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A Current Design Approach for Ming Chairs

Yifan Bai *, Khairul Manami Kamarudin * and Hassan Alli

Industrial Design Department, Faculty of Design and Architecture, Universiti Putra Malaysia, Serdang 43400, Selangor, Malaysia; halli@upm.edu.my
* Correspondence: baiyifan1600@gmail.com (Y.B.); manami@upm.edu.my (K.M.K.)

Abstract: Ergonomics are key in the design and application of Ming-style chairs. However, there are presently few specific design frameworks to guide Ming-style chair design. Under this background, the present study developed a questionnaire on the ergonomic design of Ming-style chairs and assessed its validity and reliability. Fifty-two respondents involved in the design and manufacture of Ming-style chairs participated in this study. The statistics of the questionnaire were analyzed and yielded a significant reliability coefficient ($\alpha > 0.70$, $p < 0.01$). This ergonomic design framework study of Ming-style chairs analyzed the domains of Chair Form, Aesthetics, Safety, Comfort, Ease-of-use, and Productivity. To assess the importance of various design elements, we used a five-point Likert scale to score items within each domain. This scoring system enabled us to prioritize features, allowing the designers to focus on the essential elements before beginning the design process. We found that designers and manufacturers focused primarily on the Four-headed Official Chair with Armrests form.

Keywords: ergonomics; statistical data; chair design; Ming-style chairs

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1. Introduction

Under the increasing level of economic development today, humanization is essential for contemporary furniture design solutions. Thus, ergonomics is gradually becoming an expression of humanization. Specifically, the aspects of comfort, aesthetics, and safety play a vital role in the design of furniture. Silviana et al. utilized anthropometric measurements as a design tool for ergonomic furniture to reduce the likelihood of various health problems and improve employee performance [1]. Siregar et al. conducted research suggesting that non-ergonomic postural habits can lead to lower back pain and that adding back support to chairs is beneficial in reducing this pain [2]. Lu et al. analyzed the pressure distribution in forward-leaning and upright sitting postures [3], and Moon et al. optimized the elastic support material on the chair's surface to improve comfort [4]. Kim et al. analyzed the effects of postural changes in the angle between the torso and thighs and the angle of the knee on muscle fatigue in the lower body under sitting conditions [5]. Cardoso et al. studied the biomechanics in office seating to analyze the physiological comfort from a mechanical perspective [6]. Bahrampour et al. determined the depth of the chair through a subjective ergonomic evaluation method of comfort and discomfort [7]. Overall, ergonomics is clearly crucial for the comfort and safety of a chair. Historic chair designs can be adapted to incorporate contemporary ergonomic principles while considering the secular shift in body size and weight to ensure optimal user comfort and well-being. Maciej et al. structurally designed a chair by emphasizing the critical gap between contemporary chairs and user needs, focusing on the user's anthropometric dimensions to better improve the ergonomic parameters of the chair. This study determined the optimal functional dimensions required to meet the needs of users with different heights and weights [8,9]. The needs of the user are particularly important in historical chair design due to changing times. Vos et al. investigated variations in seat cushion interfacial pressure in terms of both posture and seat structure design and found that variation in the seat structure design plays a dominant role in seat cushion interfacial pressure [10]. Changes in pressure directly affect user comfort. The results of Thariq et al.'s study further validated the need for chair design to incorporate the user's anthropometric data and industry-relevant dimensions to enhance comfort and provide proven effects for the user's health [11]. At the same time, comfort also directly affects the user's sense of well-being and aesthetics, which can be amplified by the aesthetic elements of the design during use [12]. An investigation of Musculoskeletal Disorders (MSDs) found that the lower back is the most important area in the occurrence of MSDs and that ergonomic design can reduce work-related MSDs [13–15].

