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Research Article

The Comfort Analysis Model Design of the Ground Light Environment of a Dome Reflective Badminton Court in a University

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School sports is an important part of sports. The participants are mainly school students. Students play an important role in the development of the country. The development of campus sports is particularly important for the future development of the country. With the continuous improvement of the level of sports technology, to achieve higher, faster, and stronger sports goals, the requirements for sports venues continue to increase. To study whether the environment of the school's badminton court meets the requirements of the school's teachers and students to exercise and whether it can achieve the purpose of improving their own sports skills, the above problems are studied. Through the analysis of the light environment in the school grounds, to judge some problems existing in the badminton field of the school, improvement measures are put forward through research, and feasibility analysis of the improvement measures is carried out.

1. Introduction

The light environment is an important indicator that affects the comfort of the badminton court, so a suitable light environment affects the performance of athletes to a certain extent [1]. The impact of the light environment on athletes is mainly manifested as glare, due to inappropriate distribution or range of brightness, or too strong contrast, causing discomfort or visual conditions that reduce the ability to distinguish details or objects. According to the degree of glare's impact on vision, it can be divided into disability glare and discomfort glare. Disabling glare can cause a decline in visual ergonomics, while discomfort glare affects people's visual comfort [2–5]. Generally speaking, the presence of glare in badminton courts is uncomfortable glare. Uncomfortable glare will weaken visual function to a certain extent, affect visual performance and work efficiency, and cause safety hazards in important visual workplaces. Long-term effects will cause psychological damage, discomfort, and visual fatigue, which in turn lead to physical discomforts such as irritability, inability to concentrate, migraine, and eye diseases. Therefore, uncomfortable glare is an important indicator in lighting design, which is usually evaluated by the UGR system (unified glare value) [6–9]. In addition, there are the VCP method, the cutoff angle method, and the CIBSE LG3 method for reflected glare. The physical term for the light environment is called light intensity, abbreviated as illuminance, and the unit is lux or lx.

2. Experimental Investigation

2.1. Experimental Objects and Instruments. In the badminton court of a university gymnasium, a student was selected as the experimental object, and the serving test was performed in 3 different illumination time periods. An experimental subject is picked, and the skin temperature, heart rate, etc., are recorded before the test, so that the heart

rate is stable, and then, the ball is served in sequence in 7 fields. Make sure that the test subjects are tested when their heart rate is basically stable. The test subjects serve on the side of the court, and then, the data are recorded. The experimental equipment used mainly includes thermometers, black ball thermometers, sports watches, and hula hoops.

2.2. Experimental Method. This study investigates the badminton court in a university gymnasium and mainly analyzes the problems existing in the light environment of the badminton court in the gymnasium of the university. The research methods mainly include survey method, literature research method, simulation method, qualitative analysis method, and experimental summary method.

2.3. Experimental Scheme. The university arranged a total of 7 indoor badminton courts side by side. 7 courts were used as the control group, and only the light environment of these 7 courts was studied. The light environment experiment is mainly divided into two parts. The first part is to test the illumination of each area of the badminton court in the gymnasium of the school. Since each field is large, each field is divided into 12 areas to test the badminton field in groups and test the illuminance of each area of each site. Figure 1 shows the division of badminton test area.

The lighting of the school's gymnasium badminton court consists of two lighting modes: natural light sources and lamps. There are windows on the north and south sides of the venue and a ribbon-shaped skylight on the top. The illuminance test is to test the illuminance of the site at different times, record the illuminance of each site area under different light environments, and conduct statistical sorting and analysis. According to the use time of the venue, the illumination data of each venue will be obtained in six time periods: 9 : 00, 11 : 00, 13 : 00, 15 : 00, 18 : 00, and 21 : 00. The test content includes glare in each area and direct illumination in each area. The second part of the light environment experiment is to analyze whether the light environment of the school's gymnasium badminton court has an impact on sports through experiments.

