

Research Article Construction of Evaluation Index System of Office Sitting Comfort Based on Ergonomics

Jiadian Hu 🝺, Shoudong Shi 🝺, Jiaqing Zheng 🝺, and Zhiyuan Fang 🕩

Faculty of Electrical Engineering and Computer Science, Ningbo University, Ningbo, China

Correspondence should be addressed to Jiadian Hu; 1911082207@nbu.edu.cn

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People who sit incorrectly can have musculoskeletal disorders like cervical spondylosis and lumbar vertebra disease, but without the guidance of a health care professional, it is difficult for people to evaluate their posture and adopt a more appropriate posture. Therefore, to solve this problem, we established a multilevel sitting posture evaluation system by analyzing the parameters such as joint angle, joint torque, joint force, and muscle force. Use the analytic hierarchy process and entropy comprehensive weighting method to weight evaluation indicators. According to their evaluation standards, each parameter is given weight after quantization and normalization. Firstly, take several sitting postures that often appear in office work as examples and use the lower back analysis and joint and static pressure analysis tools in JACK software for simulation analysis. Then, the weights of various parameters such as joints and muscles of the human body were calculated using the hierarchy analysis and entropy weight method, and the quantitative evaluation system of office sitting comfort was constructed. We recruited 50 subjects for an office simulation experiment to verify the feasibility of the evaluation index. Finally, we classified the sitting posture and selected those commonly used in life for evaluation. The proposed sitting posture evaluation system can objectively and comprehensively reflect the quality of sitting posture and guide people to adopt what kind of sitting posture.

1. Introduction

In recent years, the number of patients with cervical spondylosis and lumbar spondylosis has increased dramatically. In the working population of Xuhui district, Shanghai, the prevalence of cervical spondylopathy is 13.8% [1]. In Xinjiang, the prevalence rate is as high as 23% [2]. The prevalence of cervical and lumbar vertebrae in long-term computer users was 60% [3]. The total cost of treating cervical spondylosis is more than 30,000 RMB [4, 5]. Treatment abroad is more expensive [6, 7]. Studies have shown a close relationship between these chronic diseases and sitting posture. Improper stress during occupational activities leads to neck back disease, which experts in the field of ergonomics or occupational health call occupational musculoskeletal disease. It is damage to all aspects of muscles and bones, including muscles, joints, ligaments, and nerves [8, 9]. The spine, muscles, and other body tissues may also bear different pressures simultaneously with different postures. Office people who keep sitting and using computers for a long time lack knowledge of ergonomics. If they adopt the incorrect working posture, they will have discomfort or pain and other symptoms in the musculoskeletal system [10]. Therefore, the evaluation of sitting comfort is of great significance to sitting correction.

Previous studies on sitting comfort have covered several research scenarios, including high-speed trains, automobiles, schools, and offices (Table 1). Sitting posture analysis data mainly comes from objective measurements and subjective evaluations. Objective measurements generally use pressure sensors and elastic sensors. To study the effects of pressure distribution and contact area on sitting comfort, subjective evaluation is done by using questionnaires or analysis of online reviews to rate all aspects of user comfort. Statistical and decision methods are used to analyze the data to obtain comfort and ranking.

Existing studies have shown that sitting comfort has an important impact in various settings. Although previous

