Research on Ergonomics Design of the Height and Operation Force for Furniture Lockset

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Abstract. This study investigated the comfortable lockset height and the suitable force to open it. The experiment was designed and carried out with 14 participants. The data were measured by varied experimental tools. The factors that influence the comfort of lockset height such as the angle and body dimensions were analyzed. The results showed that the preferred/comfortable lockset height was below shoulder in 60 cm. The differences between male and female on comfortable force and maximum force were found. The capacity difference between male and male were significant, but the perception in comfort was almost unanimous. According to Chinese anthropometry data and ergonomics knowledge, the comfortable lockset height and the comfortable opening force were recommended.

Keywords: Lockset · Height · Force · Torques · Anthropometry · Ergonomics

1 Introduction

As one of the appliances to maintain the normal life and work, furniture appeared and developed by human, which can not only comfort daily life but also improve the work efficiency. In order to make the furniture more suitable for modern life, ergonomics need to be considered during the furniture design.

Ergonomics has been widely used in the field of furniture design. Lee and Merzenich [1] find that the anthropometric differences between the Turkish students and other nations by measuring 13 body dimensions of 1049 students with the standing posture and sitting posture. The data can be used to determine the limit values of designing classroom and laboratory design. Deros, Mohamad et al. [2] found that by using the anthropometric data of 1007 Malaysian respondents' physical body parts, the furniture would fit, appropriate, comfortable to at least 90% of the Malaysian population with respect to ergonomics, which helps to reduce the risks of injuries and pains among Malaysian home furniture users. Taifa and Desai [3] came up with exhaustive

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dimensions for designing adjustable classrooms furniture by collecting and analysing the health status of all students who have been using poorly designed furniture. The recommend furniture dimensions will help to create comfortability, safety, well-being, suitability, reduce Musculoskeletal disorders, and improve performance of students in terms of attentiveness. Hrovatin and Prekrat et al. [4]. used 3D modelling technology to simulate the optical depth and the height of storage capacities, and then provided advices for designing kitchen furniture that would meet the needs of the elderly based on the measurement analysis.

Most of the research used the anthropometry as the principle to guild the furniture design, furthermore, the anthropometry data are distinct differences between different areas. In China, the anthropometry and ergonomics were also widely used in the design of variety products, including furniture, vehicles and communal facilities, which has been improving the living quality. The domestic relevant researches were also significative for this study. Ai-ping, Xin, Guang et al. [5]. recommended the ergonomics value of the height shelf height of home bookshelf by using the VICON and JACK combined with the subjective evaluation, where the anthropometry are necessary for the conclusions.

The major aim of this study was to find the preferred lockset height and the force of opening the lockset, which can satisfy the ergonomic requirements when using the lockset. By using the BTE (Baltimore Therapeutic Equipment), the typical customer's preferred lockset height and force were collected and analyzed and then, the results provided a reference for the design of furniture lockset height and comfortable opening force.

2 Methods

2.1 Experimental Design

The experiment was designed to collect the data of opening the lockset. The comfort of lockset height, the elbow angle and shoulder angle, the comfortable and maximum opening force were measured and recorded simultaneously with changing the lockset's height. The lockset height was the only one factor that varied in the experiment, and the height varied from 60 cm to 170 cm, which included the comfortable control area on standing posture. The step size in this experiment was 10 cm, so there were 12 different experimental heights in all. Accordingly, the changes including angle, comfort score and force were collected in this research. By analyzing the relationships between the collected data, the correlation model may be established.

2.2 Subjects

The subjects were selected by taking into account of age, sex and body size. In this study, the subjects were 14 adults, right-handed, with ages ranging between 20 and 40 ($M = 27$, $SD = 5$) and heights varying from 152 cm to 180 cm ($M = 167$, $SD = 8$). All had no physical disability and they were evenly composed of men and women.

2.3 Apparatus

The BTE Primus RS was used to change the lockset height and collect the force when opening the lockset. which can give the power of objectivity and then capture the real-time data. All the main components of BTE Primus RS system were shown in Fig. 1 and the 202 tool was used as the key in this study. This system provided the device that can change the height of lockset, and the information about force can also be seen on the display. With the help of other tools like angular instrument and Martin measuring ruler, the data can be collected completely.