3. Results Analysis

3.1. Thermal Environment-Related Indicators. In photometry, "luminosity" is the density of luminous intensity in a specified direction, but is often misunderstood as illuminance. The international unit of luminosity is the light received per square meter (called candela in mainland China, Hong Kong, and Macau). Light intensity has a great influence on the photosynthesis of organisms. It can be measured by a light meter [10–15].

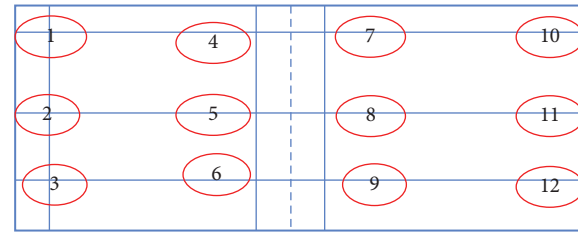

Figure 1: Division of badminton test area.

3.1.1. Calculation Formula.

$$\text{Average illuminance (Eav)} = \frac{\text{total luminous flux of light source } (N * \Phi) * \text{utilization factor (CU)} * \text{maintenance factor (MF)}}{\text{area area}\left(m^2\right)}. \quad (1)$$

(Note: applicable to indoor or stadium lighting calculations).

Utilization coefficient: 0.4 for general indoor use and 0.3 for sports.

Maintenance coefficient: generally, 0.7 ~ 0.8 is taken.

3.1.2. Standard Value. The average illuminance on the work surface or reference plane is maintained, and the average illuminance on the specified surface shall not be lower than this value. It is the average illuminance on a specified surface at the moment when the lighting installation must be maintained, which is the illuminance required to ensure visual safety and visual efficacy at work. The national standard of the People's Republic of China "Architectural Lighting Design Standards" GB50034-2013 specifies the general illuminance standard values for new, renovated, and expanded residential, public, and industrial buildings.

3.2. Illumination Data Analysis of Each Area of the Badminton Court. During the investigation, it was found that the lighting methods of the school's gymnasium badminton court mainly include complete natural lighting, combination of natural lighting and artificial lighting, and complete artificial lighting [16–19]. In most cases, the badminton court in the gymnasium of our school only relies on natural lighting and artificial lighting. In the case of the combination of the two lighting modes, it only exists in the morning and evening with natural light sources but cannot meet indoor lighting. The time is relatively short. This experimental investigation mainly studies the illuminance of indoor lighting under natural light and when the lights are turned on without natural light. In the case of sufficient natural light sources, it can be divided into two situations: curtains drawn and curtains not drawn. Therefore, this survey mainly studies various time periods of natural light, including 9 : 00, 11 : 00, 13 : 00, 15 : 00, 18 : 00, and 21 : 00. According to the illuminance of each area in six time periods, the following

statistical table is obtained according to the calculation formula of average illuminance (Eav) (Table 1).

It can be seen from Table 1 that the illuminance value of the badminton court varies with time, and there are obvious differences in the illuminance of each venue in different time periods. The comfort of the venue is judged by the illuminance value of each venue.

