Research on Improved Design of School Shower Equipment Based on Ergonomics

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Abstract. With the increasing demand of students for campus life quality, the improvement of campus public facilities has attracted much attention. In order to improve the experience of using the on-campus shower and enhance the comfort of the students in the process of using it, the design of the on-campus shower has been improved by applying ergonomic theory, taking into full consideration the physiological and psychological characteristics of the people using it, and optimizing the design of the ergonomic dimensions and operation methods of the on-campus shower equipment to make it more in line with the ergonomic dimension requirements. It provides users with higher efficiency and more comfortable use, and provides reference for the design research of campus shower public facilities.

Keywords: Ergonomics, Shower equipment, Optimal design.

1. Introduction

Public bathrooms play an important role in daily life on campus, providing a clean place for students, but there are also problems such as far distance, poor quality, and no privacy for bathing. With the continuous improvement of living standards, it has become a trend to create a more comfortable on-campus life for students. However, through the field research of shower facilities on campus, the research and analysis of the people who use them, many problems of shower equipment are found, such as complicated operation process and low display screen. Only the need of using function is satisfied, ignoring the convenience, comfort and reasonableness of operation when using. These problems can largely affect students' experience of using the device. In this paper, we use the theory and method of ergonomics to focus on its human-computer interaction, and improve the height, size and operation of each area in a reasonable way to improve the operation experience of students. Effective design dimensions and design ideas are provided for the existing campus public shower facilities.

2. Ergonomic factors in school shower equipment

Ergonomics is a discipline that studies the interrelationship between human beings, machinery and the environment in which they are used, and designs and modifies machines and environments that are directly related to human beings according to their various characteristics. Ergonomics is closely related to people's life, and its research content plays a crucial role in design, which is summarized as the following aspects: 1. To provide human body size parameters for considering "human factors" in design; 2. 3. to provide design guidelines for the consideration of "environmental factors" in the design. In this paper, we take the men's bathroom in the university as the design object to study the adaptation relationship between human-machine-environment, so that the designed products can meet the human dimensions and optimize the overall human-machine system.

3. Analysis of the current situation and problems of public shower facilities in schools

3.1. Analysis of the current situation

This paper takes the shower equipment in the men's bath as the research object, and firstly analyzes and summarizes the shower equipment through field research to clarify the layout and operation of each part of the area. Figure 1 shows the pictures of the field research on the shower equipment in male bathrooms in domestic universities.

Figure 1. Field research pictures

Functional partitioning of the equipment can be divided into three parts: the operation area, the display area, and the water outlet area. Manipulation area is divided into water inlet and outlet valve; display area includes display screen and water pressure meter, the display is used to show the real-time consumption amount; water outlet area is the top shower, fixed on a ball valve, through the adjustment of the angle to control the direction of the water. After the field measurement of each inch of data: the top spray shower height 2300mm, diameter 60mm; display screen: 40mmx35mmx1310mm; water pressure gauge: 30mmx30mmx1250mm; water inlet: 200mmx20mmx1000mm; outlet valve: 100mmx30mmx1000mm.

3.2. Questionnaire analysis

A questionnaire was distributed to investigate the user experience of the shower. The main questions were related to the operation experience, design and interface design of the shower. The survey was conducted among 50 college students who had used the shower, and a total of 50 people were surveyed. A total of 50 questionnaires were distributed and 50 were returned, of which 45 were valid. Respondents evaluated 3 areas of the shower unit: display area, water outlet area, and overhead shower. The main problems of each area and the percentage of people who reported the problems are shown in Table 1.

Table 1. Table Type Styles

Region	Major Issues	Number of reflectors	Number of people as a percentage
Manipulation area	1.Complex process requires cell phone scanning code. 2.The placement of the QR code is not obvious	30 38	66% 84%
Display area	1. Screen glare, low content recognition. 2. Low placement height, need to bend down to view	29 40	64% 89%
Outlet area	Smaller water outlet area	35	78%

In response to the above problems, this paper will make a relevant size improvement design for the shower equipment in the west side of Shenyang University of Architecture for men. According to the application of ergonomics, anatomy and physiology theories, the equipment will be optimized and improved from the improvement of product size, human body size percentile, human visual characteristics and manipulation devices to present a product more in line with ergonomic design.

