Original Article

Using intelligent, interactive LED lighting systems in the development of medical care for the elderly

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Background: The age-related decline in vision among the elderly can lead to a reduced ability to adapt to glare stimulation, no longer being able to identify all parts of the chroma and taking longer to adapt to changes of light. This reduced vision can hinder the elderly's activities, thus affecting their lifestyles. Figuring out how to assist the elderly through improving their lighting, especially to keep them from falling or colliding with things in general or whether in hospitals and nursing homes, has attracted considerable attention in the medical community.

Methods: A room was designed with adjustable lighting so elderly patients could find a visually comfortable level of light. The subjects had been collected in those equipped room between 1/1/2010 and 12/30/2010. At the start of the experiment, a questionnaire was administered in the fever observation room of the Mackay Memorial Hospital Emergency Room. This was used to understand how the lighting affected the patients. Another focus of the experiment was to save energy by using light-emitting diode (LED) lamps, which use less energy and can be configured to easily adjust their brightness. Considering medical staff and patients cannot be in a space with glare for extended periods, they have a higher need for an antiglare solution. Glare was reduced by using an intelligence lighting-control system (ILCS) by LED lamp, which has an array of light sources, equipped with a diffuser plate.

Results: Most patients were satisfied with the lighting environment created by the LED lamps. Among the 200 randomly selected patients, 92.5% of patients preferred the LED lighting to ($P<0.001$). The satisfaction with LED lighting among the 121 people over the age of 50 that indicated the LEDs were better at providing sufficient lighting (116/121, $P<0.001$) and better aided the patients in identifying the things around them (121/121, $P<0.01$).

Conclusions: The power measurements showed that LED lighting as a substitute for T5 lamps could save around 20% on energy and this return period would last about four years. There is a high potential for future growth as the popularity of LEDs rises and prices fall. It is widely accepted that LEDs can be used to improve the lighting environment for the elderly in medical institutions. The ILCS can ameliorate the lighting problem and help prevent the elderly from falling or having accidents due to insufficient lighting. LED lights have adjustable characteristics. Coupled with the design of the intelligent lighting sensing system, LEDs could be used to help elderly people all over the world cope with reduced vision. This is an important part of the development and application of LED lighting in the future.

Keywords: Light-emitting diode (LED); medical care; elderly; lighting

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Introduction

Age-related vision loss is caused by a loss of elasticity in the crystalline lens of the eye creating a surface that is no longer smooth (1). Age-related vision loss can make it hard for the elderly to see colors and adapt to changes in light (2). This vision impairment can negatively affect their lifestyles (3).

The MMH Emergency Department is a free-standing emergency medical care facility operating twenty-four hours a day. There is a rescue area, intensive care unit and observation ward. Lighting in the emergency room is important and the hospital must be well lit during all hours of operation. The bright light can result in vision impaired patients falling, complaints that the lights are too bright to sleep (4), and an increased energy cost from running the air conditioning to counter the extra heat from the continuous light. The MMH Emergency Department needs brighter lighting like the Obstetrics and Gynecology Departments have. However, these departments lighting equipments are also requested turning into softly lit walkways, while especially in the night, to prevent causing insomnia in the patients. This keeps their eyes from being directly exposed to the light too much. In order to keep glare and reflections off computer screens and avoid causing the dazzling, or eye-blind, effect when the staff look up from their screens, the emergency care and service stations should be brightly and clearly lit (5,6).

Manipulating light to reduce falls and accidents among the elderly has garnered much attention in the medical community (7-9). Elderly patients would feel more comfortable under proper lighting and would be able to read inside without eye fatigue (10). The change could also aid in their recovery and improve their satisfaction with their care (11). The purpose of this research is to reduce the number of falls and accidents among the elderly by improving the lighting in their care facilities, such as emergency rooms, hospitals and nursing facilities.

Figure 1 Room with LED lamps.

Figure 2 Room with T5 lamps.

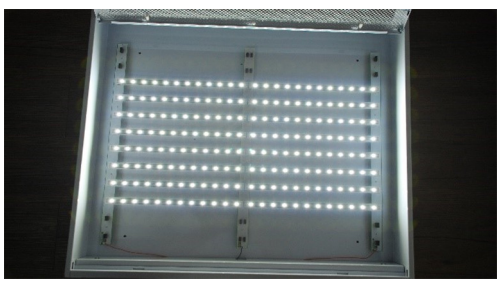

Figure 3 An array of low-power LED lamps.