Author	Data sources	Sample	Major findings
Li et al. [11]	Body pressure measurement system and cushion comfort questionnaire	16 adult college student volunteers (8 male and 8 female)	Both the seat cushion contour and the sitting posture result in significant pressure distribution differences, while the seat cushion contour additionally results in changes in pressure parameters, and the sitting posture affects the location of peak pressure.
Choi et al. [12]	Elasticity measurement system	Seven healthy male students participated in the experiment and had no musculoskeletal disorders	Proposed a model of the self-adjustable seats (SSA seats) that have a uniform and improved pressure distribution, compared to the conventional seat, in various sitting postures; the contact area between the seat and user is enlarged, and the pressure concentrated on the ischial bone is lowered.
Fasulo et al. [13]	A pressure data acquisition system, a photo/video-graphic acquisition system, and a (dis)comfort questionnaire	Twenty-five students (12 females, 13 males), all volunteers. None had a history of musculoskeletal diseases	In our study, however, the movements were obligatory as subjects had to write or listen within a limited space, with no possibility to change the combo-desk layout. We thus observed the opposite result: a decrease in discomfort when the subject changed position.
Chen et al. [14]	Online-review analysis and online questionnaire investigations	Using web crawler tools, the online reviews were collected from a microblogging platform	This research constructs an index system of HSR passenger satisfaction evaluation based on online-review analysis and evaluates the process by using LSGDM approaches.
Estrada and Vea [15]	Accelerometer sensor of smartphones and JACK Siemens software	Some participant	This study concludes that each person has different body frames that require different degrees in recognizing proper and improper sitting posture.

TABLE 1: Overview	of the	reviewed	sources.
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studies have examined comfort from several aspects such as seat shape, contact area, passenger's body type, and surroundings, there are limitations in the following areas.

- Analysis of the seat structure and user evaluation without considering the effect of the human posture itself
- (2) Need to use additional sensors such as pressure sensors and elastic sensors, increasing the cost
- (3) Does not consider joint forces, joint angles, and other skeletal joint information inside the human body
- (4) No systematic classification of the human body's sitting posture to evaluate sitting posture

The rest of the paper is organized as follows. The second part presents the modeling process of sitting posture and the simulation results of several common sitting postures, and the weights of each parameter are assigned using a combination of the entropy weight method and the AHP method. The third part designs an experiment on office sitting posture to verify the feasibility of the evaluation method. The fourth section analyzes the evaluation results of common sitting postures. The last two sections describe the idea of continuing the study and point out the main contributions.

2. Materials and Methods

2.1. Simulation Modeling and Analysis of Office Sitting Posture. JACK is a simulation software for digital human modeling and ergonomic analysis. Compared with other simulation software DELMIA, 3D SSPP, and OpenSim, JACK's simulation and analysis function are more comprehensive and perfect [16] and have the most accurate human biomechanical model in the industry. Therefore, this paper carries out man-machine modeling and simulation based on JACK software to analyze the comfort of different sitting positions.

2.1.1. Office Modeling. The content of office work includes browsing files and web pages, inputting data, making phone calls, and doing other homework. This paper selects computer input data as the main content. Use the software to create desks, seats, and other entities that meet the national standard GB/T 39223.3-2020 [17] size, body pressure distribution, and ergonomics requirements and make a reasonable layout of these entities in the space to build an office space model as shown in Figure 1.

2.1.2. Building Virtual Human Model. The mannequin in JACK consists of 71 segments, and 61 joints have reached 135 degrees of freedom. JACK provides nine standard human body databases, including ANSUR1988, CHINESE, and CDNLF97. Since the age range of legal adults engaged



FIGURE 1: Office space model.

in industrial production in the country is (males 18-60 years old, females 18-55 years old), according to the corresponding body size data of various parts of the human body in the national standard Chinese adult body size (GB/T 10000-1988), according to the 50th percentile scale, 26 kinds of size data of digital manikin were determined, which can satisfy most people [17] as shown in Figure 2.

2.1.3. Construct Common Sitting Posture. In order to model and simulate the sitting posture accurately, the portable ergonomic observation method (PEO) proposed by Fransson-Hall et al. [18] is adopted as shown in Figure 3. The reference system takes the L5 joint of the lumbar spine as the coordinate origin, and the plane, horizontal plane, and vertical direction of the pelvis are the z-axis. Using Euler angles, describe the trunk space position. The Euler angle of torso posture includes pitch, yaw, and roll angles. During modeling, set the digital human head control parameter "vision target;" that is, the target of gaze, as "follow site," selects the site as the center point of the computer screen. Moreover, adjust the neck joint to make the line of sight look at the center of the screen. Adjust the position of other joints according to the position of the body torso in the three dimensions of the Euler angle to maximize the influence of the parameters such as muscle strength, joint angle, and force in these three dimensions and keep the line of sight right in the middle of the screen. Hands fixed on the keyboard. Simulate the posture that often occurs in the office, and finally, get seven sets of mannequins, as shown in Figure 4. Seven trunk changes, for example, have carried on the simulation analysis [19].

