Design of kneeling-sitting dual-use office chair based on ergonomics

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Abstract. With the popularity of paperless office methods, the proportion of people who use sitting posture as the main office posture is increasing[1], but at the same time, some disadvantages of sitting office are also highlighted. From the perspective of ergonomics, this article designs and analyses the structure and specific dimensions of the kneeling-sitting dual-use office chair. Based on the analysis of human spine curvature and lumbar electromyography, the effects of kneeling and sitting postures on human spine were compared. Then perfect the kneeling-sitting dual-use office chair that is more suitable for people's office style.

1 Introduction

With the popularization of paperless office, the number of people who use sitting posture as the main working posture is increasing gradually. However, there are some problems in the use of ordinary ergonomic seats. Therefore, the design of working seat and the analysis of sitting posture based on the concept of ergonomics have gradually become the research topic of scholars and designers[2].

2 The shortage of common office chair

- The common ergonomic office seats require people to actively fit the waist and back with the backrest when sitting, so that the backrest can provide enough support for the waist. However, due to the long-term attention to the electronic screen and sitting, people tend to subconsciously lean forward due to blurred vision and waist fatigue, and thus form a bad sitting posture, resulting in further waist and back fatigue. As shown in Figure 1.

Figure 1. Posture changes after sitting for a long time.

- When drawing and writing, people need to lean forward, and the angle between trunk and thigh decreases, resulting in increased pressure on pelvis and abdomen. At the same time, the upper body leans forward leading to neck fatigue.
- Sedentary lifestyle increases the incidence rate of many diseases including heart disease, diabetes, hypertension, depression and anxiety[3].
- A single working posture for a long time can make people get bored and reduce work efficiency.

3 Introduction to usage scenarios and structure

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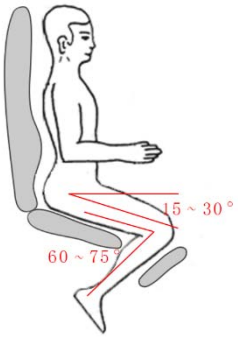

Figure 2(a). Kneeling position

Figure 2(b). Sitting position

Figure 2. Schematic diagram of different use postures.

When in the kneeling position, the movement of the lower legs is restricted, so the different forms of the seat must be switched in a balanced state of the upper body. Therefore, the controller of the switching device between the two forms is placed at the armrest. The seat surface is tilted forward by a turning device connected to the seat post.

Figure 3. The structure of this chair

Figure 4. Structure of the knee-rest

The knee-rest is particularly important when the kneeling position is adopted. The knee-rest should be as perpendicular to the thigh bones as possible to provide sufficient support for the knees and lower legs. The height and angle of the knee-rest can be adjusted continuously.

The lower part of the knee-rest is connected with the chair foot and the column, and the upper part can be rotated, extending from the lower part of the chair surface to the front, so as to ensure enough support and activity space for the knee when using in the kneeling position, and does not affect the placement of the legs when sitting position.

4 Ergonomic analysis

4.1 Force analysis of the lower leg

According to the physiological structure of human body, the human calf is composed of fibula and tibia. The tibia is relatively large and located in the front of the lower leg, as shown in Figure 5. The upper part of the tibia is the main stress position of the lower leg when kneeling.

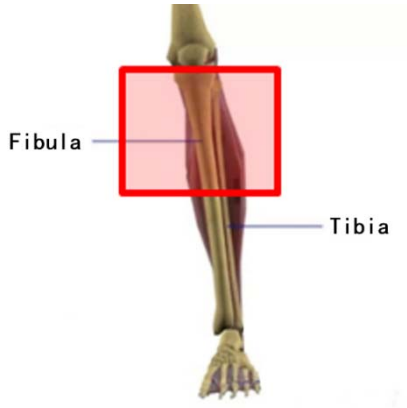

Figure 5. Fibula and Tibia

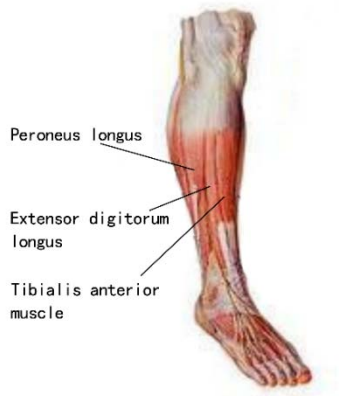

Figure 6. The anterolateral muscles of the lower leg

The nerves and blood vessels in the calf are mostly located in the muscles on the back of the calf, as shown in Figure 6.