Methods

A questionnaire was administered to understand how the elderly felt about and experienced the lighting. Patients were divided into an experimental group and a control group (*Figures 1-3*) and exposed to different levels of brightness and light intensity. In the experimental group, adjustable light-emitting diode (LED) lights were installed for patients in the Mackay Memorial Hospital Emergency Room, but traditional lights were installed in the control group. The subjects had been collected in those equipped room between 1/1/2010 and 12/30/2010. The questionnaire focused on the Ergonomic Lighting Indicator (12), which evaluates the following characteristics of lighting: (I) the object discrimination effect, which involves the contrast levels between objects; (II) depth of field, which is the distance between the nearest and farthest objects that appear acceptably sharp in a scene; (III) lighting comfort, which

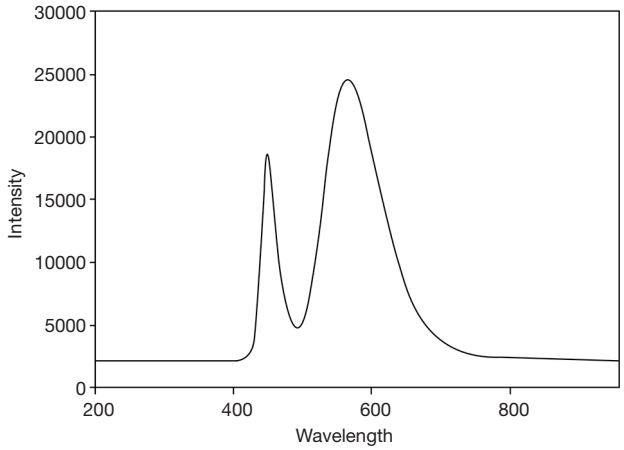

Figure 4 Color temperature 4700K, spectrum of white LED lighting.

is mainly used to avoid glare; (IV) dynamic visual acuity, which involves the perception of a moving object with low shadow; and (V) lighting management, in which a lighting control switch is provided to help users adjust their lighting according to their needs (*Figure 4*). Energy conservation was also studied by measuring the disparity with kilowatt-hour meter between energy-saving LED lamps and traditional lamps with adjustable lighting capabilities.

Results

Among the 200 randomly selected patients, the number of males was 101 and the number of females was 99, accounting for 51% and 49% of the total number of subjects, respectively. Five patients were under 20 years of age, 27 patients were 21–30 years old, 34 patients were 31–40 years old, 23 patients were 41–50 years old, 21 patents were 51–60 years old, and 42 patients were 61–70 years old. Twenty-five patients were 71–80 years old, accounting for 13% of the total number of subjects, and 23 patients were over age 80, accounting for 12% of the total number of subjects (*Table 1*). 49 patients had fallen in the past because of dim light. They assume that LED lighting could effectively prevent future accidents. Power saving was identified as the most important concern overall on the patient questionnaire, as 78 patients ranked it first. The intensity of the lighting was the second most important concern overall. The patients' behavior varied during the experiment. There were 127 patients that often watched TV, making it the most popular activity among the subjects, followed by reading and resting. One-hundred-forty-nine patients turned off the lights while sleeping, but those who left the LED lamps on had a better quality sleep. Most patients were satisfied with the lighting environment created by the LED lamps. According to the questionnaire results, 92.5% of patients preferred the LED lighting to (P<0.001) (*Table 2*). According to the 121 patients over the age of 50, the LEDs were better at providing sufficient lighting (116/121, P<0.001) and better aided the patients in identifying the things around them (121/121, P<0.01) (*Table 3*). The power measurement showed LED lighting as a substitute for T5 lamps would save around 20% on

Table 1 Demographic data of 200 patients

Variable	Number of cases, n (%)
Gender	
Female	99 [49]
Male	101 [51]
Age	
<20	5 [3]
21–30	27 [14]
31–40	34 [17]
41–50	23 [12]
51–60	21 [11]
61–70	42 [21]
71–80	25 [13]
>80	23 [12]
Education*	
Elementary school	57 [29]
Junior high school	9 [4]
senior high school	37 [19]
Junior college	28 [14]
University	38 [19]
Graduate school	24 [12]
Eye diseases	
Yes	122 [61]
No	78 [39]
Chronic diseases	
Yes	105 [53]
No	95 [47]

*, indicated that the data exclude 7 oversea education.