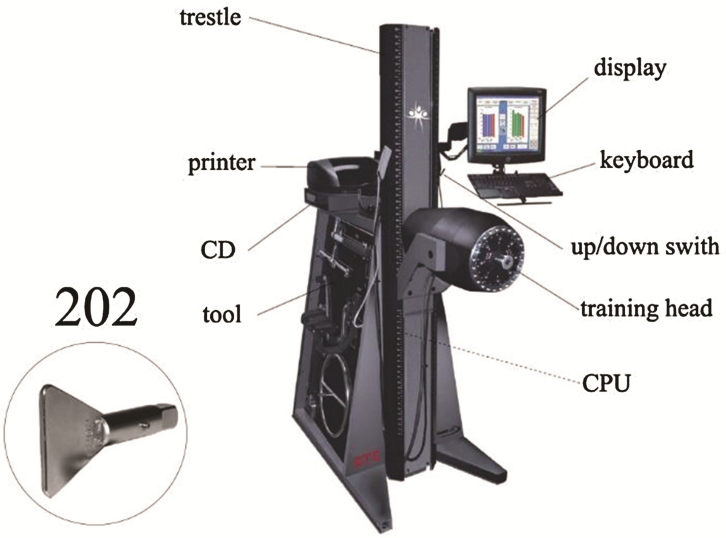

Fig. 1. Components of BTE primus RS

2.4 Task and Procedure

The experimenter need to collect the basic anthropometry data of subjects, including height, weight and shoulder height. Each subject was required to take part in the following steps with the help of experimenters:

(1) Understand the basic purpose and process of the experiment;
(2) Stand his/her best comfortable distance from 100 cm away to the lockset when the tester adjusted the height of lockset by using the elevator mechanism of BTE;
(3) Open the lockset with a natural and comfortable posture with the elbow naturally drooping and unable to deviate inward or outward from the body excessively. Figure 2 shows the experiment scene. Meanwhile, the angles of shoulder and elbow were also recorded;
(4) Evaluate the comfort of locket height according to the comfort of shoulder and elbow by using the 7 levels subjective score, see Table 1;

(5) Open the lockset by using a comfortable force that the subject expected 3 times and the equipment can record the data. Likewise, use the maximum force to open the lockset after rest;
(6) Take a rest and then prepare for the next experimental height.

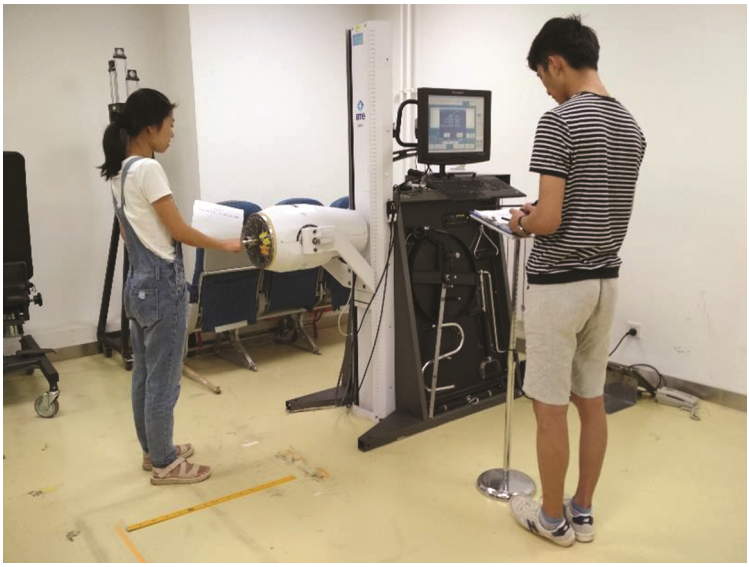

Fig. 2. Experimental scene

Table 1. 7 levels subjective score

1	2	3	4	5	6	7
Very uncomfortable	Uncomfortable	Less comfortable	General	More comfortable	Comfortable	Very comfortable

3 Data Analysis and Results

3.1 The Lockset Height

In this experiment, each subject gave a score about the comfort of different locket height and a total of 168 scores were collected from all the 14 subjects. At the same time, the angle of elbow and shoulder were also recorded to research the main factors that influence

the comfort. Figure 3 shows the shoulder angle, where 1 to 14 represent the number of the subjects. It can be seen in the diagram, with the lockset height increasing from 60 cm to 180 cm, the angle of shoulder decreases firstly to the minimum at around 90 to 100 cm and then rises steadily. For certain height, for example, at the height of 120 cm. the shoulder angles of all subjects are totally different, which varies from 10° to 60°.

