Research on the Design of Non-intelligent Elderly-Friendly Seat Based on Ergonomics

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Abstract. With the acceleration of the aging process of China's population, the market for age-friendly products is constantly optimized and restructured, and the age-friendly design of seats, as one of the tools frequently used by the elderly, has attracted a lot of attention. This paper lists and analyzes the typical aging seat products in the market through research and analysis of the seat needs of the elderly and extracts the main design elements of the aging seat, based on ergonomics analysis, according to the physiological dimensions of the elderly, changes and psychological characteristics of the seat dimensions of the improved design, and the design of the non-intelligent aging seat from aspects of the structure, material, color, and so on, in order to provide a wider dimension for the design of the aging product ideas.

Keywords: Age-friendly seats, Ergonomics, Assisted rising, Design

1 Introduction

With the development of society, the aging process accelerates year by year. Statistics show that in 2017, the number of elderly people over 65 years old in China was close to 160 million, accounting for about one-fifth of the world's elderly population, and will be close to 400 million by 2050[1]. In order to actively respond to the problem of population aging, the Fifth Plenary Session of the 19th CPC Central Committee has taken adaptation to aging as one of the national strategies and has continuously introduced relevant policies and measures, while governments around the world rely on the National Medium- and Long-Term Plan for Actively Responding to Population Aging, the Fourteenth Five-Year Plan for Healthy Aging, and other policies to actively promote the construction of an age-friendly society and encourage enterprises to research and develop an age-friendly society. Governments around the world are actively promoting the construction of an age-friendly society based on policies such as the National Long-term Plan to Actively Cope with Population Aging and the “14th Five-Year Plan for Healthy Aging” and are encouraging enterprises to research and develop age-friendly products. At the same time, society attaches more and more importance to the problem of old age, and the huge elderly group provides a good opportunity for the development of the market for age-friendly products. With the development and progress of science and technology, the elderly seat presents a diversified, intelligent development trend, but at the same time, tends to be an intelligent seat product. In the use of the process, there are many problems: expensive, function stacking, complex operation, lack of emotional needs, and other factors have become the new user pain points. In the era of intelligent products, we

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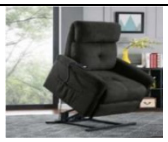
should also pay attention to some of the “non-intelligent” voices. In the era of intelligent products, we should also pay attention to some “non-intelligent” voices. This paper takes ergonomics as the theoretical basis, fully combines the physiological data samples of the elderly and the seat demand research results, and designs a non-intelligent seat for the elderly, aiming at alleviating the problem of population aging and making contributions.

2 Analysis of the current status of aging-friendly seats

2.1 Physical product analysis of aging-ready seats

Table 1. Physical seating products analysis

Product Serial Number	Product name	Photograph	Advantages	Shortcomings
1	Elderly sofa seats		With auxiliary stand up function and high comfort	Bulky, expensive, and poor emotional experience in old age
2	Ordinary geriatric seats		Inexpensive, simple and easy to operate	No assistive functions and poor backrest comfort
3	Electric massage seats		Multi-functional, comfortable and intelligent	Bulky, expensive and complicated to operate
4	Booster seats		With auxiliary stand up function and simplicity of form	Overly mechanical, cold feeling, safety hazard and poor backrest comfort
5	Booster sit-up cushion		With auxiliary stand up function and free Installation	Inadequate aesthetics and have safety hazards

Intelligent and mechanized age-friendly seat products predominate in the market at present, and ordinary seats based on traditional materials and processes are gradually being replaced. The design of new age-friendly seats mainly focuses on assisting getting up, improving comfort, functional diversification, and intelligence, but at the same time, it brings about pain points and shortcomings such as high unit price, difficulty to use, large volume, and poor emotional experience in old age (see Table 1).

