorded higher nurses' satisfaction than nurses in ICU2 (m = 3.20) and nurses in ICU3 (m = 2.40). The results indicated differences between the ICUs in nurses' viewpoints about the availability of space for the family in the ICU. The mean values indicated that nurses in ICU1 (m = 2.27) are satisfied with the availability of space for family more than nurses in ICU2 and ICU3 (m = 2.20 and 1.20).

On the other hand, the Tukey HSD test confirmed differences between the ICUs in nurses' viewpoints about the arrangement of patients' rooms around the nurse station. The mean values indicated that nurses in ICU2 (m = 3.60) are satisfied with the arrangement of patients' rooms around the nurse station in the ICU2 more than nurses in ICU1 (m = 3.45) and nurses in ICU3 (m = 2.33). Moreover, the mean values indicated that nurses in ICU2 (m = 3.00) are satisfied with the primary workspace design because it provides auditory privacy where others cannot hear their conversations in their primary workspace. Unlike ICU1 and ICU 3, the nurses feel that others cannot hear your conversations in their primary workspace (ICU1; m = 2.82, ICU3; m = 1.70).

3.2. Pedometer records

According to the pedometer readings for nurses in the three ICUs, the analyses indicated that nurses in ICU2 and ICU3 recorded high mean walking distance and walking steps (ICU2: mean distance = 2.87km; mean steps = 4041.67) (ICU3: mean distance = 2.96km; mean steps = 4208.17) in comparison to nurses in ICU1, where ICU1's nurses recorded the lowest walking distance and steps taken (mean distance = 2.28km; mean steps = 3237.08). ANOVA analysis verified the mean differences in nurses' walking distance and steps across the three intensive care units (ANOVA walking distance $F(2,28) = 3.693$, $p = 0.038$) (ANOVA steps $F(2,28) = 3.760$, $p = 0.036$). Post hoc comparison using the Tukey HSD test revealed statistically significant differences in nurses' walking distances and steps taken between ICU1 and ICU2 nurses ($p = 0.049$) and between ICU1 and ICU3 nurses ($p = 0.017$). There were, however, no significant differences in nurses' walking distances and steps taken in ICU2 and ICU3 ($p = 0.877$). These discrepancies suggest that the placement of the nursing station and the unit layout have an impact on nurses' walking behavior.

3.3. Behavioral tracking

Behavioral maps record nurses' movement paths inside intensive care units; they illustrate the most frequently utilized areas and the effect of the nursing station's placement and layout on nurses' walking distances in

Table 2. Differences between three units in nurses' satisfaction with their unit layout (excluding the charge nurses).

		Item	F	*P*	Eta	1-β
Nurses satisfaction with ICU design attributes	C2	Environmental features (temperature, light, Air velocity)	1.907	0.167	0.120	0.362
	C3	The ability to control the temperature and light penetration	3.062	0.063	0.179	0.545
	C4	Privacy in primary workspace	0.701	0.505	0.048	0.156
	C5	Auditory privacy	**4.414**	**0.022**	**0.240**	**0.713**
	C6	Sufficient work surfaces	0.966	0.393	0.065	0.201
	C7	Proximity to the team members	2.275	0.121	0.140	0.423
	C8	The number of healthcare providers in the workstation	2.233	0.126	0.138	0.416
	C9	Ability to monitor patients from the station	1.818	0.182	0.119	0.346
	C10	Satisfaction with the primary workspace design.	0.873	0.429	0.059	0.185
	B2	Layout supports informal meetings.	2.623	0.090	0.158	0.479
	B3	Layout supports teamwork or collaboration.	1.008	0.378	0.067	0.208
	B4	The location of the nurse station	**5.219**	**0.012**	**0.272**	**0.788**
	B5	The arrangement of patients' rooms around the nurse station	**3.474**	**0.045**	**0.205**	**0.600**
	B6	Nurse station proximity to patients, supplies, and high-usage care items	1.653	0.215	0.106	0.319
	B7	The layout reduces the traffic.	2.015	0.152	0.126	0.380
	B8	The number of patients beds	1.731	0.196	0.110	0.332
	B9	Storing medication near the patient room	0.075	0.928	0.005	0.060
	B10	The availability of space for family	**3.747**	**0.036**	**0.211**	**0.637**
	B11	Satisfaction with the overall unit layout	0.023	0.978	0.002	0.053
	B12	Spending more time walking in the unit in relation to other activities.	0.177	0.839	0.013	0.075
	B13	Walking takes away from the patient care time	0.877	0.427	0.059	0.186
		Steps	**3.693**	**0.038**	**0.209**	**0.630**
		Distance	**3.760**	**0.036**	**0.212**	**0.638**