From Figure 2, it can be seen from the broken line graph of the illuminance of the badminton court that the illuminance changes in each venue in different time periods and the illuminance of the draw is also different for different venues in the same time period according to different distribution positions. Combining the statistical table of illuminance values of each venue at different times in Table 1 and the two graphs of the broken line chart of illuminance of the badminton court in Figure 2, it can be clearly found that the illuminance of the venue increases from both sides to the middle under natural light sources, while the illuminance of each area is relatively stable when the lights are turned on. The reason for affecting the illuminance is the use of lamps and lanterns. The survey test tested six time periods, namely, the illuminance of the site under three relatively typical lighting conditions under the condition of sufficient natural light source on sunny days, without drawing the curtain, pulling the curtain under the condition of sufficient natural light source, and turning on the light under the condition of insufficient natural light source. Among them, the test is 9 : 00, 11 : 00, 13 : 00, and 18 : 00. The four time periods are the data when the curtain is not drawn under the condition of sufficient natural light source, and 15 : 00 is the area of the venue after the curtain is drawn under the condition of sufficient natural light source. The data of 21 : 00 are the illuminance of each venue area under the condition that the natural light source is insufficient at night and the lights must be turned on at night. It can be seen from the test that the illumination of each area in the room is the highest when the curtains are not drawn under the condition of sufficient natural light source, followed by the curtains drawn with sufficient natural light source, and the illumination of each site is the lowest under the condition of artificial lighting. Among them, the illuminance is higher at 11 : 00 and 13 : 00 in the four time periods when the curtains are not drawn under the natural light source, followed by the time periods of 9 : 00 and 18 : 00, and the indoor curtains are shading at 15 : 00, but the illuminance inside the site is still higher than that in the morning and evening. From the experimental data, it can be seen that the lighting conditions of each site are also different in the same time period, because the installation of indoor windows is asymmetric on the north and south sides, and the installation positions of the windows are different, so the lighting conditions are not the same. The average illuminance on the north side with windows on both sides is higher than that on the south side. Because there are windows on the south side of Nos. 3 and 4, the lighting conditions are good, and there are pillars on the north side of Nos. 3 and 4 to block the light. The southern site is higher than the northern site under lighting conditions. Due to the location of the windows, the north and south sides of Site 1 and Site 7 are walls, so the illuminance under natural lighting is the lowest in the entire site. There are no windows on the west side of the No. 2 field, but there are windows on the east side. Therefore, the illuminance of 1, 4, 7, and 10 areas of No. 2 field is lower than that of 3, 6, 9, and 12 areas. According to the illuminance test data when the lights are turned on under the condition of insufficient natural lighting, it is found that the average illuminance of each area is between 250 lux and 350 lux under the condition of turning on the lights. There is a malfunction for some reason, resulting in the failure of normal lighting. Among them, the faulty lights have the first light and the second light on the north side of the east row in the middle of Nos. 3 and 4; the lights on the northwest side between No. 4 and No. 5 are faulty; the two lights on the south side of the row on the side were faulty; the two lights on the southernmost side of the west column between sites 5 and 6 were faulty, and the lights on the east side between sites 5 and 6 were faulty; a row of lights were in the middle of venues 6 and 7. Therefore, the illuminance of some areas is lower than the average value of this time, which leads to areas 2, 3, 7, 8, 9, 10, 11, and 12 of No. 4, areas 1, 2, and 3 of No. 5, and the entire No. 6 illumination in areas 1, 4, 7, 10, and 11 of the site; Site 7 will be affected.

Table 1: Statistical table of the average value of illuminance at different times in each site. Unit: lux/m^2.

Numbering	Time					
	9 : 00	11 : 00	13 : 00	15 : 00	18 : 00	21 : 00
Venue 1	495	627	655	542	558	271
Venue 2	571	678	708	596	609	308
Venue 3	788	895	925	736	827	304
Venue 4	730	977	867	838	772	218
Venue 5	729	1008	866	820	711	255
Venue 6	716	931	851	761	752	131
Venue 7	611	714	744	714	645	243

3.3. Analysis of the Experimental Data of the Ground Light Environment of the Badminton Court. There is a control experiment in this experiment. To verify the influence of the light environment on the exercising population, other environmental factors and the personal factors of the experimental subjects should be basically controlled to avoid affecting the experimental results. Their heart rate and skin temperature are tested before each experiment to ensure that the heart rate of each experiment is basically the same, so as to avoid the testers' own physical conditions affecting the experimental results. The different time periods of the experimental illumination are divided into six groups. The illumination conditions in the six groups are the same as the conditions in the illumination experimental data. Each group of experiments is divided into seven times, and seven sites are tested. Test data of badminton court ground illumination environment (Table 1). The variable in the data is the time period of the test, and the ambient temperature in the test will be different due to the different control time period. Therefore, the ambient temperature is also used as a control variable, and both horizontal and vertical analysis are required to avoid as much as possible. Experimental bias:

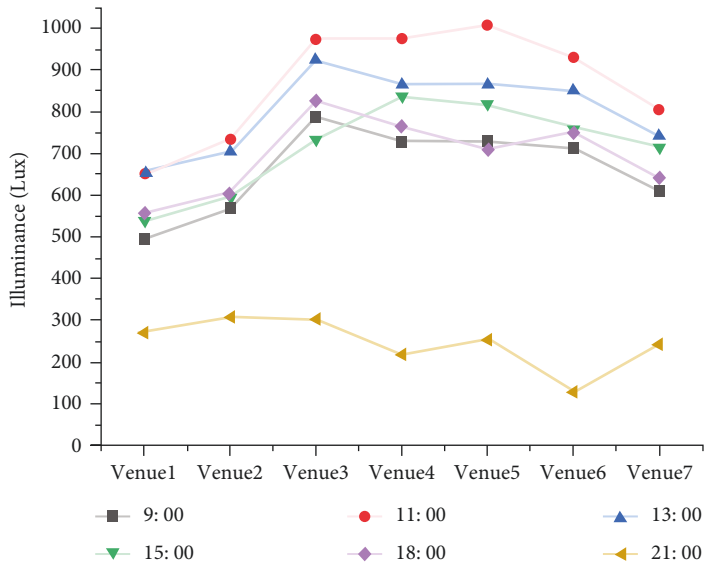

Figure 2: Badminton court field illuminance line chart.

To more intuitively see the influence of different temperatures and illuminance on the experimental results in this experiment, the bar graph of the ground light environment test data of the badminton court in Figure 3 is drawn according to the experimental data.

Figure 3 is a bar chart of the ground light environment test data of the badminton court, which can visually display the scores of each venue at different temperatures in different time periods and the scores of each venue at the same temperature in the same time period. Comparing the illumination environment scores of the same venue in different time periods, we can find the impact of different illumination in different time periods on sports performance. Through the difference in the scores of different venues in the same time period, it can be found that the impact of illumination in different venues on sports performance. The bar chart mainly shows the score of each field, and the main influencing factor is the different illumination of each field under different conditions during the test period. According to the experimental data of the badminton light environment, it can be seen that the illumination in each test period is different, so the final experimental result score data will also be different. The temperature during the experiment is also one of the influencing factors of the experimental results. Therefore, to visually see the score data under the influence of the two environmental factors, temperature and illuminance, the origin data analysis software is used to draw a 3D scatter diagram as shown in Figure 3. The three-dimensional scatter diagram is drawn from the test data of the ground light environment of the badminton court, and the three-dimensional scatter diagram obtained by the test data of the ground light environment of the badminton court. In Figure 2, we can see the scores of the experimental objects under the two experimental conditions of X-axis ambient temperature and Y-axis field illumination. Through the line chart and the three-dimensional scatter chart, it can be seen that the badminton court in the school gymnasium has different effects on sports under different time and light conditions. From the line graph of the ground light environment experiment data of the badminton court in Figure 1, it can be seen that in the six time periods, in these groups of experiments at 9 : 00, 18 : 00, and 15 : 00, the scores of each venue are higher than other time periods; in the experiment at 21 : 00 (insufficient natural light source, turn on the lights), the low scores of each venue were lower than other time periods. By analyzing the experimental data under the conditions of light and temperature, using the temperature as a quantitative measure, and analyzing the data of the experiment under the same or similar temperature conditions, we can know that for sports, the light intensity needs to be within an appropriate range, and people can exercise to achieve intended purpose, when the illumination is too high or too low is not conducive to physical exercise. The three time periods with the highest scores, 9 : 00, 15 : 00, and 18 : 00, are basically between 500 lux and 800 lux. The experiment shows that when the illumination is between 500 lux and 800 lux, athletes will achieve the best performance.