2.2. Ergonomic Analysis of Sitting Posture. The most significant impact on sitting comfort is the force and muscle force of the L4/L5 lumbar spine, followed by the angle parameters of other joints, which implies the static load and tolerance level of relevant muscles. Then, analyze the joint angle, joint force, torque, and muscle force. Get the influence of different sitting postures on these aspects.

2.2.1. Evaluation of Joint Comfort. The comfort evaluation module (Comfort Assessment) of the JACK software calculates the comfort level according to the opening and closing angles of the main joints of the human body, implying the static load and tolerance level of the relevant muscle groups. JACK provides six different comfort evaluation databases, such as Porter [20], Krist [21], Grandjean [22], Rebiffe

[23], and Dreyfuss (2D↦ 3D). Among them, Dreyfuss 3D has the most abundant joint indexes. Its data comes from comparing various human test databases, covering 16 human joints. Here, the database is selected to evaluate the comfort level of the joint angle.

The analysis results of upright sitting posture are shown in Figure 5. Three indexes slightly exceed the limit value of the index, and the comfort is generally reasonable.

At this time, the upper body of digital people is straight, lacking certain backward tilt and back support, and there is room for further improvement.

Most indicators have exceeded the limit when the torso is tilted forward due to a significant pressure concentrated on the wrist and arms. In addition, the comfort of the wrist and arm will also decrease. This posture does not conform to physiological requirements and cannot keep it for a long time. The other joints are near the recommended value when the torso tilts, except the elbow joint, which exceeds the limit value. Simulation shows that all joints can be in a comfortable range as long as they reduce the amplitude of the torso. The left and right tilt of the torso will make the upper limb joints of the corresponding side at an uncomfortable angle, reducing the flexibility of the corresponding upper limb.

2.2.2. Lower Back Analysis. L4/L5 joint is the primary stress joint in sitting posture, and the harmful stress of the L4/L5 joint is also the main factor causing lumbar diseases. So, use the lower back analysis modules provided in JACK software to analyze the different postures of the digital people, as shown in Figure 6. The simulation results show that the tilt of the torso will have a significant influence on the L4/L5 joint. Moreover, the stress at L4/L5 joints increases significantly when the trunk tilts forward and left and right. The trunk retroversion reduces the force on L4/L5 joints. The pressure of other postures fluctuates up and down around 600 N, with little impact.

When the trunk leans forward, the shear force of L4/L5 joints in the *x*-axis direction increases significantly. Keeping the trunk upright and leaning back slightly can reduce the shear force in the *x*-axis. The left and right inclination of the torso will lead to a significant increase in the shear force in the *z*-axis direction of the L4/L5 joint, while the left and right rotation of the torso has little effect on the shear force in all directions.

The analysis of the force on the muscles of the back shows that the left and right inclination of the trunk requires more muscle force, and the number of affected muscles also increases a lot. Moreover, the muscle force is concentrated on the erector spine muscle when the trunk is tilted forward. The rectus abdominis is stretched in the late trunk. The leftright rotation of the trunk has little effect on the muscles.

2.2.3. Static Pressure Analysis. People can see a static work posture when the posture is used in the computer office input. Moreover, there are slight or no changes in the forces provided by muscles and other body structures. However, the muscles are in a state of contraction, the blood vessels are compressed, the flow is insufficient, and it is easy to feel



FIGURE 2: Accurate digital human model.

fatigued. Use the static strength prediction of JACK software to evaluate the percentage of people who can complete the work task in different sitting postures from the perspective of dynamics and evaluate whether each posture meets the strength standard of NIOSH through simulation.