Bolded values represent statements with statistically significant differences. F = F statistic value; P = Statistical Significance value; Eta squared = The proportion of variance; 1-β = observed Power.

the three ICU units. It is evident in Figure (5) that there is a difference in the places where the movement is concentrated. In ICU1, most nurses' movements are concentrated around and close to the nursing station. The walking paths in ICU2 are speared out across the unit and along the hallway that connects the nursing station, patient areas, and supporting spaces outside the patient area. While in ICU3, nurses' movements form a route connecting the nursing station and the storage area.

The researchers compared movement layouts to functional space arrangements to better understand the movement pattern in ICUs. They found that Nurses' movements in ICU1 were concentrated around the nursing station due to the nursing station's central location and the patient rooms arranged around it, as well as the support rooms (medicine room, soiled room, storeroom, staff changing room, and handwashing sinks) located behind the nursing station, which required the nurses to travel fewer distances throughout the unit.

While ICU2 is split into two sections, as shown in the Figure (5), the unit is divided into a patient area and a support area. As a result, nurse movements are intense inside the patients' area and along the corridor between the patients' area and the support area. The nurses on this unit had a greater walking distance than on ICU 1 or ICU 3. The increased walking distances are caused by nurses' movements to the medicine room, soiled room, storeroom, staff changing room, and handwashing sinks situated distant from the nursing station.

In ICU3, the support rooms, including the medicine room and soiled room, are situated close to the nursing station. However, the storeroom is located distant from the nursing station, resulting in a dense movement flow of nurses between the nursing station and the storeroom. Additionally, the unit design had increased walking distances due to the nursing station's placement, which is not central to the patient's area. Additionally, a wall blocks the view of some patients from the nurses' station, as shown in Figure (6), forcing them to walk constantly towards these patients to monitor them. Additionally, there are two locations for handwashing sinks in the unit: one near the nursing station and another located at the unit's end, which requires some nurses to travel there.

The research concludes that the unit with private patient rooms design outperformed the units with open ward design due to the optimal arrangement of patient rooms around the nursing station and the ease with which nurses can reach the supporting rooms that are near the nursing station. The most common travel route for a critical care nurse (CCN) is between the nursing station and the storage area, indicating that the adjacency of these two areas can reduce the number of non-essential travels for the CCN. The second most common travel route for CCN is between the workstation and the handwashing area. Therefore, adjacency between these two regions may be beneficial.

4. Discussions

Intensive care units are the most important place in the hospital that provides intensive nursing and medical care for patients who are acutely very ill. A physically well-organized setting is essential to the health team members to deliver efficient care for their patients. Designers need data to assist them in developing knowledge-based design guidelines (Van Hoof et al., 2015). The study's strength stems from its comprehensive approach and the fact that the research results may be integrated into Jordan's ICUs design process.

The current study attempted to identify the design characteristics in intensive care units that have an influence on nurse satisfaction. According to the questionnaire findings, nurses expressed varying degrees of satisfaction with the placement of their nursing station. In the first unit, which has a private patient rooms design, nurses were more pleased with the placement of the nursing station than the second and third units due to its proximity to patients rooms and other support rooms (such as medication room, dirty room, utility room, and storages). These findings are consistent with the study of Nazarian et al. (2018), which recommended that the nursing station be central to the ward or unit to facilitate access to patient rooms, treatment rooms, staff rooms, isolation rooms, and the entrance to the ward.