4. Design principles of bathroom shower equipment

According to the functional requirements level by level analysis, can be divided into basic functions, core functions, secondary functions, additional functions.

At the level of basic functions, with reference to the parameters of different human bodies at rest and during activities in ergonomics, the design needs to consider perfecting the parameters such as the suitable water touch area and water temperature settings for people at different heights and angles.

At the core function level, firstly, based on the research summary, it is found that the bathroom shower has a single system function, water temperature adjustment is not convenient and the interaction system is not perfect, the degree of personalization is low and the correlation between the shower and the operation interface is low. Therefore, the design needs to first strengthen the correlation between the shower and the user's operation, i.e. to improve the interaction system between the system and the user, and to increase the user's personalized adjustment operation.

At the secondary function level, users cannot find or easily find the empty space. Since it is impossible to change the general environment of the number of users and the layout of the bathroom space in the public bathroom on campus, we can consider improving the guidance system at the software level, and improve the ease of finding the empty shower space by making reservations online and checking the number of users in the shower room in real time. At the additional function level, because the shower equipment is made of stainless steel, there is a risk of aging and corrosion of the equipment due to long-term scale accumulation, and there are certain safety hazards. From the perspective of campus public infrastructure maintenance and durability needs, the durability of the shower system and the ease of cleaning and repair can be improved by improving the materials and design of the use process.

In general, the design should be based on ergonomic needs, taking into account the following principles:

1. The shape, scale, and layout of the shower equipment is relevant to the people who use it;
2. The human-machine-environment fit should be fully considered;
3. The design should be based on accurate data from human measurements;
4 The height of the top shower should be easy to adjust and avoid head-butting problems;
5. The height of the display should be consistent with the height of the eyes of the people using it;
6. The design of the manipulation device should match with ergonomics;

7. The spatial arrangement of the display screen should match with the characteristics of the human eye gaze patrol.

5. Man-machine analysis and dimensional improvement

5.1. Improved design of the top spray shower

The school's shower installation only has a top spray shower which is a water device. After research and analysis have the following characteristics: 1. top spray shower is fixed in the head, when bathing without hands to hold the wine, can free hands, more convenient when bathing 2. top spray rosette head is very large water area is also large, water from the head down, cleaning comfort is higher. 3. top spray shower is fixed on a ball valve, can only adjust the angle of random replacement. 4. top spray shower only A function and a water effect, the use of a relatively single. To determine the height of the top spray shower needs to ensure that "reach" and "not to touch the head" two conditions.

In accordance with the requirements of the male "reach" shower design calculation. Belonging to the IIB male general product size design (small size) problem, according to the body percentile selection principle, should choose the 5th percentile as the lower limit of product design. Table 2 male standing posture size percentile.

Table 2. Male standing size percentile (in mm)

Age and percentile / Measurement items	18-60 years old					18-25 years old				
	1	5		50		1	5		50	
	95	99				95	99			
Middle finger fingertip point raised upwards	1913	1971	2108	2245	2309	1930	1990	2122	2264	2329
Double arm function up high	1815	1869	2003	2138	2203	1828	1889	2018	2155	2220

According to the minimum functional size = body size percentile + functional correction amount, the relationship is as follows.

$G_1 \leq J_5 + X_1$

Were

G_1 - by the "reach" requirements to determine the height of the top spray shower minimum functional size;

J_5 - men's "middle fingertip point upward height" of the 5th percentile, from GB/T13547-1992, J5 = 1990mm (18 ~ 25 years old);

X_1 - men's shoe correction amount, take X1 = 20mm

Substitute the value to get $G_1 \leq 1990mm + 20mm = 2110mm$. Therefore, the "enough" requirements to determine the height of the top spray shower the minimum functional size of 2110mm.