Table 2 Questionnaire results from 200 patients

Variable	Number of patients, n (%)			P
	T5	LED	Indeterminate	
Prevent accidents				
Sufficient lighting	15 [7.5]	178 [89]	7 [3.5]	<0.001
Identify surrounding objects clearly	11 [5.5]	137 [68.5]	52 [26]	<0.001
Identify distant buildings clearly	11 [5.5]	131 [65.5]	58 [29]	<0.001
Lighting comfort				
Comfortable feeling	0 [0]	196 [98]	4 [2]	<0.001
Increased temperature	26 [13]	6 [3]	168 [84]	<0.001
Comfortable environment	24 [12]	172 [86]	4 [2]	<0.001
Skin irritation	4 [2]	0 [0]	196 [98]	<0.001
Vision quality				
Eye discomfort	21 [10.5]	2 [1]	177 [88.5]	<0.001
Eyes strain	34 [17]	2 [1]	164 [82]	<0.001
Reflective while reading	14 [12]	0 [0]	186 [88]	<0.001
Affect sleep	25 [12.5]	2 [1]	173 [86.5]	<0.001
LED satisfaction				
Lighting environment satisfaction	0 [0]	185 [92.5]	5 [2.5]	<0.001
Choose lighting in bed	2 [1]	188 [94]	10 [5]	<0.001

LED, light-emitting diode.

Table 3 The satisfaction with LED lighting among the 121 people over the age of 50 (P)

Variable	Number of patients, n (%)			P
	T5	LED	Indeterminate	
LED				
Sufficient lighting	3 (2.5)	116 (95.9)	2 (1.6)	<0.001
Feel comfortable	0 (0)	121 (100)	0 (0)	<0.001
Identify surrounding objects clearly	4 (3.3)	74 (61.2)	43 (35.5)	<0.01

LED, light-emitting diode.

energy by measuring the disparity with kilowatt-hour meter. Therefore, LED lighting is not only energy-saving, but also provides a better experience for patients (*Figure 5*).

Discussion

Traditional lighting sources, like fluorescent lamps, easily generate heat, which can cause headache. They can also affect the ability to correctly identify objects and color, which causes troubles while reading or working (13). The greatest drawback of the T5 daylight tubes is the serious glare condition and it increases the stimulation of the eyes (14,15). Exposing the naked eye to such an environment may cause soreness or discomfort and potentially lead to myopia in the long-term due to ciliary muscle fatigue (15). T5 lighting can cause tremendous harm to eyes. The most

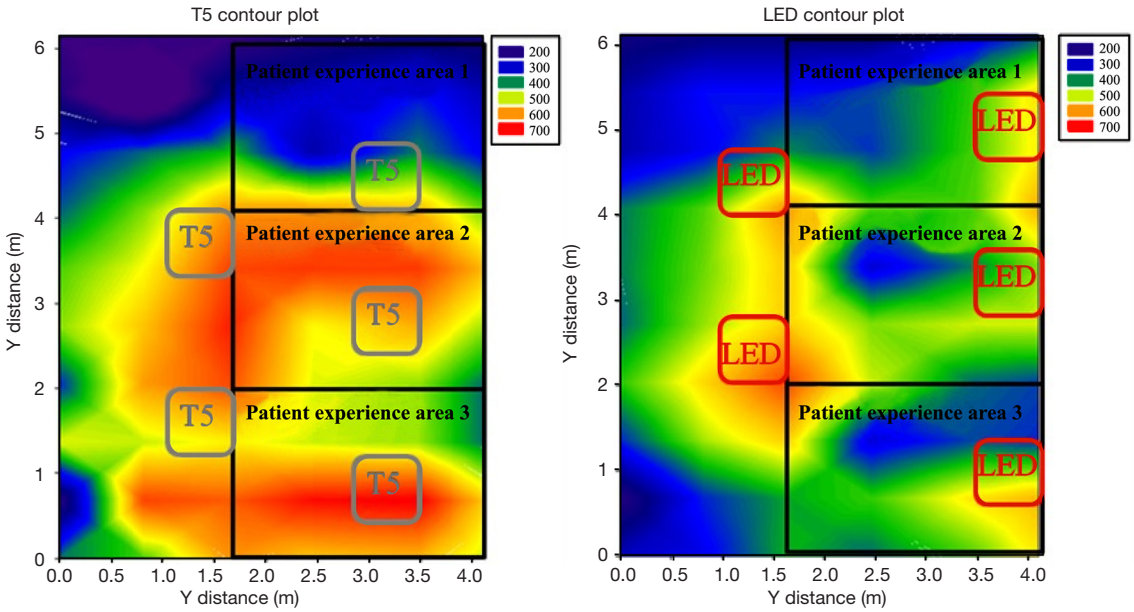

Figure 5 Comparison of the illumination between T5 and LED.

promising alternative light source is the solid-state LED, which has a theoretical maximum luminous efficiency as high as 289 Lm/W (16). According to previous laboratory data, the luminous efficiency of LEDs reached up to 249 Lm/W (measured at current 20 mA) (17), surpassing almost every type of existing traditional light source. LED lighting is therefore expected to have more breakthrough developments in future commercial applications (18).