The notion that the care unit's design and layout of functional areas affect nurse behavior and satisfaction has been supported (Yi and Seo, 2012). Most nursing activities with critically ill patients need nurses to travel across several functional and transitional areas rather than

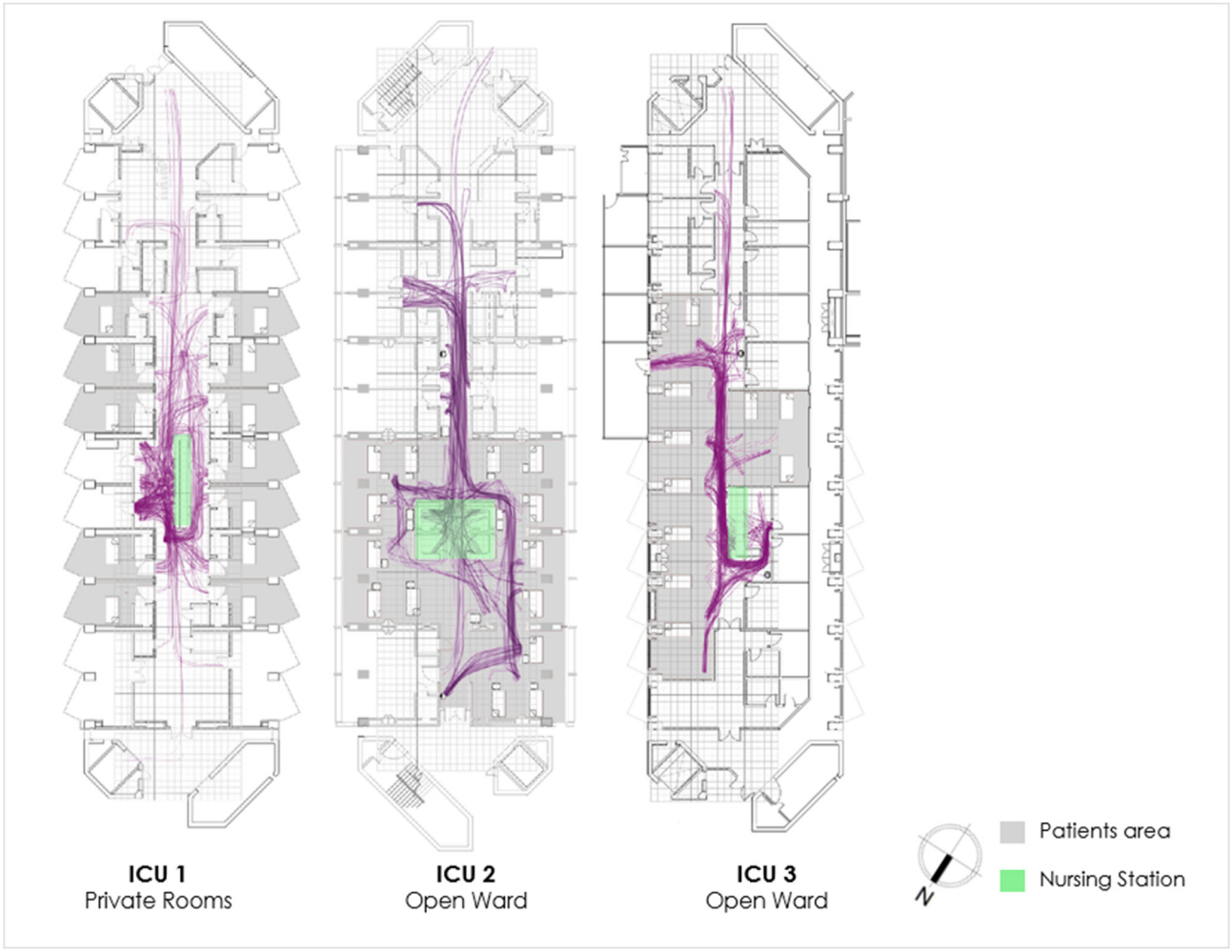

Figure 5. Nurses' Walking Paths in the three ICUs.