4. Discussion

4.1. Influence of Light Environment on Motion. Lighting mainly affects the illuminance and glare in the light environment [20–22]. When the illuminance is not enough, it will affect the judgment of the sports people on badminton and causes visual damage. Through the illumination test experiment and the analysis of the light environment experiment, it can be seen that there are many problems in the badminton court in the gymnasium of the school. First of all, the illumination of the indoor badminton court of the school is uneven and there is glare. According to the national standard, the illumination of the badminton court is not less than 300 lux, while the illumination of our school's indoor badminton court is only about 200 lux when the natural light source is insufficient, which is not up to 300 lux. Illumination standard: in the experiment, No. 4 field

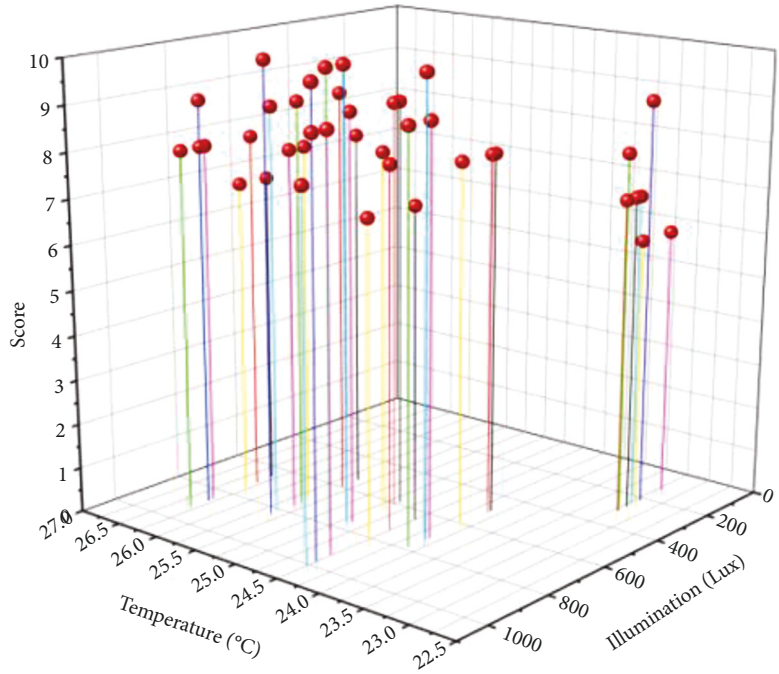

Figure 3: 3D scatter plot of the experimental data of the ground light environment of the badminton court.

scored the highest, and No. 4 field had medium illumination in each experiment, neither the highest nor the lowest. In the three experiments, the site with the lowest score data was the site with the highest or lowest illumination during the test during that time period. From the three-dimensional scatter diagram of the ground light environment test data of the badminton court in Figure 2, it can be found that both the illumination and temperature of the environment have a certain influence on the exercise performance, and there is also a standard value when the temperature and illumination affect exercise. In the influence process, it can be found that the influence of light on the movement is mainly in two cases, the illumination is too high or the illumination is too low. When the illuminance reaches a certain range, it is the most comfortable illuminance for exercise. Under this and illuminance conditions, people who are exercising will neither be unable to judge the movement situation because the illumination is too low, nor will they cause glare because the illumination is too high. Through this experiment, it can be found that the most suitable illumination range is in the range of 500 lux to 800 lux, so the final improvement of the stadium badminton court should also reach this illumination range. From the above data analysis, it can be concluded that the illumination has a certain influence on the badminton movement, and the optimal illumination required for the exercise is between a certain value. When the illumination is too high or too low, it is not conducive to sports.

4.2. Improvement Measures for Badminton Court. Through the above experiments and data analysis, it can be found that the problems to be improved in the badminton court in the gymnasium of the school mainly include insufficient lighting and glare [23–25]. Regarding the problem, we will improve the badminton court in the school's gymnasium. For the problem of insufficient light illumination, higher-power lamps can be selected, and the existing damaged lamps can be repaired, to achieve the effect of increasing the illumination. For the glare problem, the illumination mode of the lamps can be changed and the illumination angle can be adjusted. Aiming at the problem of field illumination, the DIALux lamp modeling software is used for analysis. First, the spatial structure diagram of the badminton court in the gymnasium of the school as shown in Figure 4 is established to carry out the overall simulation analysis.