Chinese traditional furniture has a long cultural history and offers the characteristics of rigorous design, smooth structure, ease-of-use, and comfort [16]. While reflecting the knowledge of past generations, such furniture also maps the idea of traditional Chinese ergonomics. The modeling, materials, patterns, and motifs in the design process of traditional furniture must fully consider the physiological and psychological factors of the society at that time [17]. The most typical variety of traditional furniture is the Chinese Ming-style chair, which embodies the principles of ergonomics combined with traditional aesthetic ideas and knowledge of the human body [18,19]. However, there remain some deficiencies in the research of ergonomic design and the modern design and modeling of Ming-style chairs. The design of related furniture mainly focuses on simulation-based research, while the integration of overall ergonomic elements in Ming-style chairs is relatively uncommon.

Integrating ergonomics into Chinese traditional culture is a topic worth exploring to promote this area of research for sitting furniture design. However, it remains difficult to balance the culture of traditional furniture and the theory of ergonomics when exploring sitting furniture ergonomics and modeling. Ergonomics is mainly used to enhance the user's comfort, with both subjective and objective methods used to assess the comfort of chairs [20,21]. Subjective methods involve questionnaire surveys and direct questioning. Objective methods utilize pressure distribution and postural or electromyographic measurements to determine the associated discomfort. The subjective approach is influenced by personal factors and also reactions to the environment. Objective measurements also complement subjective evaluations when they correlate with comfort. To date, most research on the design of Ming-style chairs has been based on people's subjective descriptions and perceptual understanding, mostly focusing on describing the relevant characteristics and generalizing the embodied concepts. This kind of fuzzy description with individual differences lacks objective standards or a clear analysis of the results using quantitative experimental methods. The primary purpose of this study is to analyze the ergonomics of Ming-style chair design to develop a corresponding design framework and thus provide design guidance for subsequent Ming-style chair designers.

2. Materials and Methods

The research method used in this study was a questionnaire structured to analyze the ergonomics of Ming-style chairs. The target respondents of the questionnaire were designers and manufacturers of furniture. The questionnaire was designed in seven domains: Personal Information, General Ergonomics, Aesthetics, Safety, Comfort, Ease-of-use, and Productivity [22]. The factors under different domains were subdivided according to the studies of Reich [23], Qureshi [24], Kolich [25], and Cai [26], and different items were selected for the questionnaire. A series of questions was asked in different domains, and respondents' choices were assessed using a 5-point Likert scale (not at all = 1, slightly = 2, moderately = 3, Well = 4, extremely = 5).

Chinese traditional and modern chairs have various forms and shapes, with many varieties of chairs and stools. Therefore, to ensure the comparability and consistency of the research objects in this study, the chairs in the furniture category were selected as the objects of the collection. After the preliminary modeling collection work, a total of 100 Ming-style chair images were collected. From the sample, we sought pictures in which the chair shapes were clear and easy to identify. Thus, all fuzzy, high-similarity, and similar-form pictures were excluded by screening the preliminary sample pictures. Ultimately, eight samples of the most desirable Ming-style chairs were selected from the 100 images, with the sample images and numbers shown in Figure 1.

Figure 1. Chair form images.

This questionnaire started in June 2023 and ended in July 2023. Fifty-two people engaged in the design and manufacture of traditional Chinese furniture participated in this study. To avoid data errors caused by unnecessary factors, the experimental subjects were selected to be relatively balanced in terms of age, gender, and education. The subjects were free of visual impairment and had a balanced ratio of males to females. The frequency distribution of age among the respondents was as follows: 9.62% were 18 to 24 years old, 21.15% were 25 to 34 years old, 36.54% were 35 to 44 years old, 15.38% were 45 to 54 years old, and 17.31% were more than 55 years old. In terms of gender, there were 23 male respondents (44.23%) and 29 female respondents (55.77%), as shown in Table 1. All participants were asked to read the questionnaire carefully and then determine their preferences for ergonomics items based on their design and manufacturing experience.

Table 1. Distribution of the survey respondents.