completing an activity inside a single functional area. Transportation of equipment and supplies necessitates traveling through more transitional regions as well. These material-related tasks include retrieving supplies and tools which may be time-sensitive under certain operating circumstances. Consequently, proximity to locations of patient care activities may result in decreased travel time and sufficient retrieval of materials, supplies, and equipment (Lee et al., 2020).

The pedometer's findings for distance traveled and steps taken indicated that nurses in the open ward design's units walked long distances in comparison to the ward with private rooms layout. This finding is in contrast to prior research findings indicating that an open design may assist reduce the travel distance (Hicks et al., 2015). Interestingly, the walking path diagrams revealed increased distance traveled results from the functional spaces' layout. The existence of places necessary for nurses to support patients' health care, such as medication rooms, storage, and a handwashing area distant from the nursing station, has contributed to the increase in distance traveled. Distancing these primary spaces from one another increases nurse fatigue and records a long time for travel between these spaces. Observations in the units revealed that the ICU1 design enabled nurses to remain at their station and utilize it, unlike other intensive care units. This unit's nursing center was used to monitor patients, make phone calls, input patient data into their files, and use the computer to enter and order medicine, obtain blood samples, and do other medical procedures.

A nursing station's primary function is information and communication. It is responsible for documenting medical records during health care and serves as a liaison to other medical team members regarding any contact with other departments (e.g., laboratory, blood, and radiology) or nursing station personnel. Thus, supplies, instruments, and medications necessary for the intended care and operation must be kept near the nursing station; this includes acquiring, installing, and maintaining equipment. As a result, the consolidation of the support area and nursing station may be advantageous, given the frequency of visits to this area. According to Nazarian et al. (2018), it is also critical to define the supply region regarding other commonly visited locations. Additionally, as shown in the spaghetti charts (Figure 5), critical choices regarding the placement of supplies in a unit may impact how nurses enter and exit the unit.

Based on our observation, we noticed that the nurses in ICU2 seldom utilize the nursing station unless they need to use computers or make a phone call, and the nurses sit near their patients. Additionally, the nurses prepared four medical carts and distributed them in the patients' area to ease access to essential medical equipment and minimize travel to the medication room. While on ICU3, nurses sit near patients to monitor them since they cannot watch them from the nursing station. In this unit, the nursing station is seldom utilized since it is only used when a computer or phone is required.

Frequent overlapped flow patterns in health care may jeopardize both patient and staff safety. They can arise due to interactions with the physical environment, other personnel, or items on the unit (Neyens et al., 2019). The research demonstrates shortening the distances between places to be visited or placing regularly traveled start and finish sites closer or next to one another may help decrease nurses' fatigue throughout the care activity.