Light pollution is a prevalent and harmful result of poor light sources. LEDs could be used to lessen the harmful effects of light pollution. The Japanese believe the use of artificial light inhibits the creation of a good luminous environment and creates adverse effects from light passing (Japanese Ministry of Environment, 1998) (19). In addition, the International Commission on Illumination (CIE) defines light pollution as the volume of astigmatism, the direction of trespassing, or the spectrum that causes disgust, discomfort, distraction, or decreased visual ability (CIE, 2003) (20). Taiwan defines light pollution as a disturbance or excessive amount of light radiation (including visible light, ultraviolet and infrared light radiation) that imposes adverse effects on human health and the human living environment (21).

The harmful effects that light pollution could potentially have on human health range from a minor biological clock disorder to serious mental illnesses, such as neurasthenia. CIE president Van Bommel mentioned that light can adjust and suppress human physiological processes (22). The Jasser *et al*. study in 2006 pointed out that light at night will inhibit the production of melatonin in human blood and increase the risk of cancer (23). Also in 2004, Narisada stated that light will inhibit the growth of human melatonin and that women are especially sensitive to this effect (24). Therefore, women workers who turn night into day have a 50% higher chance of getting cancer compared to someone who does not leave the lights on (25). In addition, excessive light can cause the reproductive disorder, increasing the risk of breast cancer and colorectal cancer (25,26). As the elderly mostly stay indoors, the intensity of indoor lighting greatly impacts their lives. The Japanese studied the impact of the environment on melatonin levels in the elderly and indicated that excessive strong lighting led to lower melatonin, which further caused insomnia, poor mood and even melancholy (27). However, research in the United States also showed that blue light can protect eyes and slow down their degeneration. Blue light can also enhance the quality of sleep and improve emotions (28).

Eyes are constantly exposed to different types of lighting. People often overlook their eye discomfort, which can develop into eye injuries. The color of the light can change the psychological feelings of people in the environment. Inappropriate ambient color may easily make people feel fatigue and discomfort (17).

The LED has characteristics that can improve the

light of a space and reduce eye discomfort in the elderly. Traditional lighting sources can only improve an area's lighting by making adjustments to the configuration and this has limited effects on the comfort of lighting in a space. The LED lamp is arranged in a low-power array and can be adjusted to emit different light types to reduce the glare effect and prevent reading problems.

Conclusions

According to the power measurement results, approximately 20% less power can be used by changing T5 tubes to LED lamps. This calculation also indicated that the return period for the energy-saving effect is about four years. There is a high potential for growth in LED production as LED lighting should rise in popularity and then the price will fall in the future (29). However, the performance of LED lighting in terms of the distribution of illumination is still below the T5 standard (30). The illumination uniformity of LEDs is better, though (31). This uniformity allows the elderly to properly identify their surroundings when walking and eliminates visual blind spots that cause accidents or falls (32). A questionnaire analysis revealed that among the 200 respondents, LEDs were significantly preferred in terms of preventing accidents, lighting comfort, visual quality and satisfaction. The literature review pointed out that the lighting requirement for people over 50 years old was twice as high as for those under 40 years old. In light of this, we also questioned 121 patients over the age of 50 about their satisfaction with LED lighting and found that they agreed that LEDs provide more adequate light and lighting comfort.

In summary, our research indicates that applying LED lighting in medical institutions to better the elderly's lighting environment is very well accepted. This study found that many average illumination problems can be improved through a smart control system and can help prevent the elderly from walking in an environment that is too dark. Using LEDs also led to a better quality of sleep. Lighting sources have a large impact on the vision of people who spend a lot of time indoors. After replacing traditional lights with LED lights, the lighting environment is better and offers more protection for the eyes.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/ht.2017.09.01). WHC serves as an Editor-in-Chief of *Health Technology*. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and informed consent was taken from all individual participants.

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