In accordance with the requirements of the male "do not touch the head" shower design calculation belongs to the IIA male general product size design (large size) problem, according to the table below human body percentile selection principles, should choose the 95th percentile as the lower limit of product design, according to the minimum functional size = human body size percentile + functional correction amount, the relationship is as follows:

$G_2 \geq J_{95} + X_1$

Were

G_2 - by the "no head" requirements to determine the height of the top spray shower the minimum functional size;

J_{95} - men "standing height" of the 95th percentile, from the table GB/T 10000-1988, J_{95} = 1789mm (18-25 years old);

X_1 - men's shoe correction amount, take X_1 = 20mm

Substitute the value to get $G_2 \geq 1789mm + 20mm = 1809mm$. Therefore, the minimum functional size of the top spray shower height determined by the "no touching" requirement is 1809mm.

In summary, the height of the top shower needs to be lower than the minimum functional size of "reach" 2110mm, higher than the minimum functional size of "not touching the head" 1809mm,

compromise the minimum functional size of the shower height G3 is 1959.5mm According to the best functional size = body size percentile + functional correction + psychological correction, the relationship is as follows.

$G_4 = G_3 + X_{psychological}$

Were

G_4 - shower height of the best functional size;

G_3 - the minimum functional size of the shower height;

$X_{psychological}$ - in order to eliminate the sense of space depression, fear, or for aesthetic and other psychological factors and add the size of the correction. Take X psychological =10mm

Substitute the value to get G_4 = 1960mm + 10mm = 1970mm. therefore, the height of the top spray showers the best functional size of 1970mm.

Top spray shower diameter problem belongs to the design of type III products, according to the general product average size design principles, combined with GB10000-1988 in China's adult human body main size can be known, China's 50% of adult male shoulder width of 375mm, so the minimum functional size of the shower diameter of 375mm, can be appropriate to increase the amount of 10mm psychological correction, so the shower water area The best functional size of the diameter is 385mm.

5.2. Ergonomic analysis of the top spray shower

The top spray shower needs to use the hand to control the angle of the water, need to comply with the design principles of the manual manipulation device, the improvement measures are as follows:

1. in the shower edge to increase the groove or raised design, increase the contact area.
2. can be added to the edge of different colors, to prompt the user here to adjust the design.
3. the size of the resistance and the type of control device, location, the distance moved, the frequency of operation, the direction of the force and other factors Related. Here the resistance is set to 2.8N.

6. Improved design of display area

6.1. Determine the horizontal length of the display area

First need to determine the distance between the human standing state and the display X. Shower equipment belongs to the general industrial products common to adult males, is for standing posture operation products, according to the human measurement data application standards, in order to meet the needs of most users, choose the 50th percentile data of human body parameters as the size reference. According to GB1000-1988 "China's adult human body main dimensions", take the forearm length of male (18-25 years old) P50, the length of 237mm, that is, the horizontal distance from the person to the display screen X is 237mm. Figure 2 is a schematic diagram of the person and the display screen. Table 3 shows the main dimensions of the human body.

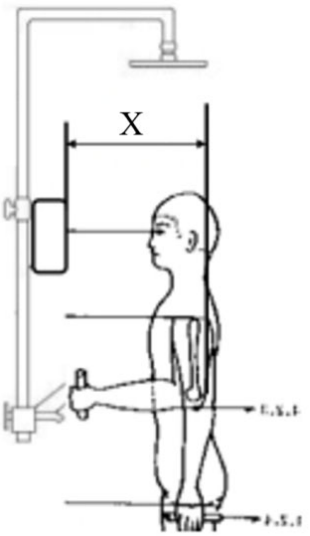

Figure 2. Horizontal distance diagram

Table 3. Male standing size percentile (in mm)

Age and percentile / Measurement items	18-60years old					18-25 years old				
	1	5	50			1	5	50		
	95	99				95	99			
Height	1543	1583	1678	1775	1814	1554	1591	1686	1789	1830
Upper arm length	279	289	313	338	349	279	289	313	339	350
Forearm length	206	216	237	258	268	207	216	237	259	269

The direct field of view, also called the static field of view, refers to all the spatial extent within the horizontal and plumb planes that can be observed by the human eye when the head and the eyes are stationary. The direct field of view is used here to determine the size range of the display area.