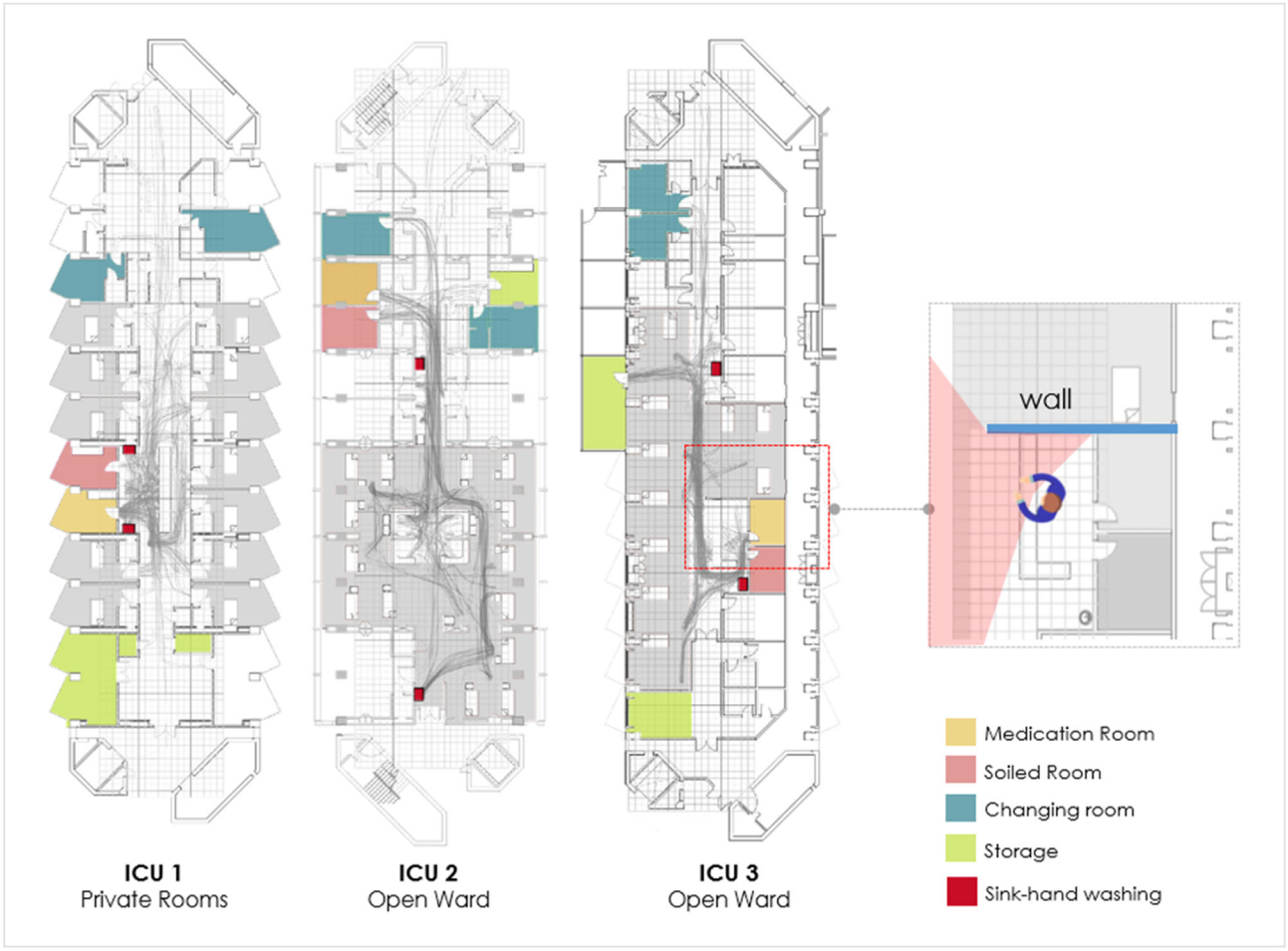

Figure 6. Supportive rooms distribution in the three ICUs.

Additionally, regardless of the design of the care unit, it was necessary for employees to move inside the area and avoid colliding with equipment or other personnel while doing their assigned tasks. Thus, although nurse flow patterns may be influenced by the convergence of an activity's start and finish zones, they can also be influenced by the requirement to avoid people or other medical equipment on their travel route. Similar to the current literature, which indicates that ICU layouts contribute to adequate collision-free flow (Chisholm et al., 2008), this study illustrated that different areas could have a distinct flow pattern. According to spaghetti diagrams of nurse movement, locating supporting rooms outside the patient area may contribute to the rise in movement interruption due to the dense concentration of people.