2.2 Academic research results on ageing-friendly seats

Under the social background of population aging, research on aging seats focuses on product comfort. Sun Shisheng, in “Research on the Comfort of Seats for the Elderly” [2], weighted the

factors influencing the comfort of seats for the elderly and, combined with the theoretical research on the comfort of seats for the elderly, established a model of the factors influencing the comfort of seats for the elderly in terms of softness, structural dimensions of the seats, and seating time. Yang Juan, in “Research on Seat Design for the Elderly Based on Spinal Disorders” [3], takes spinal disorders of the elderly as the background, clarifies the relationship between seats and spinal disorders, and proposes that the seat design principles should also satisfy the three aspects of curvature, dynamics, and load-bearing and improve the design of the seat from the four aspects of modeling, dimensions, materials, and functional expansion to prevent and alleviate the discomfort brought by spinal disorders of the elderly.

However, there is a relative lack of research on the auxiliary function and emotional experience of the aging seat. As society's concern about the aging of the population continues to increase, the scenario-based design of the aging seat is of great research value and practical significance.

2.3 Aging seat user pain points

After the market competitors and related academic research, found that the current aging seat there are the following product pain points:

2.3.1 Functionality is complicated, and the emotional experience is mechanical and cold

Product use is a process of experience; this process should make the user feel convenient and comfortable; however, the modern design of elderly seating products tends to be intelligent and mechanized. For example, in Table 1, the No. 3 seat product's numerous functions and complex operation make it difficult for the elderly to master a series of use methods and achieve the required operation results, which is easy for the elderly to produce a psychological burden; the No. 4 product mechanization of the materials and construction forms gives people a cold and unfamiliar emotional experience, which is difficult to meet the emotional needs of the elderly. Therefore, for the design of age-friendly seats, the operation cost should be reduced, excessive function stacking should be prevented, and warm materials and simple constructions should be used to facilitate easy use by the elderly.

2.3.2 High prices and poor economic utility

There are differences between the consumption concepts of the elderly group and the young group, who are more concerned about the cost-effectiveness and practicality of the items. Such as No. 1 seat products increase the electric-assisted rise function, resulting in an increase in unit price. At the same time, they become mechanized and bulky, and their product competitiveness is poor. At the same time, the development trend of seat intelligence has increased the competition in the elderly seat market. Companies continue to iterate product features, increasing the cost of learning and use for the elderly. Some of the intelligent seats on the market have many functions but are not refined, and most of the functions are seldom used, making their economic practicality inferior to that of ordinary elderly seats.

2.3.3 Assisted rise and backrest comfort to be improved

Aging-related decreases in muscle strength and changes in joint range of motion can affect the ability of older adults to rise from a seat [4]. Assisted rise design can help the elderly stand up

stably and effortlessly, but there are many shortcomings in the existing assisted rise seats: e.g., Seat No. 1 adopts a motorized tilt assisted rise, but the volume is too bulky and heavy to discourage the elderly; Seat No. 4 adopts a spring device in the assisted rise design, which is mechanized to give a cold and unfamiliar feeling, and at the same time there is a potential safety hazard.

Seats should not only have the simple functions of support and leaning but also have the attribute of making the user feel comfortable physiologically and psychologically, i.e., they should have a certain degree of comfort[2]. The degree of backrest comfort is especially important for the elderly. As far as the research competitors are concerned, the softness of the backrest of the No. 2 and No. 4 seats is not good, and the adjustment range is limited when it fits with the back, so the comfort of the backrest needs to be improved urgently.

3 Study on the characteristics of the elderly population

3.1 Physical manifestations and recommendations for the elderly

Table 2. Physiological characteristics of the elderly performance and recommendations

Physiological factors	Concrete expressions	Suggestions
Muscles and organs	Decreased muscle strength, weaker lower extremities and organ aging.	Avoid applying force to a greater extent and add an assisted rise feature.
Action capability	Decreased motor function and slowness of movement.	Reduce the number of steps in the operation and make the operation simple.
Ability of thinking	Thinking and learning abilities decline and reactions become sluggish.	Avoid complex logical thinking and design for simplicity of use.
Vision	Reduced visual ability and color sensitivity.	Use colors and materials that seniors like and that are gentle and vibrant.