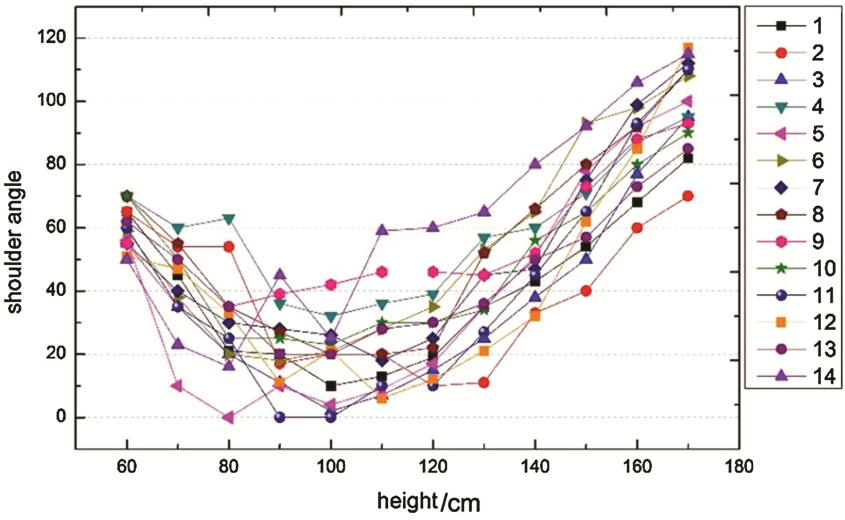

Fig. 3. Shoulder angle distribution on each height

Likewise, the elbow angle distribution is shown in Fig. 4, where the 1 to 14 represent the number of all subjects. In general, the elbow angle decreases to the minimum at 120 cm to 140 cm and then growing at a slow rate in the diagram. The changing trend is obviously the same for each subject, but the value of each subject was totally different at the same height.

The aim of this experiment in this part was to find the factors that may influence the comfort of lockset height. The arm is the main actor and the shoulder is the starting point during the movement of opening the lockset. The angle of elbow and shoulder will change when the lockset was at different heights However, the increment of angle was difficult to measurement and the variation trend was kind of different when the height of lockset changing. What's more, the comfortable angle was totally different for each subject. Figure 5 shows the range of elbow and shoulder angle when the sore was over 4, which shows that the statues of the arm with these angles was comfortable. It is a wide range and the distribution is even, which means the angle cannot be used to design the comfort height of lockset. There is a variation tendency that the range gets narrowed with the score increasing. It was difficult to find a regular pattern by using the elbow and shoulder angle. But the changing trend can be used for further research.

However, the correlation between lockset height and the subject height was more significant. The height of 14 subjects varied from 152 cm to 180 cm, so the relative position between the heights of lockset and each subject's shoulder was different.