Survey Respondents		Number
Age	18–24	5
	25–34	11
	35–44	19
	45–54	8
	>55	9
Gender	Male	23
	Female	29

The results of the subjects' preferences for the ergonomic aspects of Ming-style chairs in the questionnaire were collated and counted. The data from the sample were then entered into IBM SPSS Version 26.0 software for analysis. The mean value of each item was listed separately to determine a high or low priority based on the level of the value.

For the reliability analysis, the Cronbach's alpha [27] (calculation Formula (1)) of the scale was higher than 0.7, indicating good internal consistency among the multiple variables constructed for the scale. For validity analysis, Kaiser–Meyer–Olkin (KMO) (calculation Formula (2)) and Bartlett's test were used. Considering the general nature of the ergonomic and productivity domains, no reliability analysis was conducted:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum s_i^2}{s_t^2}\right) \quad (1)$$

where k is the number of items, s_i is the variance of the ith item, and s_t is the variance of the total score formed by summing all the items:

$$\text{KMO} = \frac{\sum\sum_{i \neq j} a_{ij}^2}{\sum\sum_{i \neq j} a_{ij}^2 + \sum\sum_{i \neq j} b_{ij}^2} \quad (2)$$

where a_{ij} represents the correlation between variables i and j, and b_{ij} represents the partial correlation between variables i and j.

3. Results

In the survey data from 52 traditional furniture designers and manufacturers, 67.31% of the respondents indicated that they knew a great deal about Ming-style chairs, 17.31% indicated that they knew the topic somewhat, and 15.38% knew the topic to a moderate degree. Based on the data, the vast majority of designers and manufacturers who participated in this survey have a good understanding of Ming-style chairs, which increases the reliability of this survey.

Table 2 presents the reliability and validity analysis of the questionnaire in the aesthetic domain. Here, the Cronbach's alpha values corresponding to the four dimensions of the aesthetic domain designed in the questionnaire are 0.876, 0.905, 0.907, and 0.854, respectively. These values are all greater than 0.7, indicating superior internal consistency among the dimensions in the aesthetic domain of the traditional furniture users' survey questionnaire. Thus, the results of the present survey have good reliability. Based on the validity analysis results in Table 2, the KMO values of the 4 domains were 0.65, 0.67, 0.75, and 0.77—all greater than 0.6. Meanwhile, Bartlett's test provided a result of $p < 0.05$, meaning that the statistical data could be used for the factor analysis.

Table 3 provides the descriptive data from the respondents on the eight types of Ming-style chairs. Analyzing the data shows that Chair Form 1 scored 3.5 on the five-point Likert scale, indicating that the 52 traditional furniture designers and makers reported that Chair Form 1 is more in line with the shape of Ming-style chairs, whereas the Official Chair with armrests is more in line with the characteristics of Chinese Ming-style chairs. In addition, the respondents considered Aesthetics to be the highest priority in the ergonomic design process of Ming-style chairs, with a mean value of 3.25, followed by Comfort (3.21), Safety (3.21), Ease-of-use (3.08), and Productivity with a mean value of 2.98.

To explore designers' and manufacturers' preferences for Chinese Ming-style chairs in the Aesthetic domain section. Four influences were analyzed considering the application of senses, external influences, modelling data, and aesthetic elements. The scores of each item in the five-point Likert scale are shown in Figure 2. Designers considered the application of senses to have the highest priority when selecting Ming-style chairs, with the sense of touch ranking highest. Taste (M = 3.15) was the lowest-scoring item among the senses, while symbols had the highest priority among the choices of items for external influences. Among the nine items for styling data, seat width had the highest priority, while form and texture had the highest priority in the preference selection for aesthetic elements.

Table 2. Reliability and validity analysis of questionnaire data from Ming-style chair designers and manufacturers.