The physiological functions of the human body are negatively correlated with age. Generally speaking, the physical function of people over 60 years old will decline by 25%, marked by the decline of muscle strength, and their athletic ability will decline by 60% [5]. Therefore, when conducting age-appropriate design, attention should be paid to the specific performance differences in the physiological aspects of the elderly compared to adults, and reasonable and effective optimization suggestions should be made (see Table 2).

3.2 Psychological Manifestations and Recommendations for the Elderly

Table 3. Psychological characteristics of the elderly manifestations and recommendations

Psychological factors	Concrete expressions	Suggestions
Consumption concept	Elderly people live frugally and seek to be economical and practical.	Reduce the cost of seats appropriately and increase durability.

Self-esteem	Elderly people have high self-esteem, desire to perform activity behaviors independently and are afraid of troubling others.	Enhance the auxiliary functions of the seats and reduce the cost of use for the elderly.
Sense of security	Elderly people are physically weak, worried about injuries and focused on safety and stability.	Designed from the structure, appearance and material of the seats to reflect a sense of security.
Feeling of nostalgia	Older people are nostalgic and enjoy natural, simple experiences.	The design should reflect simplicity and nature and meet the emotional needs of the elderly.

The psychological characteristics of the elderly will change with age, and a full understanding of the specific psychological factors of the elderly is highly informative for age-appropriate design. Table 3 briefly describes the psychological factors of the elderly and gives suggestions for seat design from four aspects: consumerism, self-esteem, security, and nostalgia.

3.3 Research and analysis of the elderly population

The design of this offline 100 elderly people over the age of 60 years old "elderly seat demand research" questionnaire analysis measured some of the elderly body size data to provide reference for the design of the seat.

3.3.1 Research and analysis of seating needs of the elderly

The questionnaire contains 3 questions on the basic information survey and 3 questions on seat product-related questions. The results of the questionnaire were statistically analyzed (see Table 4), and 83% of the elderly were dissatisfied with the seats they were currently using. The factors affecting their dissatisfaction were three aspects: seat characteristics, materials, and functions.

Table 4. Statistics on the results of the research on the demand for seats for the elderly

Elderly Seats Demand Survey Results Statistics				
Type of requirements	Specific demand factors	Number of persons required (men)	Number of persons in demand (women)	Total number of persons
Characteristic preferences for seats	Affordable	43	39	82
	Long service life	31	32	63
	Lightweight and convenient	10	17	27
	Good looking	8	17	25
	Multifunctional	11	6	17
	Safe and steady	40	35	75
	Other than	1	4	5
Functional preferences for seats	Height adjustment	10	14	24
	Auxiliary stand up	44	41	85
	Easy to move	9	12	21
	Intelligent operation	11	6	17
	Soft and comfortable	51	42	93
	Massage function	12	9	21
	Other than	3	1	4

Material preferences for seats	Wood	49	39	88
	Leather	25	14	39
	Ordinary plastic	12	8	20
	Metal material	14	4	18
	Fabrics	25	29	54
	Rattan	40	34	74
	Other than	4	3	7

Aiming at the preferences of the elderly for the characteristics of the seat, the questionnaire was designed with the title “the 2-3 characteristics of the seat that you pay most attention to when you buy it," and the results of the data were analyzed (Fig. 1): in line with the elderly's pursuit of thrift and sense of security, the price is affordable, safe, and secure, and the service life is long, which is the main concern of the elderly groups of the three characteristics, and at the same time, the elderly's attention to the functionality of the seat is relatively low.