According to the relationship between the viewing angle and the visual distance a=2arctanD/2L can get D/2=L-tana/2. According to the visual characteristics of the human eye, the best horizontal gaze field of the human eye for the left and right 25 ° each as shown in Figure 3.

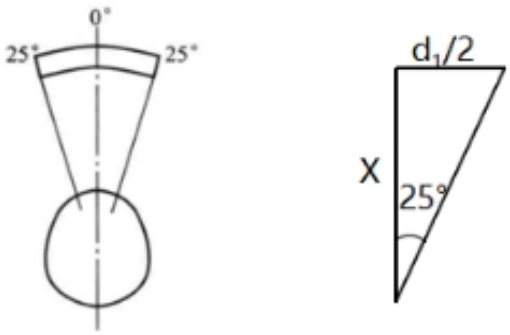

Figure 3. Horizontal distance diagram

According to the geometric relationship: the relationship between the maximum vertical length of the optimal viewing area d1 and the distance between the human body and the shower equipment monitor is as follows

$d_1=2X\cdot\tan25°$

Were

d_1 - the length of the display in the horizontal direction;

X - the horizontal distance from the vending machine in the standing position of the person;

25° - the best horizontal direct field of view for the human eye in a standing position;

Bring in the value to get d1=221.02mm, take the integer as 221mm. thus we can know the horizontal length of the display is 221mm.

6.2. Determine the vertical length of the display area

According to human visual characteristics, the best horizontal gaze field of the human eye is 25° on the left and right as shown in Figure 4.

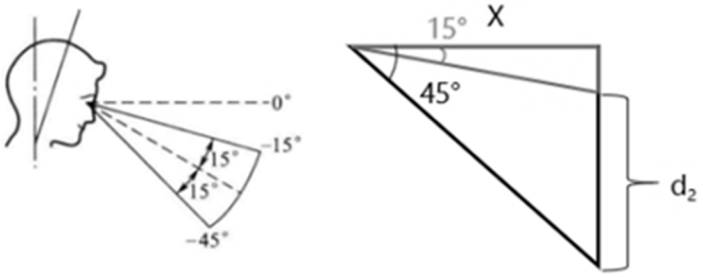

Figure 4. Vertical direct field of view perspective and distance relationship

According to the geometric relationship: the maximum length d2 of the longitudinal direction of the optimal viewing area and the distance between the human body and the shower equipment display.

$d_2=X\cdot\tan45°- X\cdot\tan15°$

Were

d_2 - the length of the display in the vertical direction;

X - the horizontal distance between the human standing posture and the display;

55°-maximum angle of the best direct field of view of the human eye in the standing posture;

5° - the minimum value of the best direct field of view of the human eye in the standing posture;

Bring in the value to get d2=137.95mm, take the integer to 138mm. thus we can know the vertical length of the display is 138mm.

6.3. Determine the height of the display area

In order to make the design more reasonable, the reference benchmark for eye height should be taken as the eye height parameter for men aged 18-25 years, with an eye height of 1576 mm. eye height dimensions for men are shown in Table 4. The height of the display from the ground is calculated based on the difference between the eye height of the human standing posture and the length of the downward area of the human eye field of view.

Table 4. Male Body Level Dimensions (In Mm)

Age and percentile / Measurement items	18-60years old					18-25 years old				
	1	5	50	95	99	1	5	50	95	99
High-sighted	1436	1474	1568	1664	1705	1444	1482	1576	1678	1714
Shoulder height	1244	1281	1367	1455	1494	1245	1285	1372	1464	1507
Hand function height	656	680	741	801	828	659	683	745	808	831

According to the minimum functional size = body size percentile + functional correction amount, the optimal functional size = body size percentile + functional correction amount + psychological correction amount can be obtained from the following relationship.