Domain	Factor	Item	Cronbach α	KMO	p
Aesthetic domain	Sense application	Smell, See, Hear, Taste, Touch, Emotion	0.88	0.65	0
	External influence	Symbol, Pattern, Commonality, Theme, Manufacturing process, Value, Language	0.91		
	Modelling data	Length, Width, Hight, Backrest height, Backrest curvature, Armrest height, Seat surface material, Seat height ratio, Leg height	0.91		
	Aesthetic elements	Form, Color, Texture, Balance, Material, Functionality	0.85		
Safety domain	Risk factors	Repetitiveness, Required force, Prolonged positions, Inadequate tools	0.81	0.67	0
	Common ergonomic injuries	Musculoskeletal disorders, Carpal tunnel syndrome, Rotator cuff injuries, Lower back injuries	0.87		
	Discovering ergonomic hazards and fixing them	Redesigned tools and adjustable equipment, Work close to the body, Alternate postures and motions, Keep the workspace clean and clear	0.87		
	Safety item	Seat height, Seat width, Seat depth, Seat curvature, Seat inclination and backrest inclination	0.87		
Comfort domain	Physiological comfort factors	Muscle fatigue, Partial pain, Seated posture	0.81	0.75	0
	Psychological comfort factors	Emotions, Mental health	0.76		
	Physical comfort factors	Seat modelling, Seat support, Seat adjustment, Breathability, Material	0.87		
	Environment comfort factors	Noise, Temperature, Vibration, Illumination	0.85		
Ease-of-use domain	Ease-of-use	Effectiveness, Efficiency, Satisfaction, Context of use	0.82	0.77	0
	Common attributes	Easy to learn (or easy to read), Efficient, Easy to remember, Fewer mistakes, Satisfaction	0.85		

Table 3. Analyzed data from the respondents' evaluations of eight different forms of Chinese Ming-style chairs.

Items	Mean Value	Standard Deviation
Chair Form 1	3.50	1.336
Chair Form 2	3.35	1.118
Chair Form 3	3.15	1.211
Chair Form 4	3.00	1.048
Chair Form 5	3.21	1.035
Chair Form 6	3.19	1.155
Chair Form 7	3.19	1.189
Chair Form 8	3.12	1.182

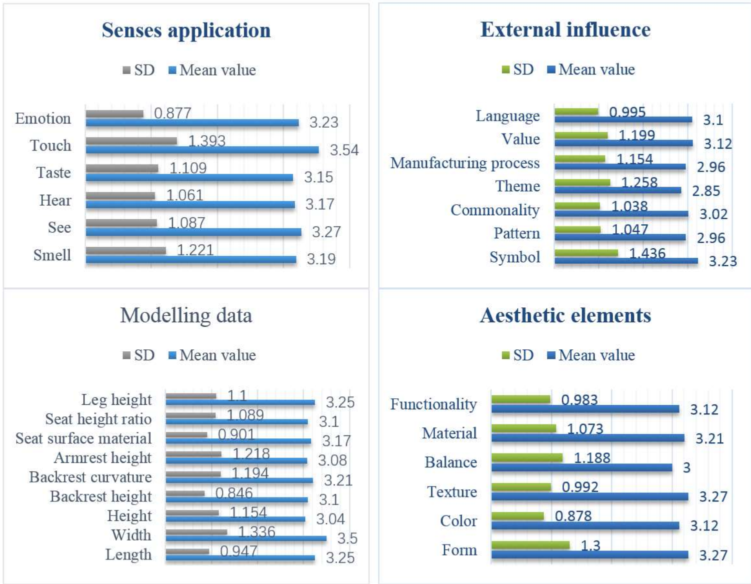

Figure 2. Selection statistics of respondents' preferences for Chinese Ming-style chairs in the Aesthetic domain.

Figure 3 provides a data analysis of the respondents' preferences for Chinese Ming-style chairs in the Safety domain. The statistics were analyzed based on four factors: risk factors, common ergonomic injuries, identifying ergonomic hazards and fixing them, and seat safety design. In terms of risk factors in the use of Ming-style chairs, Prolonged positions scored the highest. For ergonomic injuries, Musculoskeletal disorders had the highest mean value of 3.46. In terms of prioritizing the identification of ergonomic injuries and fixing them, Redesigned tools and adjustable equipment had the highest priority. Finally, Seat Depth was prioritized in the seat safety design.