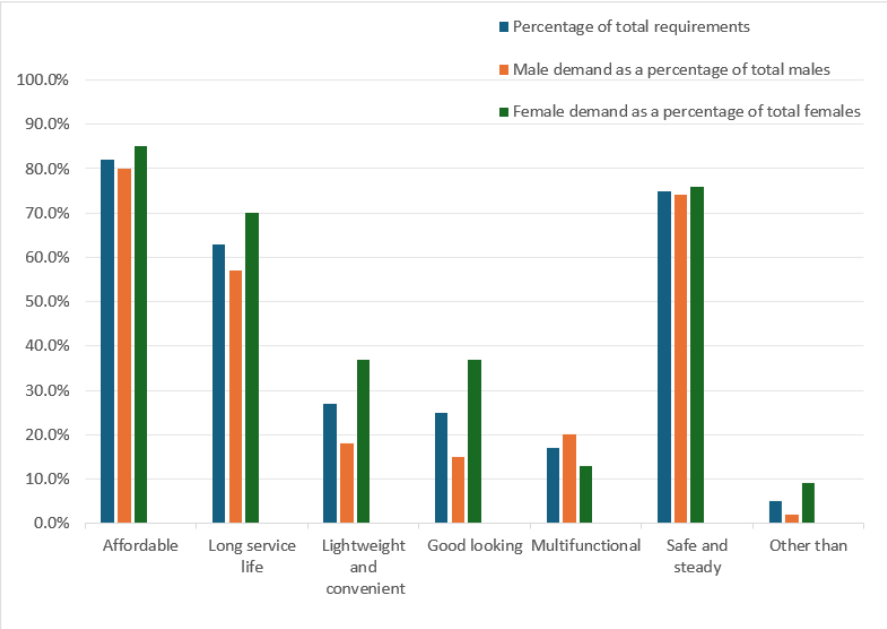


Fig 1. Elderly people’s preferences for seats’ characteristics

Analysis of the questionnaire data on the topic “2–3 functions you expect the seat to have” (Fig. 2): In terms of seat function preferences, assisted rising and softness have become indispensable functional factors in the design of aging seats, and the demand of the elderly for them is much higher than that of other factors such as intelligent operation and massage function.

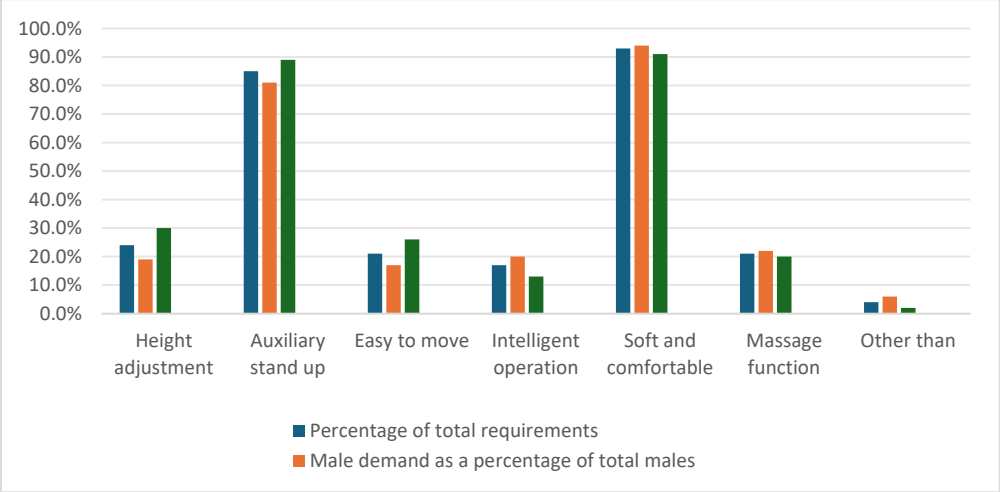


Fig. 2. Elderly people's preferences for seats' functions

From the title "Your preferred 2-3 seat materials," research results (Fig. 3) can be concluded: compared with ordinary plastic, metal, and other materials, the elderly's nostalgia is manifested in their preference for wood, rattan, and other natural materials. Wood and rattan are warm and natural; stability, durability, and other material properties are more likely to meet the needs of the elderly in pursuit of their natural, stable emotional needs.

