

A Proposal for a Model to Estimate Lumbar Load by Considering Seat and Backrest Reactions

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Sitting for long periods of time, such as while driving, is believed to be a cause of poor blood circulation and low back pain. To identify the causes of these issues, it is necessary to accurately assess the lumbar load. Since it is known that the lumbar load is greater when sitting than when standing, this study focused specifically on the seated position. This study hypothesized that the reaction forces from the seat and backrest surfaces might be a cause of the higher lumbar load during sitting. Therefore, this study proposes a lumbar load estimation model considering the backrest reaction force (F_b) and surface reaction force (F_s).

Figure 1 shows a schematic diagram of the model. In this model, the forces applied to the seat and backrest of the chair, as well as the angles of the user's neck and sacrum, are used as parameters. The difference between the angles of the neck and the sacrum is defined as the postural angle θ .

Equation 1 represents the lumbar load, calculated by combining the overturn moment and the upper body weight. Hereafter, this will be referred to as Model (1). Here, M_u is the upper body mass, g is the gravitational acceleration, and L_u is the distance from the center of the sacrum to the center of mass of the upper body. F_{em} is the force exerted by the muscles, and L_{em} is the distance from the center of rotation of the lumbosacral spine to the point of application of the force exerted by the back muscles. L_l is defined as the distance from the point of application to the upper center of mass, denoted by $L_u \sin \theta$.

$$F = \left(\frac{L_l}{L_{em}} + \cos \theta \right) M_u g \dots (1)$$

Furthermore, the forces acting on the chair seat and backrest are incorporated into Equation (4). Here, the backrest reaction force is considered to act in a direction that reduces the moment causing the chair to tip backward, while the seat reaction force is considered to act as a load on the lumbar spine. The lumbar load incorporating the seat and backrest reaction forces is given by Equation 2. Hereafter, this will be referred to as Model (2).

$$F = \left(\frac{L_l - \frac{F_b L_b}{M_u g}}{L_{em}} + \cos \theta \right) M_u g + F_s \cos \theta \dots (2)$$

This study evaluated the lumbar load estimation model with simulated user's physical characteristics (height: 168.4cm, weight: 67.5kg). This study compares the estimated lumbar load using Model (1) and Model (2) with those using BlessPro2, an estimation model that has already been developed, under the same conditions. This study examined the estimated values when the pitch angle was varied in 1° increments from -30° to 90°.

As a result of comparison between Model(1) and BlessPro2, in the range where the postural angle θ was greater than 20°, the error remained below 10%. On the other hand, the error became larger within the range of less than 10°. This is because this model does not take into account the force generated by the abdominal muscles.

Also, the ratio between Model(1) and Model(2) was calculated in this study. For the range of postural angles θ from 10° or 70°, the ratios for both models fall within the range of 1.1 to 1.5 times. These results show a trend consistent with previous studies. The reason for the larger error in other areas is the increase or decrease in the seat reaction force component. Although this results in a greater load near 0°, the current results show that this increase is extremely large. Therefore, it is necessary to reconsider how to apply the seat reaction force in the range where the postural angle is close to 0°.

Furthermore, the current model is a simplified one that approximates the human torso as a single rigid rod. Previous studies have indicated that each vertebra in the spine has a different angle of inclination. Therefore, it is believed that increasing the number of segments in the spine could improve estimation accuracy. To address these issues, it is necessary to develop a musculoskeletal model that more closely resembles the actual human body in order to improve estimation accuracy.

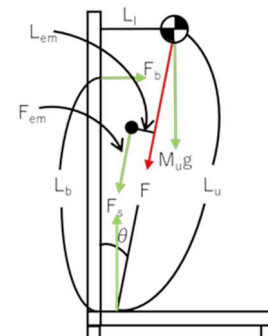


Fig.1 Force diagram of lumbar load estimation model for seated posture

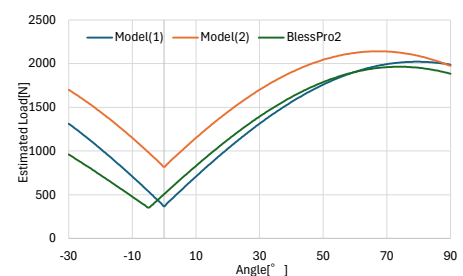


Fig.2 Estimated lumbar load comparison among Model(1), Model(2) & BlessPro2