$C_{minimum} = H_{50} + X_1 - X \cdot \tan45°$

Were

$C_{minimum}$ - the minimum functional size of the selection area height above the ground;

H_{50} - the 50th percentile of men's eye height;

X_1-functional correction amount, including the dress correction amount and the posture correction amount of the man because of hunchback and stoop, take X1=24mm;

X - the horizontal distance between the person's standing posture and the vending machine;

b - the length of the area of the downward field of view in the standing posture of the person.

Bring in the value to get C minimum = 1363mm. thus we can know that the minimum functional size of display screen height from the ground is 1363mm.

$C_{optimum} = C_{minimum} + X_{mental}$

$X_{psychological}$ - psychological correction, taking into account the depression of people in front of the machine, set X psychological = 10mm.

Bring in the value to get $C_{optimum}$= 1373mm, so we can know the best functional size of display area height is 1373mm.

6.4. Determine the spatial layout of the display area

The law of motion of vision is also known as the gaze tour characteristics, because the human eye in the instantaneous can see a small range, people observe things rely on the gaze tour, so the design of the layout of the display must consider the gaze tour characteristics. The gaze inspection characteristics are mainly as follows.

1. The customary direction of gaze inspection is, horizontal direction: left → right; plumb direction: up → down; rotating inspection: clockwise. Eye tour movement is pointing jump rather than continuous movement.

2. The horizontal movement of the line of sight is faster than the plumb direction, and it is not easy to feel fatigue; the estimation of the size and proportion in the horizontal direction is more accurate than that in the plumb direction.

3. When the eye deviates from the visual center, in the case of equal deviation distance, the human eye has the best observation of the left upper limit, followed by the right upper limit, left lower limit, and right lower limit in order. The arrangement of instruments in the visual area must take this into account.

The spatial layout of the display area and the distribution of information need to be determined according to the characteristics of the human eye's gaze tour. The most important information is arranged at the top left of the screen where it can be easily observed, and the importance of information decreases from the top left to the bottom right. In the visualization area, the amount of consumption can be arranged in the center of the display, and the bottom half of the display is the time of use and user information from left to right.

6.5. Human-machine analysis of the display area

The process of using the on-campus shower equipment is to scan the QR code on the phone - use the equipment - end the order on the phone. Therefore, the placement of the QR code is crucial. The field research found that the QR code is set on the side of the machine, which is not ergonomic. The QR code can be attached to the front of the display screen or directly to the wall. Reduce the complexity of the operation.

Water meters measure the flow of water meters. Mostly the cumulative flow of water is measured. Mounted on a water pipe, when the user releases water, the needle or word wheel on the meter turns to point out the amount of water passing through. This serves no purpose for the user and also takes up space in the display area, so appropriate trade-offs can be made. Figure 5 shows a picture of the field study.

Figure 5. QR Code Placement

7. Man-machine improvement of the operating device

7.1. Height improvement of the manipulation device

Faucet equipment belongs to the adult male general industrial products, is for standing posture operation products, according to the anthropometric data application standards, in order to meet the needs of most users, choose the 50th percentile data of human body parameters as a size reference. According to GB1000-1988 "China's adult human body main size", take the male (18-60 years old) P50 hand function, the length of 237mm, as shown in Table 4, so the minimum functional size of the faucet height is 741mm.

The minimum functional size of the faucet is 771mm, including the correction amount of the dress code and the correction amount of the posture of the person because of the hunchback and bending.

In order to overcome people's psychological "height fear" and other uncomfortable psychological feelings, or in order to meet people's "beauty", "curiosity" and other psychological needs, the minimum functional size of the product on an additional increment, known as the psychological correction amount. The height of the faucet can be properly raised to alleviate the psychological discomfort, here to take the psychological correction amount of 10mm. therefore the height of the faucet the best functional size of 781mm.