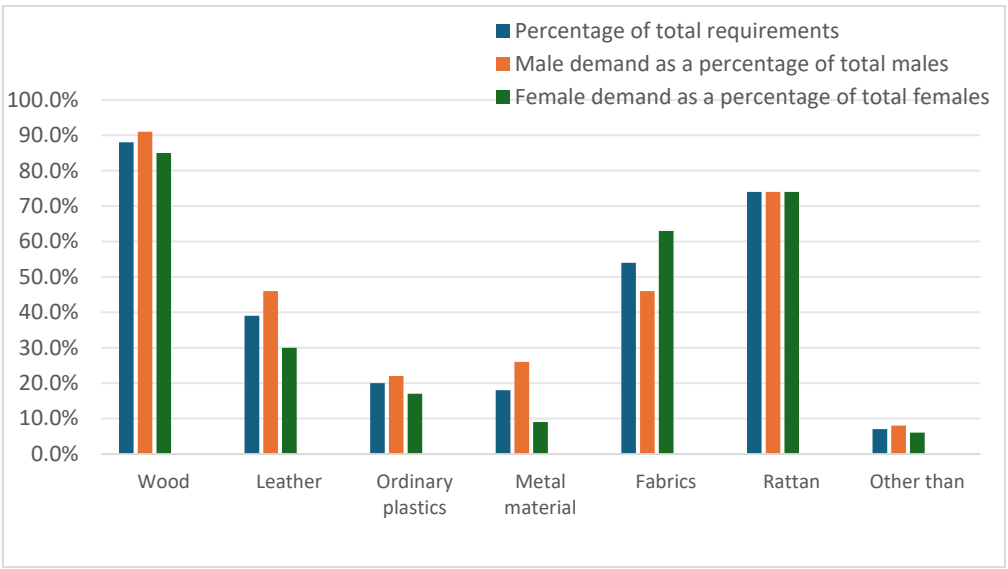


Fig. 3. Elderly people's preferences for seats' material

3.3.2 Body size measurements in the elderly population

The research measured the relevant body dimensions of 100 older adults and statistically

summarized the data using the mean formula (1) and standard deviation formula (2) (Table 5).

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

$$S_D = \left[\frac{1}{\mathrm{n}\text{-}1}\left(\sum_{i=1}^{n} x_i^{\,2} - n\bar{x}^{\,2}\right)\right]^{\frac{1}{2}} \tag{2}$$

where n = 100 (sitting shoulder height is taken as the total number of men; n = 54), $1 \leqq \mathrm{i} \leqq \mathrm{n}$; $\bar{x}$ is the mean; x_i is the ith sample measurement; and S_D is the standard deviation.

Table 5. Measurements of some body dimensions of the elderly (unit: mm)

	Sitting popliteal height	Sitting hip width	Seated hip-popliteal distance	Seated elbow height	Seated shoulder height
Average value	402.7	359.6	472.4	249.1	594.7
Standard deviation	12.3	12.6	15.8	11.8	14.5

4 Design solutions for age-friendly unintelligent seat

4.1 Ergonomic analysis

4.1.1 Ergonomics theory

Ergonomics is a comprehensive discipline that takes the human-machine-environment system as the basic object of study, applies the knowledge of physiology, psychology, and other related disciplines, and adapts the operating functions of humans and machines according to the conditions and characteristics of the humans and machines while creating a comfortable and safe working environment to maximize work efficiency. [6]

Its theory fully penetrates and integrates “human body science," “technology science,” and “environmental science” and is widely used in various fields, providing a basis for rationally solving the relationship between the three major elements of man, machine, and environment. Provide a basis for rationally solving the relationship between the three elements of man, machine, and environment. The author takes ergonomics as the research perspective for the design of the seat for the elderly and selects the seat size suitable for the elderly after fully considering the relationship between humans, machines, and the environment.

4.1.2 Dimensions of the seat under ergonomics

As an indispensable object in life, the design of the seat, in addition to the proper use of materials and a beautiful and generous shape, is more important to have ergonomic size parameters. Based on the theory of ergonomics, the currently common size of the seat is GB/T

3326-2016 “furniture table, chair, stool main dimensions” [7] to meet most of the adult seat scale requirements. The relevant seats’ size data is in Table 6.