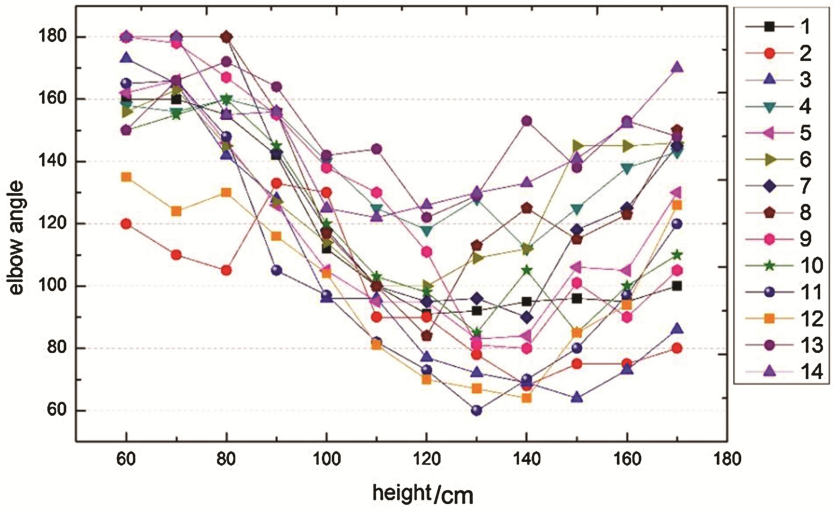

Fig. 4. Elbow angle distribution at each height

According to the movement of opening the lockset, the shoulder is the basic starting point. When the height of lockset changed in the experiment, the subject's shoulder was the original point. All the 14 subjects with different height can be put in one line by using the height of lockset from the subject's shoulders. In this study, the shoulder of each subject was seen as the original point, and the shoulder height minus the lockset height was the real variable, shown in Fig. 6.

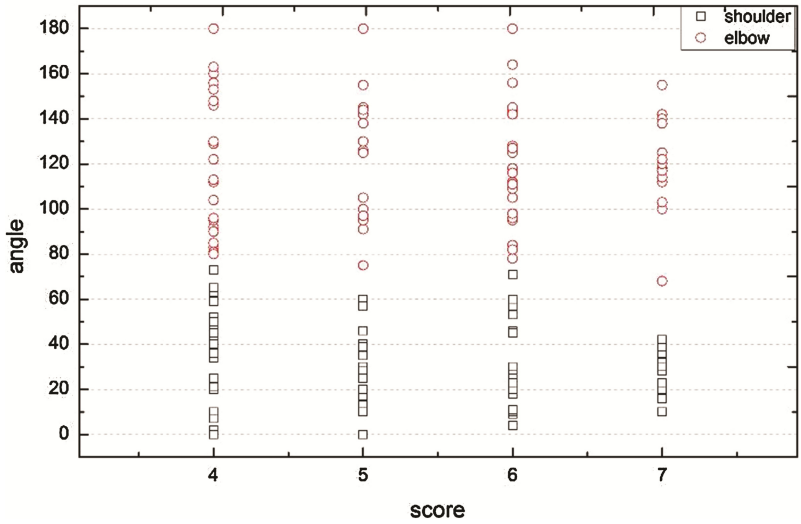

Fig. 5. The elbow and shoulder angle

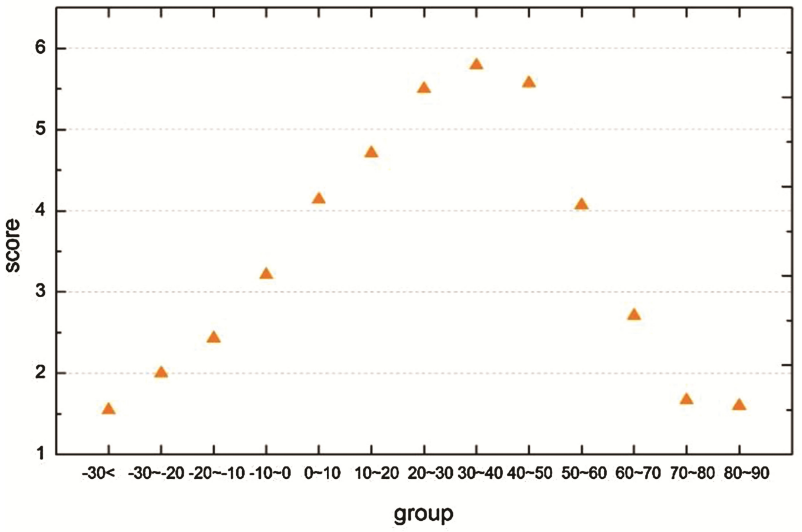

Fig. 6. The score distribution

The range of lockset height from the subject's shoulder was between -45 cm to 88 cm, which can be divide into 13 groups: −30<, −30~−20, −20~−10, …, 70~80, 80~90. Each group had an average score of the comfort of locket height, and the distribution of the score was shown in Fig. 6. The scores of 13 groups are distributed in a nearly normal fashion, which is consistent with the actual situation that people may be uncomfortable when the lockset is over high or low. As is shown in the graph, the scores of groups 0~10, group 10~20, …, group 50~60 are over 4, which means the heights are acceptable; the scores of groups 20~30, group 30~40 and group 40~50 are over 5, which means the heights are more comfortable; the scores of other groups are less than 4, which means the heights are uncomfortable. Results showed that the acceptable comfortable height of lockset was below shoulder in 60 cm.