When the area of contact between the knee-rest and the calf is large and soft, the front side of the calf can withstand a certain amount of pressure without causing heavy pressure on blood vessels and nerves, resulting in poor blood circulation and numbness of the calf.

4.2 Balance analysis

One of the basic requirements for seat design is to ensure the stability of people when sitting.

As shown in Figure. 7. The upper body is supported by the force F1 from the seat surface to the hip and the force F2 along the thigh. The direction of the two forces is upward along the upper body.

When the person leans back, the backrest can provide some support, but at the same time, the pressure F2 on the thigh will increase, and the human body has a downward trend along the chair surface.

When the person leans forward, the center of gravity moves forward. Because the angle between the body and the thigh increases, the torque from the thigh to the body decreases, so that in order to keep the balance of the body, the person cannot lean forward excessively, and must keep the upper body upright.

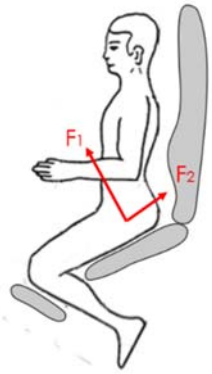

Figure 7. Force analysis in Kneeling Position

4.3 Analysis of spine curvature in kneeling position

The Electromyographic analysis of the waist during standing and sitting positions also shows that sitting posture is more likely to cause waist muscle fatigue than standing. When standing, most of the body's weight is distributed in the thighs, knees and feet, which is not easy to cause lumbar muscle fatigue. At this time, the waist is in the best shape[4]. Analogous to standing position, part of the weight is borne by the calf when kneeling, reducing the pressure on the waist when sitting.

A slightly tilted forward seat surface is considered to be a method to alleviate the kyphosis. Compared to a slightly tilted back seat, a slightly tilted forward seat results in a reduced tendency for kyphosis[5]. A similar conclusion can be drawn from the Figure 8: The larger the angle between the trunk and the thigh, the smaller the degree of lumbar posterior process and the more normal it is.

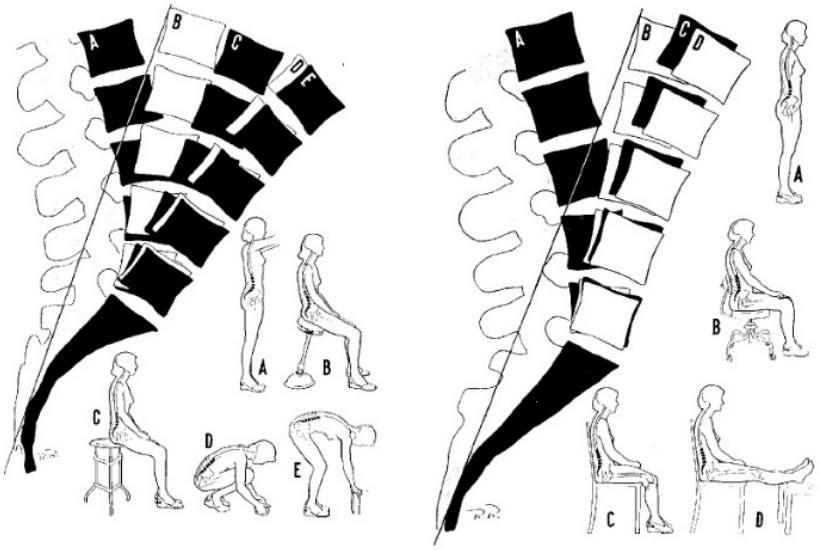

Figure 8. The adaptation of the spine in sitting and while performing other tasks[5].

For this seat, when kneeling, the support of legs and crotch to the body is more similar to that when standing, so the curvature of spine tends to be more normal[6].