Table 6. Major dimensions of adult seats under national standards

Types of seats	Size factor	Size (unit: mm)
Armchair seat	Seat height	400—440
	Seat width	≥380
	Seat depth	400—480
	Inside width of handrail	≥480
	Height of handrail	200—250
	Backrest length	≥350
	Seating surface inclination angle	1°—4°
	Backrest tilt angle	95°—100°
Backrest seat	Seat height	400—440
	Seat width	≥380
	Seat depth	340—460
	Backrest length	≥350
	Seating surface inclination angle	1°—4°
	Backrest tilt angle	95°—100°

4.1.3 Seat size design for the elderly

For the elderly, aging makes their body form and motor function change greatly, so the ergonomically designed adult seat size is not fully adapted to the elderly. The author takes the main dimensions of the adult seat as a reference basis, and at the same time, according to GB/T 10000-2023 “Chinese Adult Body Dimensions” [8], the sitting body dimensions of adult males and females aged 61 to 70 years old (see Table 7) as well as the body dimensions of 100 elderly people participating in the questionnaire survey determine the size of the aging seat.

The height of the seat surface is one of the important factors affecting the comfort of the seat, while in limb movement, the knee joints of the elderly are hardened and their cushioning ability is reduced, resulting in their knee mobility being restricted. Therefore, by appropriately reducing the height of the seat surface so that the lower leg of the elderly and the seat surface are at an obtuse angle, we can alleviate the lack of knee joint function. In order to meet the needs of the majority of elderly people and ensure that the seat height is not too low, with reference to the fifth percentile male sitting popliteal height of 374mm plus 20mm shoe height, the design of the seat height of the elderly seat is 400mm.

Since there is little difference between the sitting hip width dimensions of elderly men and women, universal dimensions can meet the needs of elderly men and women. The maximum guideline should be chosen for the design of the seat width, while taking into account the presence of armrests and the amount of clothing correction that should increase the seat width by 80mm, and the seat width of the seat should be determined to be 470mm with reference to the sitting hip width of the ninety-fifth percentile for females, which is 393mm.

The depth of the seat surface should be moderate, if the seat depth is too large, the popliteal fossa is squeezed so that the calf produces a sense of discomfort, while the back support point overhangs, so that the backrest loses its role [3]. The seat depth is too small, which will cause the front of the thighs to overhang, thus causing fatigue of the lower limbs. Ergonomics theory

shows that the seat depth should be slightly smaller than the human sitting hip-popliteal distance, so that there is a 30mm gap between the front edge of the seat and the popliteal fossa, so the seat depth is determined to be 430mm by taking the sitting hip-popliteal distance of the 50th percentile of men as a reference.

For the handrail, the inner width of the handrail should be slightly larger than the seat width, so the inner width of the handrail is designed to be 500mm. The handrail height design adopts the average criterion, taking the sitting elbow height of the 50th percentile of men as a reference, and at the same time, the height of the handrail should be slightly lower than the sitting elbow height, i.e., 240mm, in order to satisfy most of the elderly people's needs.

The height of the backrest is mainly determined by the height from the bottom of the buttocks to the shoulders, and the design should adopt the average criterion. Due to the large difference between the sitting shoulder height dimensions of elderly men and women, this paper is based on the reference to the sitting shoulder height of men's 50th percentile of 599mm, and taking into account the effective thickness of 20mm cushions, the height of the backrest is determined to be 620mm, and the height of the backrest if designed to fit the height of the backrest of the women will be 570mm.

The tilt angle of the backrest and seat surface should be designed to meet the needs of the elderly for comfort and ease of getting up, and the tilt angle of the backrest can be appropriately increased to 105°, so that the backrest has a larger area of support for the back and improves comfort; at the same time, the tilt angle of the seat surface should not be too large, and the dimensions of the seat tilt angle in Table 6 are determined to be 3° with reference to the dimensions of the seat tilt angle in Table 6.