The simulation results are shown in Figure 6, and the first column histogram shows the percentage of office workers who can complete the task under the muscle force that each joint can bear in the current sitting position. It can be seen from the picture that almost every joint can complete the task 100%. When the trunk tilts left and right and turns left and right, it will reduce the task completion of the lower limb, knee, and ankle on the compressed side. Through the analysis of the simulation results, it is found that when the torso tilts to the right and turns to the left

and right, the pressure will be concentrated on the lower limb joints of the corresponding side, which will increase the force on the knee joint and ankle joint. The effect on the joint can be reduced by reducing the angle of deflection while working. Go to the report page to see more detailed information, including the average force of each joint; joint torque can be seen intuitively from the figure. It is of great significance to evaluate the comfort of sitting posture.

2.3. Evaluation Method of Sitting Comfort. Through the above simulation analysis, we can subjectively evaluate the good or bad of each sitting posture to make a further quantitative analysis of the comfort degree of different sitting postures, comprehensively considering the influence of different indexes on sitting posture comfort. This paper uses



FIGURE 3: Representation of torso position.



FIGURE 4: Sitting positions.

the improved analytic hierarchy process and entropy method to evaluate the sitting posture's comfort comprehensively (Table 2). Construct the evaluation index system and take these seven sitting positions as examples of evaluating.

2.3.1. Construction of Evaluation Index System. Index evaluation methods can be divided into subjective and objective evaluation methods, including the analytic hierarchy and expert investigation methods; the objective evaluation method includes the principal component comprehensive evaluation method, entropy weight method, and multiobjective programming method. Both methods have some limitations. The subjective evaluation method reflects the decision-maker's subjective intention and can give full play to the decision-maker's subjective initiative, but the evaluation result is very subjective. The objective evaluation method has the advantage of solid objectivity, but the evaluation results are related to the composition of samples. To sum up, this paper chooses to consider the subjective and objective evaluation methods comprehensively and uses the analytic hierarchy process method for the first and second level evaluation index [24, 25]. Moreover, it uses the entropy method to evaluate the third level index [26].

Calculation of the criterion layer weight by the AHP method was as follows: construct the hierarchical structure model. They use the Delphi method to screen out evaluation indexes concerning experts' opinions [27, 28]. In order to reasonably evaluate sitting comfort, a comprehensive evaluation index system is constructed from a scientific and reasonable point of view, and the factors



FIGURE 5: Comfort evaluation results.

related to the sitting comfort evaluation are fully considered [29]. The sitting comfort is divided into joint parameter *A* and back parameter *B*. The second layer includes joint angle index, joint torque index, joint pressure index, L4/L5 pressure index, L4/L5 torque index, and muscle strength index. A total of 6 secondary indicators were recorded as $A = \{A_1, A_2, A_3\}$; $B = \{B_1, B_2, B_3\}$.

Because there are a large number of joint parameter indexes, it will be incomparable in pairwise comparison; so, the third layer index is subdivided into four parts: shoulder, waist, hip, and thigh recorded as $A_1 = \{A_{11}, A_{12}, A_{13}, A_{14}, A_{15}\}$; $A_2 = \{A_{21}, A_{22}, A_{23}, A_{24}, A_{25}\}$; $A_3 = \{A_{31}, A_{32}, A_{33}, A_{34}, A_{35}\}$. Subdivide the back parameters according to the directions of the three axes and the forces received by different muscles, recorded as $B_1 = \{B_{11}, B_{12}\}$; $B_2 = \{B_{21}, B_{22}, B_{23}\}$; $B_3 = \{B_{31}, B_{32}, B_{33}\}$.

2.3.2. Construction and Calculation of Judgment Matrix. Construct judgment matrix requires a pairwise comparison of the indicators of each layer on a uniform principle. This unifying principle is influenced by scaling reasonableness. At present, the primary scaling method is the 1-9 proportional scaling method proposed by salty [30], but there are some deficiencies in practice, and the difference between each level is also tiny. In order to make the scale value more practical, use the scale of 5/5-9/1, as shown in Table 3.