The data mainly used in this seat design is based on GB: 10000-88 Human dimensions of Chinese adults, and the data mainly used as reference has been bold in Table 1.

5 Analysis and selection of basic functional dimensions

Table 1. Sitting body size

	Male (mm)				Female (mm)			
Percentile	5	10	90	95	5	10	90	95
Sitting cervical point height	615	624	691	701	**579**	587	648	657
Calf plus foot height	383	389	439	**448**	342	350	399	405
Sitting elbow height	**228**	235	291	298	215	223	277	284
Sitting deep	421	429	486	493	**401**	408	461	469
Maximum shoulder width	398	405	460	**469**	363	371	428	438
Sitting hip breadth	295	300	347	355	310	318	374	**382**

5.1 Seat height

When the kneeling position is adopted, the kneeling position seat is slightly higher than the seated position in order to provide enough space for the lower legs under the seat surface. Therefore, taking the 95th percentile of the man's calf plus foot height as a reference, the maximum value of the seat height is 500mm, and the minimum value is 410mm, which is adjusted by the air pressure bar.

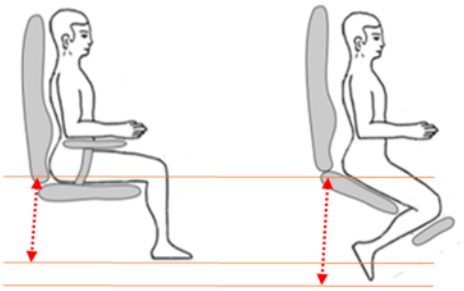

Figure 9. Schematic diagram of seat height

5.2 Chair width

The main reference value of the width of the chair surface is the sitting hip width. The width of the chair surface should be able to ensure that people have enough space to move, and consider the amount of clothing correction and psychological correction, so as to reduce the pressure caused by narrow seats. Based on the 95th percentile of hip width in female sitting posture, the chair width is 440mm.

5.3 Sitting deep

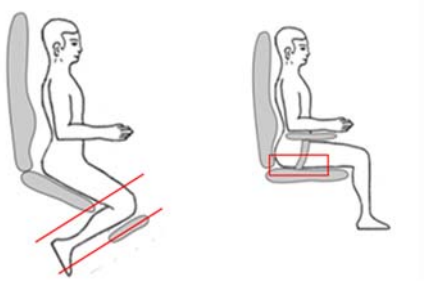

Figure 10. Schematic diagram of main forces on buttocks

As shown in Figure. 10. When sitting, the main stress parts of the human body are concentrated on the hips and the back of the thighs, taking 90% of the 5th percentile of female sitting depth as a reference, so that the backrest can correctly support the lumbar spine and the hips can be fully supported. At the same time, there should be enough room for movement at the knees.

5.4 Handrail

When the kneeling posture is adopted, the movement of the lower legs is restricted, and when a person needs to move, the armrest is required to support; and because the armrest controls the rotation of the seat surface, the armrest does not move with the rotation of the seat surface. The maximum height of the armrest from the seat surface is 300mm, the minimum is 225mm, each level is 15mm, and 6 levels can be adjusted. As shown in Figure. 11. The armrest has a simple shape and a groove in the middle, which is suitable for placing the elbows smoothly and comfortably.

Figure 11. Handrail

5.5 Height of backrest

Some women wear ponytails, and high backrests can interfere with hair. Therefore, the height of the back is based on the 5th percentile of the height of the cervical spine in the female sitting position. The height of the backrest is 580mm.

5.6 Material of chair surface

In order to maintain balance when kneeling, it is necessary to increase the friction between the person and the seat surface. Compared with common chair surface materials, such as textile cloth, nylon cloth, leather, etc., the friction coefficient of leather is the largest[7], so the surface of this chair will be made of leather.

6 Concluding remarks

For the design of the kneeling-sitting dual-use office chair, this article focuses on the ergonomics. Compared with the conventional seat, the kneeling-sitting dual-use office chair has good ergonomic considerations, showing a new type of human-machine interaction. However, there are still many shortcomings, and further improvements and improvements are needed in aspects such as appearance, practicality, structure, and material.

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