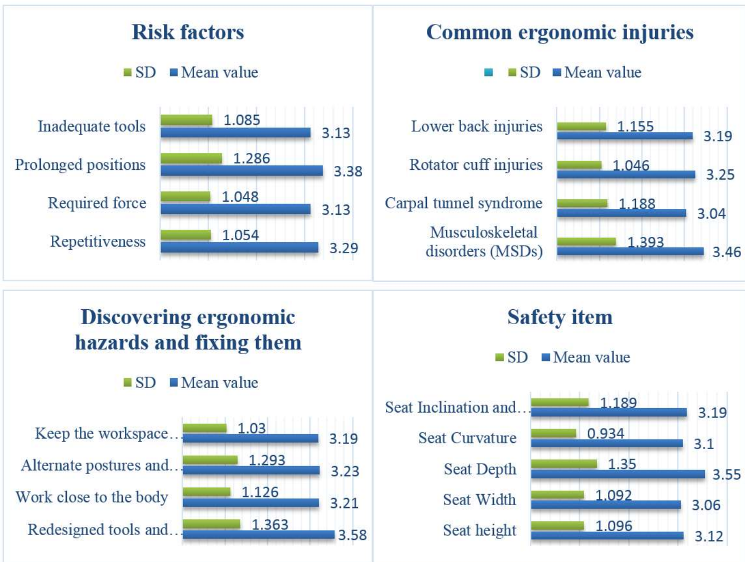

Figure 3. Selection statistics of respondents' preferences for Chinese Ming-style chairs in the Safety domain.

Physiological comfort factors, psychological comfort factors, physical comfort factors, and environmental comfort factors are the four components of the Comfort domain that have an impact on Chinese Ming-style chairs. We explored the respondents' preferences for Ming-style chairs based on four sets of data. The statistical data analysis in Figure 4 shows that Muscle fatigue was prioritized among the physiological comfort factors, while

Emotion was preferred among the psychological comfort factors in the design of Ming-style chairs. Comparatively speaking, Seat Modelling was given the highest priority among physical comfort factors. For environmental comfort factors, the influence of Temperature was prioritized.

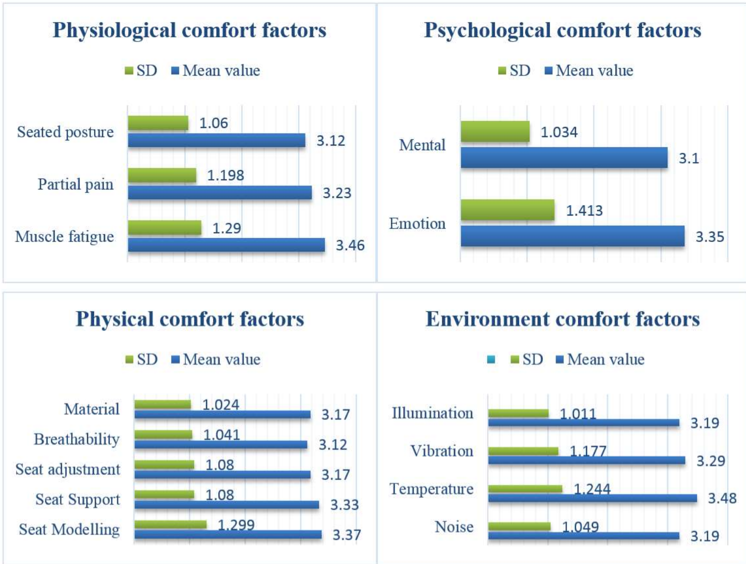

Figure 4. Selection statistics of respondents' preferences for Chinese Ming-style chairs in the Comfort domain.