3.2 The Opening Force

Both the comfort force and maximum force were collected 3 times during the experiment. Figure 7 shows the maximum force on each height, where the 1 to 7 represent the number of male subjects and the others were females. According to the average maximum force in different height of 14 subjects, there was no obvious change trend between the maximum force and the heights. The fact is when the height increases the maximum force of the subjects mainly varied from 50 N to 250 N. For a group, the maximum force of subjects 1 to 7 are bigger than that of subjects 8 to 14, which means that males are more powerful than females. For individual, the maximum force on each height is almost the same and the variation is small. According to the mentioned analysis, the average maximum force of each height can represent his/her maximum force.

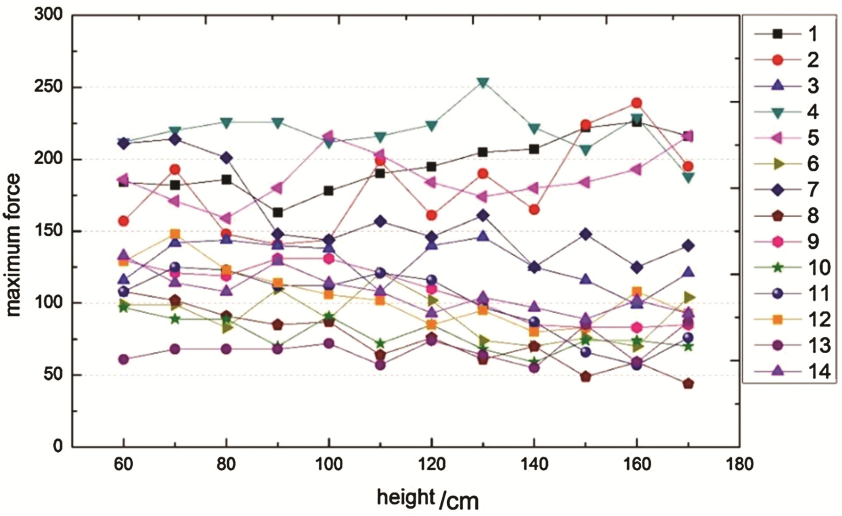

Fig. 7. Maximum force

The average maximum force of each subject is shown in Table 2. For male and female, the maximum force differences are significant and the maximum force of male is over female. The average maximum force of 7 males is 166 N and the 7 females is 92 N. The female maximum force is roughly half of male (55%). The data in the table shows the natural difference between male and female. The gender differences need to be considered during product design.

Table 2. Maximum force of different gender

No.	Male							Female						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Max force	196.3	179.7	127.9	219.8	187.1	91.4	159.9	74.6	108.0	78.1	100.0	105.4	68.1	107.1

The comfortable force on each height is shown in Fig. 8, where the variation on each height is lightly rambling in some line. It can be seen form the diagram, the comfortable force is mainly between 20 N~80 N, while some of the value was not stable. The changing trend shows that the comfortable force is irrelevant with the lockset height. For individuals, the comfortable force variation range is small, so the average comfortable force of 12 heights can represent all the subjects' comfortable force to open the lockset.