The eigenvalues and eigenvectors of the judgment matrix satisfy

$$BW = \lambda_{\max} W, \tag{1}$$

where *B* refers to the judgment matrix, *W* refers to the eigenvector, and λ_{max} is the largest eigenvalue of the





TABLE 2: Hierarchical st	ructure model of sitting	comfort evaluation.

Target layer	1st indices	2nd indices	3rd indices
		Loint angle (A)	Head $(A_{11}, A_{21}, A_{31}, A_{41})$
	Laint none store (A)	Joint angle (A_1)	Shoulder $(A_{12}, A_{22}, A_{32}, A_{42})$
	Joint parameters (A)	Joint torque (A_2)	Arm $(A_{13}, A_{23}, A_{33}, A_{43})$
		Joint strength (A_3)	Trunk (A ₁₄ , A ₂₄ , A ₃₄ , A ₄₄)
Sitting comfort		$I_{4/I}$ 5 procesure (R)	Compression (B_{11})
		$L4/L5$ pressure (D_1)	AP shear (B_{12})
	Lower back parameters (B)		X moments(B_{21})
		L4/L5 moments (B_2)	Y moments (B_{22})
			Z moments (B_{23})
			Erector spine (B_{31})
		Muscle tensions (B_3)	Internal oblique (B_{32})
			External oblique (B_{33})

TABLE 3: 5/5-9/1 intensity of importance.

Definition	Intensity of importance
Equal importance	5/5 = 1
Somewhat more important	6/4 = 1.5
Much more important	7/3 = 2.333
Very much more important	8/2 = 4
Absolutely more important	9/1 = 9
Interna diata valuas	6.5/3.5, 5.5/4.5
Intermediate values	7.5/2.5, 8.5/1.5

judgment matrix. According to the formula that can calculate characteristic vector *W*, the relative size of each element of the judgment matrix is obtained.

2.3.3. Consistency Check. Due to the evaluators' limited subjective factors and judgment ability, the comparison results are contradictory. Therefore, it is necessary to check the consistency of the judgment matrix. First, calculate the consistency indicator CI.

$$CI = \frac{\lambda_{\max} - n}{n - 1},$$
 (2)

where *n* is the order of the judgment matrix to calculate the consistency ratio Cr:

$$CR = \frac{CI}{RI}.$$
 (3)

The RI is the average random consistency index, which is the average of the consistency indicators of multiple casual sample matrices. When the order is 1-9, RI is shown in table 4 when the ratio $Cr \le 0.1$, the judgment matrix has satisfactory consistency. At this time, the weight calculated by the AHP method is effective. Otherwise, it needs to be recalculated [31].

According to the evaluation index hierarchy model of sitting comfort. Conduct a questionnaire survey on experts, compare and score the first and second-level indicators, and evaluate the importance of each indicator. Get the judgment matrix for the consistency test and calculate the index weight of each layer after passing the consistency test.

2.4. Calculation of Measure Layer Weight by Entropy Weight Method. Due to many indicators in the measure layer, selfcontradiction often occurs when experts compare, which is greatly influenced by subjective factors. The entropy weight method distributes the weight through the entropy value of the index; the more significant the entropy value, the smaller the degree of discretization of the index, and the smaller the weight; so, using the entropy method to evaluate the impact of an index on the comprehensive evaluation can get an objective evaluation result.

2.4.1. Index Data Preprocessing. There are two different indicators in the layer of measures: "the smaller, the better," such as joint stress, joint moment, and muscle force. The other

TABLE 4: Random consistency index RI.

Order	3	4	5	6	7	8	9
RI	0.17	0.26	0.33	0.37	0.40	0.42	0.44

class is that the index value is close to the recommended value, such as the joint angle is too large or too small will be uncomfortable, called negative and neutral indicators, respectively. For the two types of indicators, do dimensionless processing, respectively [32].