We explored the respondents' preferences for Chinese Ming-style chairs in the Ease-of-use domain by analyzing two sets of data: Terms of ease-of-use and Common attributes. The statistical results utilizing a five-point Likert scale are shown in Figure 5. Based on the analysis results, respondents clearly prioritized Satisfaction for Ease-of-use in the design of Ming-style chairs. Satisfaction was also prioritized among the common attributes. In the descriptive data analysis of productivity factors prioritized for Ming-style chairs, Typing net speed (number of correct words/min) scored highest with a mean value of 3.21, followed by Accuracy (percentage correct) with a mean value of 3.17.

Figure 5. Selection statistics of respondents' preferences for Chinese Ming-style chairs in the Ease-of-use domain.

4. Discussion

4.1. Ergonomic Design Framework

We categorized the items into 2–3 groups based on how high or low the items scored under different factors. The specific calculation method was as follows: First, we calculated the average value of each item's score on the five-point Likert scale and arranged the results in descending order. Next, we calculated the mean difference between each two-item pair and the percentage of the mean difference compared to the total difference and grouped the items according to the percentage of the mean difference.

The data analysis in Table 3 clearly shows the importance of form for Ming-style chairs among all respondents. The respondents reported that the armrests, backrest, and overall shape of Chair Form 1 (Four-headed Official Chair with Armrests) were more symbolic of Ming-style chair design than those of other forms. Ming-style chairs are based on simplicity, and the cross profile between the legs is low at the front and high at the back. Moreover, the top rail and backrest have a smooth transition and a shape that fits the head and neck, allowing for better relaxation when resting [28]. The shapes and sizes of the armrests on Ming-style chairs are designed to be suitable for the hand to grasp, making it simple to place one's arm on and providing additional support and comfort [29]. Armrests not only provide comfort but also help provide support when people stand or move. Ming-style chairs have an s-shaped curved back with an angle of nearly 100 degrees, which fits the spine ergonomically [30,31]. The square shapes of these chairs also give people a dignified and atmospheric feeling. These factors together contributed to the preference for the Four-headed Official Chair with Armrests style among designers. The grouping of general ergonomics for Chinese Ming-style chairs revealed that the respondents perceived Human postures and Product dimension to have the highest priority in the chair's ergonomic design, while Product handling had the lowest priority. This result does not mean that Product handling is unimportant in the ergonomics design process but rather that this factor plays a smaller role than others in the ergonomic analysis of Ming-style chairs.

Chinese wooden chairs are a valuable type of furniture produced in small batches, so greater consideration is given to their quality in the design and production processes. Consequently, among designers and manufacturers, greater attention is paid to aesthetic and comfort-based elements, the enhancement of which may increase the attractiveness of the chair. Productivity in the industrial sector, on the other hand, has received relatively little attention. In addition, industrial technology today is well developed, and the level of chair manufacturing has increased, which is another reason why productivity receives less attention than in other areas.

Touch is also an important element of judgment in furniture use. Touching a chair provides the first indication of the chair's comfort and the attractiveness of its shape. Smell, hearing, and taste are less relevant senses in the design of Ming-style chairs. However, these elements may occupy important positions in other designs. Symbols occupy a very important position in traditional Chinese culture; thus, the Symbol element was given the highest priority among respondents to the questionnaire on Chinese Ming-style chairs. The width of the seat directly affects the comfort of the user and is considered an important item by both designers and manufacturers. The last aspect of the Aesthetic domain corresponds to aesthetic elements. For example, whether the material is good or bad significantly impacts the price of a Ming-style chair and one's feelings when using it. Thus, the material of the seat was considered an important item. Traditional Chinese wooden chairs are largely based on high-quality mahogany furniture, the color of which is mostly reddish brown. Thus, the priority of color was slightly lower than that of other items in this study.

In the risk factors of the Safety domain, prolonged use of a hard wooden chair was labeled as a Prolonged Position. MSDs, as the most prevalent class of occupational disorders, are a necessary factor in the Safety domain, regardless of the scenarios and types of seats to be used. Moreover, Seat Depth directly determines the force on the user while using the seat and is an important factor in determining safety.