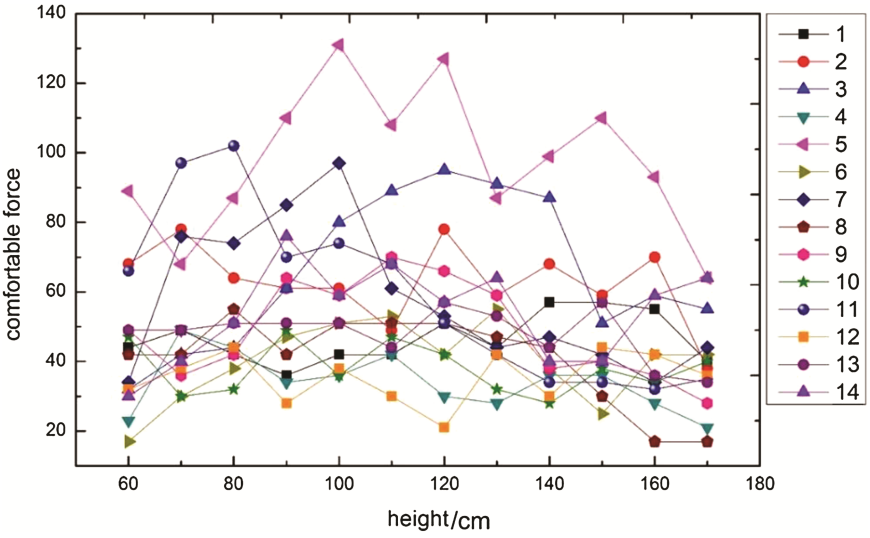

Fig. 8. Comfortable force

The average comfortable force in different height of 14 subjects is showing in Table 3, where the comfortable force is between 33.9 N to 97.7 N. The individual differences of comfort force was significant (M = 52, SD = 16.6), so the abnormal value need to be deleted when the value was lower 35.3 N or over 68.6 N [6]. The No. 4 33.9 N and No. 5 97.7 N were deleted. The average comfort force of male was 54.6 N, which was slightly over female with 46.2 N. The average of all subjects except two abnormal value was 49.7 N.

Table 3. Comfortable force of different gender

	No.	Male									Female				
		1	2	3	~~4~~	~~5~~	6	7	8	9	10	11	12	13	14
Comfortable force		46.8	62.8	65.6	~~33.9~~	~~97.7~~	40.0	57.7	40.7	48.9	37.7	58.7	35.5	48.0	54.0

4 Discussion

4.1 The Acceptable Comfortable Lockset's Height

The comfortable height of lockset was below the shoulder in 60 cm, which can be used in the height design of lockset. The standard GB 1000-88 records 47 anthropometry data of different areas, including shoulder height [7]. The data of P5, P50, and P95 shoulder

height of 18–60 years old is shown in Table 4. The comfortable lockset height can be calculated according to the anthropometry data and the experiment results.

Table 4. The shoulder height

	P5	P50	P95
Male	1281	1367	1455
Female	1195	1271	1350

When to satisfy at least 95% people, the shoulder height of P5 female is 1195 mm, adding 20 mm heel of shoes, so the upper limit of lockset height was 1215 mm. The shoulder height of P95 male is 1455 mm, adding 20 mm heel of shoes and deducting 600 mm, the lower limit of lockset was 875 mm. Finally, the rang of lockset height that satisfy 95% people should be 875 mm to 1215 mm from the floor.

Accordingly, we can get the small range, middle range and a large range that satisfy at least 5%, 50%, 95% respectively and the data is shown in Table 5. The recommended height value provides a reference for the ergonomic design of lockset height to satisfy the comfortable requirements.

Table 5. The comfortable range of lockset

Range	Lower limit	Upper limit
Small	877 mm	1202 mm
Middle	780 mm	1285 mm
Large	690 mm	1373 mm

4.2 The Comfortable Opening Force

For the maximum force of opening the lockset, the male was almost twice than female. For the comfortable force, the male was slightly over female. The capacity variance was caused by the gender difference, but it seems that the perception in comfortable was almost unanimous generally. The operation force is an important factor during the product design. If using the proper value in design, it can satisfy the need of most of the people.

In this study, the comfortable force result is around 50 N for all people. The diameter of the furniture key is around 20 mm, so the torque of opening the lockset was about 0.50 N.m, while the reference [8] said the torque should not over 0.65 N.m.

5 Conclusions

This study researched the two main factors that influence the user experience when opening the lockset. All the main factors were researched, and the results can be used in the furniture design to satisfy the ergonomics requirements. The comfort of product affected by many factors, and it is difficult to research all of them at the same time. It is proposed that the most important one should be set as the main object. The lockset height

and the opening force were the main factors that influence the comfort of lockset, but they are also other factors, which depends on the real situations. There are some aspects which should be pay special attention during the experiment are as followed:

- The standard posture is necessary for different people during experiment;
- Enough rest is needed when it involves the maximum force;
- The multiple data acquisition is recommended during ergonomic experiment.

Furthermore, the experiment design can provide a reference for other study. The movement of opening key is familiar with the opening furniture by a pair of handles. The height design of handles can refer to the recommended lockset height though the objects are different. However, the results of this paper have certain limitations due to the difference of individuals and further verification experiment may be requisite.

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