There are *m* evaluation indexes and *N* evaluation objects. The indexes of these objects constitute the original data matrix $X = (x_{ij})_{m \times n}$. For negative indicators,

$$r_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}},\tag{4}$$

where r_{ij} indicates the value of the *i*-th evaluation index of the *j*-th evaluation object, $r_{ij} \in [0, 1]$. x_{max} indicates maximum value of evaluation index, and x_{min} indicates minimum value of evaluation index. For neutral indicators,

$$r_{ij} = \frac{|x_{ij} - x_0|}{\max\{(x_{\max} - x_0), (x_0 - x_{\min})\}},$$
(5)

where x_0 is the ideal value of the index, which can be obtained after standardization:

$$R = \left(r_{ij}\right)_{m \times n}.\tag{6}$$

2.4.2. Definition Entropy. Entropy is a measure of the disorder degree of the evaluation system. In the evaluation problem with m evaluation indexes and n evaluation objects, the entropy of the I index is defined as

$$H_{i} = -k \sum_{j=1}^{n} f_{ij} \ln f_{ij}, i = 1, 2, 3, \cdots,$$
(7)

where $f_{ij} = r_{ij} / \sum_{j=1}^{n}$, $k = 1/\ln n$, when $f_{ij} = 0$. Let $f_{ij} \ln f_{ij} = 0.f_{ij}$ be the proportion of the *j*-th evaluation object in the *i*-th index; *N* is the number of evaluation objects.

2.4.3. Define Entropy Weight. After defining the entropy of the *I* index, the entropy weight of the *I* index is defined as

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^m H_i},\tag{8}$$

where $0 \le w_i \le 1$, $\sum_{i=1}^{m} w_i = 1$, H_i is the entropy of the ith index; *M* is the number of evaluation indicators.

2.4.4. Hierarchical Total Sorting. The final result of ranking is to comprehensively consider the weight of measure level indicators to criterion level and the weight of criterion level indicators to the target level, Moreover, get the evaluation result formula of each scheme as follows:

Gender	Number	Age	Weight (kg)	Computer usage time (h)	Daily average exercise (h)
Man	25	23.90 ± 0.94	71.43 ± 6.78	4.56 ± 0.95	0.86 ± 0.34
Woman	25	21.73 ± 1.21	53.42 ± 4.35	3.84 ± 1.56	0.74 ± 0.3

TABLE 5: Basic information of recruiters.

$$W_j = \sum_{i=1}^{j} W_i W_{ij}.$$
 (9)

In the formula, W_{ij} is the weight of the measure layer to the criterion layer, W_i is the weight of the criterion layer to the target layer, and W_j is the weight of the measure layer to the target layer.

3. Office Simulation Experiment of Sitting Comfort

At present, there is a problem with applicability in evaluating some indicators obtained by the JACK simulation. In order to verify the feasibility of this evaluation method, it needs to be further evaluated using experimental testing. An office simulation experiment evaluated the comfort of the seven sitting positions.

3.1. Experimental Purpose. A simulation experiment is designed to evaluate the comfort of different sitting positions in office scenes. Based on the daily practice habits of users, the holding time of the sitting posture in the experiment will be set to obtain accurate evaluation results. The effects of different sitting positions on operation efficiency and comfort were evaluated.

3.2. Experimental Object. College students of different majors and grades were recruited, with 25 male and 25 female subjects. Recruitment requires that the daily computer use time is more than 0.5 hours and in good health. The volunteer did not exercise a strenuous exercise day before the experiment and kept working and resting. The basic parameters of subjects are shown in Table 5.

3.3. Experimental Method. The assignment of the office simulation experiment is to input a Chinese article, and it takes about 2.5 hours to complete the whole experiment, which includes two parts: the adaptation test and the formal test.