Figure 4 is a model based on the overall structure of the badminton court in the gymnasium of our school to restore the existing structure of the badminton court of the school, including all doors and windows. In this way, the interior lighting of the venue and the illumination of each area can be simulated under the condition of sufficient natural light sources. Then, the simulated environment is combined and arranged according to the installation method of the existing lamps. After the arrangement is completed, the DIALux software is used for lighting analysis.

As shown in Figure 5, the lighting of the badminton court in the gymnasium of the school is basically arranged around the lamps in the absence of natural light sources at night. The illuminance of the places illuminated by the lamps in a straight line is higher and then gradually decreases to the places where the lamps cannot illuminate. The calculation results show that the average illuminance on the ground of the badminton court in the entire gymnasium is about 150 lux, the maximum illuminance is 230 lux, and the minimum illuminance is 62 lux. The illuminance distribution is not uniform, and the illuminance values are quite

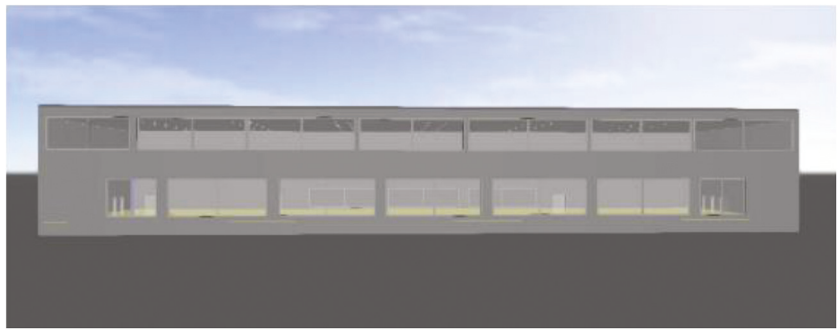

Figure 4: Construction of the badminton court model of the gymnasium.

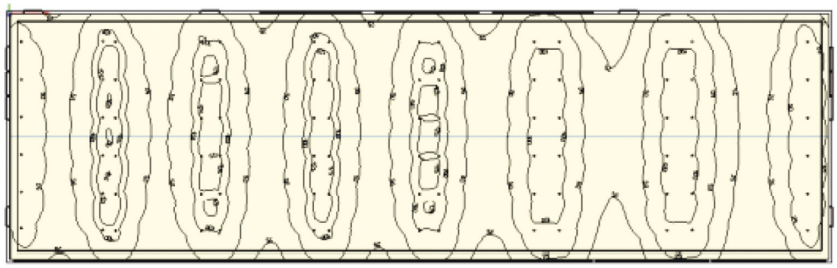

Figure 5: Simulation calculation result of the lighting tube of the badminton court in the gymnasium of the school.

different. However, considering that the light distribution method of the badminton court in the school gymnasium is mainly distributed on both sides of each badminton court, the light is irradiated to the middle of the badminton court by playing against each other on both sides, so that although the overall illumination is not uniform, exercising on the badminton court. The area can have good lighting. Therefore, although some areas have low illumination, they are basically dead ends of the movement and do not affect the overall badminton movement.

5. Conclusion

Although the venue as a whole meets the standards, some parts need to be improved. Compared with the standard facilities of the venue, the overall feeling of the sports crowd is also extremely important. Improving sports skills requires not only standard venue facilities but also the subjective feelings of sports people. Through the illumination experiment, it can be found that the illuminance of the badminton court in the gymnasium of the school is different under different illumination conditions and in different areas of the venue. The factors that affect the illumination include the light source and the building structure. Therefore, venue lighting not only needs to consider the selection of lamps but also allocates reasonably according to different venues and arranges lamps reasonably to achieve the desired effect. The ground light environment experiment of the badminton court found that among the lighting factors affecting the sports crowd, the school's badminton court illuminance has a suitable range. When the illuminance is between 500 lux and 800 lux, it is the most comfortable for the sports crowd, and when the illumination is too low, it will affect the sports. It will affect people's visual effects in badminton, and when the illumination is too high, it is easy to produce glare, so the improvement of the venue should be based on the illumination standard between 500 lux and 800 lux.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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