The primary considerations in the Comfort domain are physiological comfort factors. We found that Muscle fatigue greatly affects one's comfort when seated for a long duration of time, which is of great concern. However, one's Seated posture is relatively fixed when using Ming-style chairs, whose wooden structures and sizes limit the application of certain seating postures, giving this element a lower priority. To satisfy physical comfort, Seat Modelling and Seat Support directly affect one's sitting posture and force on one's body parts during use, which were considered crucial factors among the respondents. Breathability is less often considered in the design of Chinese Ming-style chairs, which more often consider the material integrity and consistency of the shape. In terms of environmental factors, respondents chose Temperature as the highest priority because temperature has the greatest impact on environmental comfort, and temperatures that are too high or low can make users feel uncomfortable.

In the Ease-of-use domain, Satisfaction received high attention. The purpose of easy-to-use design is to ensure that interactions between the product and the user are harmonious and comfortable, to improve the operability of the product in line with the user's operating habits and needs, and to ensure the product satisfies the user. Therefore, the user's Satisfaction should be prioritized. Comprehensive aspects of the design should ensure that the chair can meet the physiological and psychological needs of people in the use or operation process, providing users with greater safety and comfort at work. The ultimate goal is to improve people's work efficiency, which may correspond more strongly to the speed of work completion.

The basic information in the above sections and the research results of the questionnaire were categorized and analyzed to obtain the basis of an ergonomic design framework for Chinese Ming-style chairs, as illustrated in Figure 6. This design framework specifically prioritizes the five main ergonomic components of Aesthetics, Safety, Comfort, Ease-of-use, and Productivity and evaluates the general ergonomics and seating forms of Ming-style chairs. The framework shows the performance of Ming-style chairs in all aspects of ergonomics. In addition, the colors of the elements corresponding to the level of priority are arranged from dark to light, where the lighter the color, the lower the priority. The level of priority for each item is associated with the level of that item's score on the five-point Likert scale. Items with high scores should be given the greatest priority in ergonomic design.