- The adaptation test is a 10 min Chinese input task, mainly to make the subjects familiar with these sitting postures and obtain the primary data on their work efficiency
- (2) The formal test time is 140 min, each sitting position is 20 min, and there is a 10 min rest time between each sitting position. The subjects' work efficiency and work status indicators are recorded at the alternating nodes of each sitting position. Finally, the subjects' discomfort and sitting satisfaction are collected in a questionnaire

TABLE 6: Entropy and entropy weight of each evaluation index.

Evaluating indicator	Entropy	Entropy weight
A ₁₁	10.3915	0.42561
A ₂₁	6.243867	0.237645
A ₃₁	8.430606	0.336745
A ₁₂	0.930912	0.28078
A ₂₂	0.82303	0.35774
A ₃₂	0.980082	0.36148
A ₁₃	1.786538	0.440732
A ₂₃	1.936393	0.131329
A ₃₃	1.792734	0.427939
A_{14}	0.918635	0.211698
A ₂₄	0.900324	0.25934
A ₃₄	0.796696	0.528961
<i>B</i> ₁₁	0.837986	0.449038
<i>B</i> ₁₂	0.801211	0.550962
<i>B</i> ₂₁	1.840053	0.371425
B ₂₂	1.898017	0.236824
B ₂₃	1.831301	0.391751
B ₃₁	9.780082	0.36148
B ₃₂	9.576416	0.353095
B ₃₃	7.932786	0.285426

TABLE 7: Hierarchical total sorting.

1st level	Weight	2nd level	Weight
		A_1	0.2258
Α	0.5714	A_2	0.3548
		A_3	0.4194
		B_1	0.2793
В	0.4286	B_2	0.1735
		B_3	0.5472

3.3.1. Matters Needing Attention. Before the experiment, the subjects should be familiar with the process. During the experiment, the subjects should wear fitting and comfortable sports shoes.

3.4. Analysis of Experimental Results

3.4.1. Statistical Analysis of Uncomfortable Posture. A single sample K-S test was used to test the normality of sitting

Haad maatuma				Torso posture			
Head posture	Initial	Lean forward	Lean back	Left tilt	Right tilt	Turn left	Turn right
Initial	1	2	3	4	5	6	7
Lean forward	8	9	10	11	12	13	14
Lean back	15	16	17	18	19	20	21
Left tilt	22	23	24	25	26	27	28
Right tilt	29	30	31	32	33	34	35
Turn left	36	37	38	39	40	41	42
Turn right	43	44	45	46	47	48	49

TABLE 8: Classification of sitting posture (common posture).

posture score. The normality of each sitting posture was better (P > 0.05). Statistics show that sitting posture 2 has a strong sense of discomfort, sitting postures 1 and 3 have a high score, which can be maintained, and other sitting postures should be adjusted appropriately.

4. Results and Discussion

4.1. Entropy and Entropy Weight Analysis of Evaluation Indexes in Measure Layer. According to the evaluation index system of sitting comfort and the evaluation index values collected from JACK's simulation experiment, the original matrix composed of evaluation index values is standardized. The entropy and entropy weight of each evaluation index is calculated by the entropy weight method, and the results are shown in Table 6. Hierarchical total sorting is shown in Table 7.

4.2. Evaluation Results. The hierarchical evaluation system is used to evaluate seven kinds of sitting posture. Moreover, the simulation data of each sitting posture are passed through the above steps. The evaluation shows that the comfort degree of sitting posture from large to small is 3, 1, 6, 7, 4, 5, and 2, indicating that sitting posture with chair back support is the highest comfort. Moreover, the influence of torso rotation around the *z*-axis (yaw angle) on comfort is more substantial than that around the *x*-axis (pitch angle). There is no support when the torso is tilted forward, and the pressure is concentrated on the L4/L5 joint, leading to the worst comfort.

This evaluation method can be used to evaluate a variety of sitting positions. The sitting position is classified according to the combination of three coordinate axes of torso and neck around the coordinate system, the typical sitting posture in work is selected and scored (Tables 8 and 9), and the result of the score is changed to 100%. The threshold score for evaluating sitting posture is as follows: those with a score above 80 are suitable for sitting, 60-80 can be maintained for a short time (0-20 min), and less than 60 is not recommended. The results are shown in Figure 7.