Table 7. Sitting body dimensions of adults aged 61 to 70 (Unit: mm)

	Males			Females		
	Percentile					
Measurement items	P5	P50	P95	P5	P50	P95
Sitting popliteal height	374	406	442	349	374	409
Sitting hip width	306	347	385	309	348	393
Seated hip-popliteal distance	442	468	513	415	456	500
Seated elbow height	209	253	296	191	238	282
Seated shoulder height	538	599	650	502	550	596

4.2 Validation analysis of seat size design

Using the data of some body dimensions of the elderly obtained from the offline research measurements (Table 5), the seat dimensions under the ergonomic definition (Table 9) were analyzed and calculated to validate the feasibility of the above seat dimensions design scheme, which is expressed by the formula:

$$x = \bar{x} \pm \left(S_D \times K\right) \tag{3}$$

Of which K is the conversion coefficient, the value is shown in Table 8.

Table 8. Percentiles and transformation factor K

Percentile	P2.5	P5	P10	P25	P50	P75	P90	P95	P97.5
K	1.960	1.645	1.282	0.674	0	0.674	1.282	1.645	1.960

Table 9. Calculation of seat dimensions with body size data (Unit: mm)

Seat height	Seat width	Seat depth	Height of handrail	Backrest length
402.5	460.3	442.4	249.1	594.7

From the analysis of the data in the table, it can be seen that the seat dimensions in the design plan are not much different from the seat dimensions calculated from the research data and have greater feasibility.

4.3 Functional analysis of design options

Based on the results of the previous analysis, the program provides an innovative design of the age-adapted seat in terms of assisted rising and improved comfort, respectively, in order to meet the needs of the elderly for the function of the seat.

4.3.1 The design of the auxiliary stand-up

The assisted rising function can reduce the difficulty of the elderly in the process of transitioning between seating and rising postures and improve maneuverability. Compared with the mechanized and motorized seat lifting methods, the assisted rising device in the seat part of the solution is a physical pivot lifting structure (Fig. 4), which is more simple and durable to operate compared with intelligent products. When an elderly person rises, he or she holds the armrests (Fig. 4, position 1) with both hands and applies force forward so that the armrests rotate around the pivot axis (Fig. 4, position 2) at the front of the seat and drive the seat surface, thus realizing the lifting of the seat surface. In the seat surface rotation and lifting to the maximum limit, armrests and seat back structure (Fig. 4 position 3) contact and get stuck, to limit its excessive rotation of the existence of safety issues, at this time the armrests rotate 20° (Fig. 4 position 4), the seat surface vertical lift 300 mm (Fig. 4 position 5), the effect of use is shown in Fig. 5.

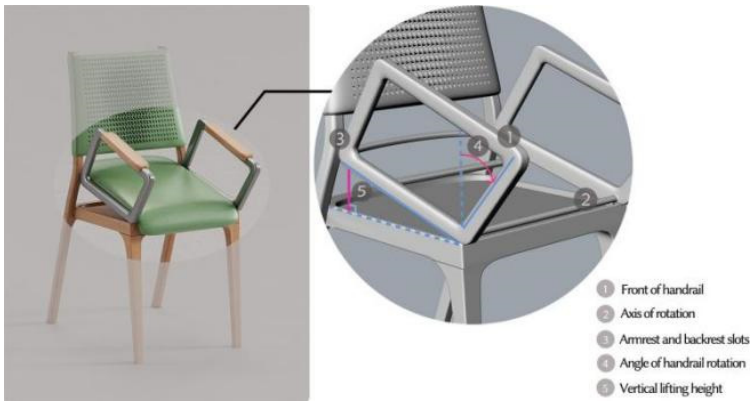


Fig. 4. Physical spindle lift structural diagram

Fig. 5. Usage effect diagram

4.3.2 The design of the patterned backrest perforation

At present, the surface of most seat backrests has a single form and lacks aesthetics, while the degree of deformation is limited, which to a certain extent restricts the adjustable range of the human back. Taking into account the weakening of muscle strength in the elderly, the decline in power, and the fact that sitting for a long time in the same posture is very easy to cause back fatigue and discomfort, the program to use a triangular pattern as the basic unit, through the combination, array, and gradient design of the backrest pattern hole array (Fig. 6), in full contact with the back of the region of the hole array is larger by the time of extrusion to provide a stronger degree of diastole, while at the same time the hole array to the four sides of the regular narrowing, which not only ensures stability and firm backrest but also a certain decorative effect. This not only ensures the stability and firmness of the backrest but also has a certain decorative effect.