Understanding the nature of nurse mobility patterns may aid in designing and planning intensive care units, and proper zoning and convergence choices can assist in minimizing unnecessary visits (Yi and Seo, 2012). By traveling via fewer areas, the time and distance traveled for each activity may be reduced. This is especially critical since nurses play an important role in ensuring patient safety (Carayon and Alvarado, 2007; Poley et al., 2011).

5. Conclusion

The aim of this study was to investigate the effect of the ICU design and environment on nurses' satisfaction and movement in three intensive care units at a university hospital in Jordan. In conclusion, the overall results of this study showed strong evidence that the ICU design and environment have significant effects on the nurses' walking distances and on nurses' satisfaction.

By examining the role of the ICU layout and its attributes on nurse satisfaction, the questionnaire results reveal that, among the variables studied, the position of the nursing station in the ICU had a statistically significant effect on the nurses' satisfaction. Nurses were more satisfied with the placement of the nursing station in the first unit, which contains private patient rooms (ICU1), than in the second and third units. This is owing to the nursing station's optimal placement in relation to the patient rooms and other support rooms, as evidenced by the data obtained through pedometer readings and the tracking of the nurses' movement.

In this study, the movement maps showed different flow patterns of nurses across the three units. The data revealed a decrease in the average walking distances and steps taken by nurses in ICU 1, where the nursing station is centrally located and patient rooms are arranged around the station. This is particularly noticeable when looking at the nurses' walking path, revealing that their movement is centered around the station. The placement of the nursing station (central location) helped reduce walking distances to reach patients. However, nursing station location alone is not enough to reduce walking distances. Mean walking distances were higher in ICU2 than in ICU1, which was explained by the proximity of the supporting spaces (medicine room, solid rooms, and storage) to the nursing station. Therefore, when designing ICUs, the location of nursing stations must be considered, and the distribution of patient rooms/beds and support spaces.

6. Recommendations

For the purpose of improving the designs and environments of the intensive care units, the researchers recommend the following tips:

1. Patient beds should be distributed around the central nursing station to allow visibility and monitoring from the station to all patient beds
2. The supporting rooms should be close to the nursing station. This allows the nurse to walk shorter distances while caring for patients.
3. Due to the need for nurses to react quickly to patients' needs and other medical team members and minimize unnecessary traffic inside the unit, closeness to the nursing station and the supply area containing critical supplies is highly recommended.
4. This study needs to be replicated with a bigger sample size and different types of this pattern in other organizations.

7. Limitations

There were a number of methodological and sampling limitations in this study. To begin, there is the problematic nature of the research work in light of the spread of the Coronavirus and the implementation of lockdown measures by the government. As a result, the research was discontinued early, and only a small sample of 36 nurses was involved. The small number of nurses at a specific institution precludes generalization of the findings. The sample was voluntary and, as such, may be less representative of the population at large. Such would negatively affect external validity (Campbell, 1979; Muller, 1989). Future research may benefit from a bigger sample size to conduct a more rigorous analysis that considers the unique characteristics of hospitals, cases, and design.

8. Implications for practice

The findings of this research have ramifications across many disciplines. Along with providing helpful information for designers and architects, this study aims to educate medical personnel and nurses about some of the issues connected with the layout and design of intensive care units.

Regrettably, this research focused only on the design of intensive care units at KAUH; however comparable studies might be undertaken in other critical care facilities in Jordan. Hospital and healthcare administrators should mandate that design teams undertake research as part of the design process. This may be accomplished with the assistance of academic researchers or healthcare experts. Surprisingly, of all healthcare workers, nurses have been pioneers in researching the physical environment's effect on patient care.

The physical environment may influence many elements of the healthcare experience, including the staff's capacity to assist patients and their families. Collaboration between medical personnel and design experts and incorporating research into the design process are critical components of successful building projects.

Declarations

Author contribution statement

Bushra Obeidat: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Esra'a Al-Shlool: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mohammad Bani Younis: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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