This evaluation method is used to evaluate and analyze different angles of sitting posture. It is recommended that the sitting position can be maintained for a long time (0-60 min) when the trunk recline is within 13° and for a short time within 13°-22°. If it is greater than 22°, it is not recom-

TABLE 9: Sitting posture score results.

Number				Score			
1	100	7	73.3	5	46.7	16	20.0
3	96.7	29	73.3	48	43.3	9	16.7
36	93.3	6	66.7	42	40.0	37	13.3
15	90.0	24	63.3	26	36.7	44	10.0
10	86.7	30	60.0	32	33.3	40	6.7
43	83.3	23	56.7	2	30.0	46	3.3
8	80.0	31	53.3	45	26.7		
22	76.7	4	50.0	38	23.3		

mended to use this sitting position. It is recommended to sit at 8° when the trunk leans forward. It can be maintained at 8°-15° for a short time. It is not recommended if it is more significant than 15°. The left and right inclination of the trunk is symmetrical, and it belongs to the recommended sitting position at about 9°. When it is more significant than 9°, the comfort is significantly reduced, which belongs to the nonrecommended sitting position. The left and right rotation of the trunk within 10° is the recommended sitting position, and 10°-15° can be maintained for a short time.

4.3. Discussion. In our present study, taking seven common sitting postures as examples, this paper constructs the sitting posture evaluation body shape and compares it with the experimental results. The proposed sitting posture evaluation method can effectively score the sitting posture of the human body and quantify the subjective feeling of sitting posture. The sitting position is classified according to the combination of three coordinate axes of the torso and neck around the coordinate system. The sitting posture commonly used in work is selected for scoring so that people can know the quality of the sitting posture. A sitting posture evaluation system is proposed compared to previous papers [10]. The use of digital results allows people to judge their sitting posture more intuitively, and the adoption of the suggested sitting posture can greatly improve their comfort level. However, there is still a problem: how to obtain the position of human joints. Due to occlusion, observation angle, and other reasons, the position of human joints cannot be accurately located [33, 34], which will lead to the error in scoring results. No one else has done the job yet.



FIGURE 7: Statistical results of sitting posture.

5. Conclusions

In this paper, we propose a novel sitting evaluation system that integrates AHP and entropy weighting methods to assign weights to the indicators of each skeletal joint in the human body and design experiments to validate it. The main findings of this paper are as follows.

- (1) The detailed information of the sitting evaluation system is introduced, the simulation environment is established by JACK software, seven groups of sitting postures are designed, the data of joint moments, joint angles, and muscle forces are collected for analysis, and the sitting evaluation indexes are established, the weights of each index are determined by AHP and entropy weighting method, and the comfort results of these seven groups of sitting postures are calculated and ranked in descending order of comfort (1, 3, 6, 7, 4, 5, 2)
- (2) 50 college students (25 men and 25 women) without musculoskeletal disorders were arranged to conduct simulated real office experiments. The experiments and simulations' results were consistent, proving the feasibility of the sitting comfort evaluation system
- (3) The possible sitting postures were classified according to the combination of trunk and neck on the three-dimensional coordinate axis. The sitting postures commonly used in work were selected for scoring so that people could understand the quality of sitting postures. It is not recommended when the assessment score is below 60, which would be a serious burden on the body. If the score is between 60 and 80, it will only last for a short time. If the score exceeds 80, this is a more appropriate sitting posture, but regular activities should also be performed to relieve muscle fatigue and joint damage

There are several directions to improve our work due to the limitations of our method. First, we should consider different people's body types, use extensive data analysis to collect more data, and expand the evaluation of sitting posture to people of all ages. Second, improve the accuracy of joint positioning, which can significantly improve the effectiveness of evaluation results. Third, environmental factors can also be incorporated into the evaluation system based on this study to achieve a more comprehensive evaluation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Consent

Informed consent was obtained from all participants in the study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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