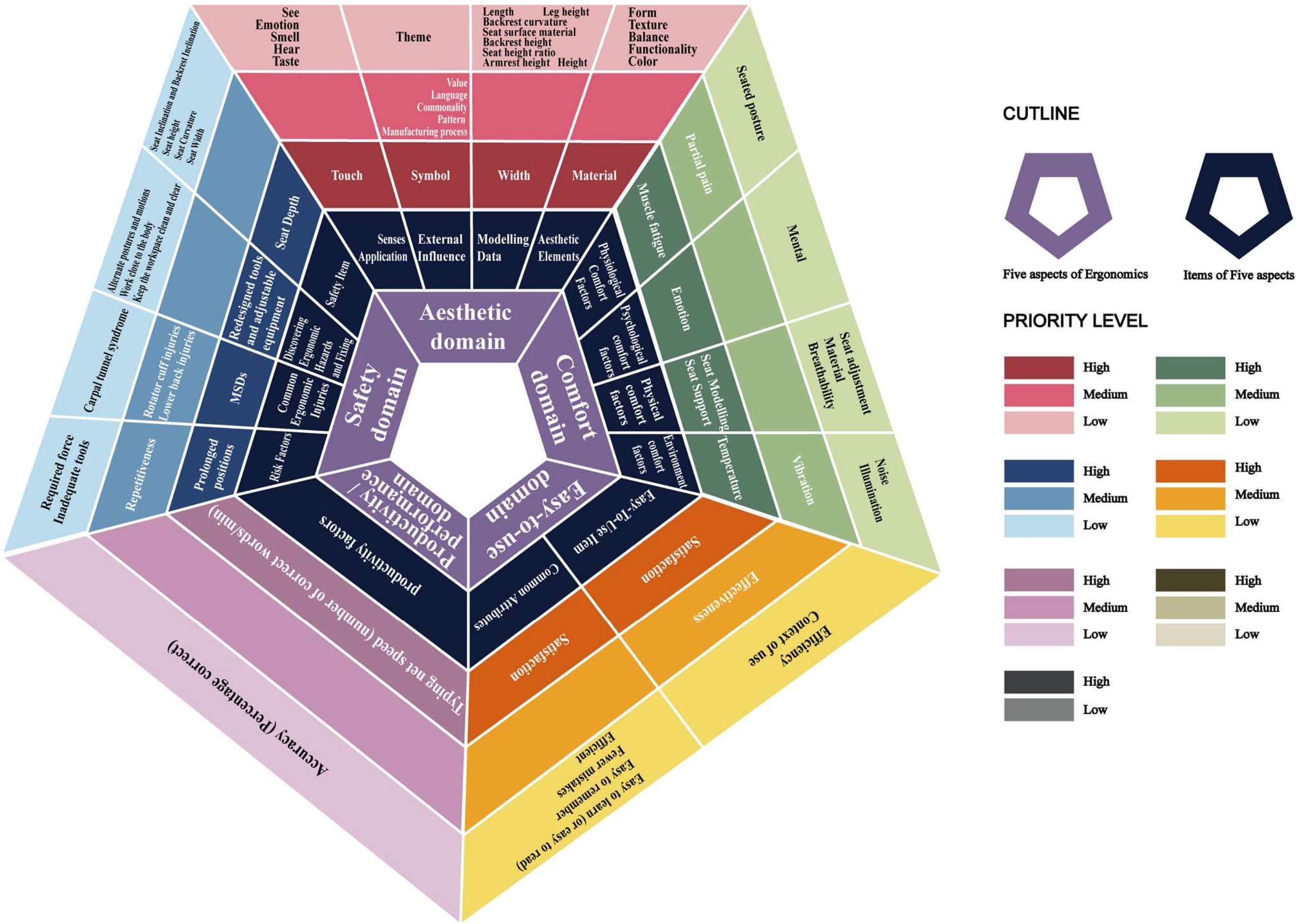

Figure 6. Ergonomic design framework for Chinese Ming-style chairs.

4.2. Study Limitations

The participants in this study's questionnaire were mainly engaged in the design and manufacture of traditional Chinese furniture. However, no research was conducted on the consumers of Ming-style chairs. Notably, there is a significant difference between designer- and consumer-level knowledge of ergonomics. Designers are engaged in chair design and have professional education and training, so their knowledge of ergonomics is in-depth and thorough. Most consumers, on the other hand, choose chairs based on their own feelings. The ultimate goal of chair design is to satisfy the needs of consumers, so it is important to investigate the ergonomics of chairs for consumers. As a chair designer, it is necessary to consider the needs of consumers in the design process. Therefore, the results of the designer questionnaire used in this study partly reflect consumer demand. However, these results do not fully represent consumer knowledge and demand for chairs. In subsequent research, we could also survey chair users, making the research results more comprehensive. The small sample size in this study could also have limited the results, which could be ameliorated by increasing the number of samples.

5. Conclusions

Data on ergonomics-related issues in the design process of Chinese Ming-style chairs were obtained with a questionnaire. By analyzing the data, a corresponding ergonomics design framework and approach was obtained. The main conclusions are as follows:

(1) In the survey, designers and manufacturers paid the most attention to the Four-headed Official Chair with Armrests form. Meanwhile, the respondents believed that the highest priority in the ergonomic design process of Ming-style chairs is the Aesthetic domain followed by the Comfort and Safety domains.

(2) A five-point Likert scale was used to score different items under the domains of Aesthetics, Safety, Comfort, Ease-of-use, and Productivity in the ergonomic design of Chinese Ming-style chairs. These domains were prioritized based on the scores, enabling designers to better distinguish between the basic elements before engaging in the design process.

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