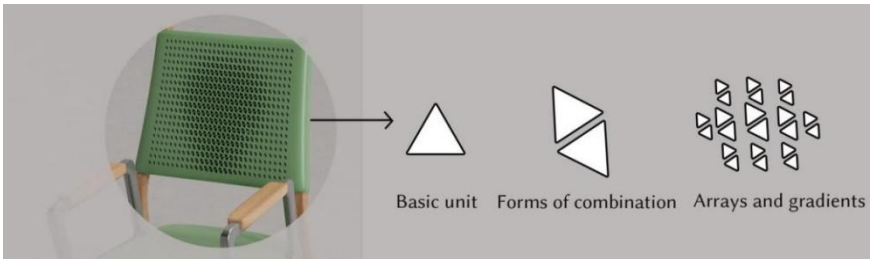


Fig. 6. Backrest pattern hole array design

4.4 Material analysis of design solutions

The material of the aging seat should avoid metal and stone with a cold and hard feeling to reduce the psychological feeling of despondency[9]. The program uses pine wood as the main frame of the seat to meet the nostalgia of the elderly and the pursuit of natural psychology. In order to realize that the backrest of the aperture array can be moderately deformed and restored and has good softness, the program adopts tetraphenyl ethylene (TPE) material with high strength, high resilience, excellent fatigue resistance, and temperature resistance, and at the same time, its low-cost, non-toxic, and environmentally friendly characteristics are also in line with the purchasing needs of the elderly; the assisted getting up The armrests are made of a stable and sturdy carbon steel alloy. (Fig. 7).

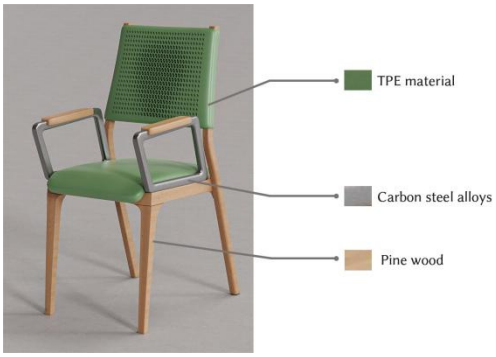


Fig. 7. Seat material analysis

4.5 Design scheme color analysis

Color has a very strong psychological implication for users; different target groups need different design approaches; and the rational use of color becomes particularly important when designing products for the elderly [10]. Considering the coldness and lack of temperature of most seats and the loneliness of the elderly, the program chooses a moderately pure yellow color for the wood; the backrest and cushion use a more vibrant green; and the rising armrest device uses the bright silver color of the alloy itself, reflecting the solid and durable characteristics (see Fig. 8).

Fig. 8. Color effect scene diagram

5 Conclusion

Under the development trend of aging in our society, the seat is of great research value and significance as a necessity for the home life of the elderly. In this paper, on the basis of analyzing the pain points and shortcomings of the existing elderly seat products, we fully consider the special characteristics and physiological and psychological characteristics of the elderly population. Sometimes intelligent products do not meet their needs but instead bring a lot of burdens, and through the questionnaire survey, we have concluded that the elderly's needs for the seat are mainly in terms of safety and affordability, auxiliary functions, high comfort, and friendly and natural materials. We have also taken ergonomics as the design

guidelines, and the size, auxiliary function, material, color, and other factors of the seat are designed, and a non-intelligent seat design scheme is proposed. As society pays more attention to the elderly, the market for age-friendly products will develop rapidly, and it is believed that in the future, research on age-friendly seats will be more in-depth and comprehensive.

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