7.2. Manipulator analysis of the manipulator

The faucet equipment in the men's bathroom is a dual single-handle faucet with a hot water outlet connected to the left and a cold-water outlet connected to the right. By swinging the handle can adjust the size of the water temperature. Faucet characteristics: no fading, no wear and tear, always new; not afraid of rubbing, not afraid of scratching easy to clean, install and repair; not corrosive, wear-resistant.

Through the faucet man-machine analysis can get the following points.

1. Faucet is a daily must use familiar goods, users of its open mode, water angle are very well understood, therefore, the faucet man-machine design focus should be placed on open, close the fast, labor-saving, safety, health. And in restaurants and other public places on the faucet man-machine design requirements are higher, not only to achieve fast and labor-saving switching action, more importantly, how to make it easy to recognize the way to switch.

2. The design of the faucet is important to consider the switch handle. Its shape must be suitable for the structure of the human hand.

This kind of wrench faucet has a clear operation sign at the switch, and the spatial position of the wrench can well illustrate the operation direction, so there is no problem of identification. In the details, the design of the wrench form will affect the comfort and effort of operation.

Figure 6 shows the structure of human hand. From the basic structure of the human hand, we can see that the palm area has the least muscles, while the finger ball muscle, the large interphalangeal muscle and the small interphalangeal muscle are the muscular parts with abundant muscles, which are the natural damper on the palm of the hand. When designing the shape of the hand control manipulator, we should avoid fitting the hand control manipulator into the hand's grip space without any difference, not to mention fitting the palm. At the same time, the fingers are the more flexible part. Four fingers can be used to turn the faucet on and off.

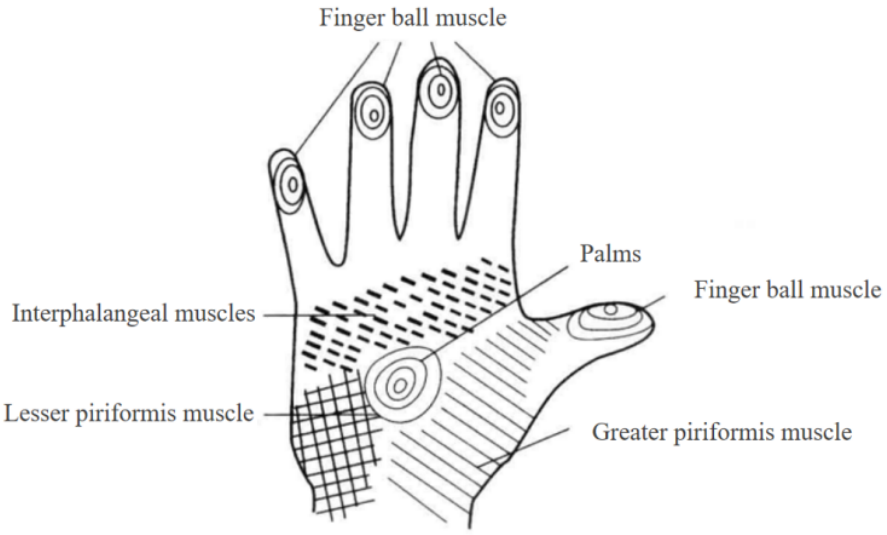

Figure 6. QR Code Placement

Therefore, in the shape of the direct use of hollow design, increase the contact area with the human hand, while the hot and cold-water outlet can be hidden, or the shell to do thickening treatment, to reduce the human bath due to inadvertent operation caused by the scalding situation.

8. Concluding remarks

As a user-centered discipline, ergonomics is an important guideline for the design of public shower facilities on campus to improve their usability, comfort, safety and user-friendliness. The article optimizes the design of public shower facilities at Shenyang University of Architecture, and improves the user experience through human dimensions, design psychology and other rationale and parameters. Through ergonomic analysis and emotional design methods, the use process is optimized in multiple dimensions such as use, experience and perception to improve user comfort and provide a reference for improving the public shower facilities on campus.

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