Supporting the Torso Through Seated Articulation

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Overview

The magnitude and rate of force required to maintain the body in a supported position throughout seated articulation will vary depending on the physical stature of the user and the seating mechanism. This study investigated five different chair mechanisms. The magnitude of force required to support the body throughout articulation, for a diverse population, was determined for each chair's mechanism. This requirement was then compared to the amount of support that the chair's mechanism was designed to produce. The relationships between the magnitude of force required by the user to maintain support throughout articulation and the magnitude of force provided by the chair mechanism is compared and evaluated.

Introduction

The primary function of a task chair's backrest and seat pan is to comfortably support the individual posture and allow the user to freely perform their work task (Chaffin 1984). A balanced posture should support the torso in various stable positions with minimal force exerted by the individual while allowing one to freely change their posture (Faiks[1] 1998). Kroemer (1994) noted that a chair should allow for stimulation of the back and trunk muscles by moving through, and supporting the back in various postures. Most researchers agree (Lueder 1994) that active movement and postural changes are inevitable, and in fact desirable, throughout the day. Postural changes should be emphasized by the chair while supporting the body in all variations of postures (Faiks[2] 1998).

A task chair's backrest and seat pan articulation is provided by a mechanism that allows the chair to recline. The seat pan may tilt down and the backrest will recline rearward.

To support the individual's posture over varying degrees of inclination, a spring force in the chair's mechanism overcomes the gravitational force of a person reclining in the chair. The spring force used to control the chair's recline has a distinctive profile depending on the design of the mechanism and type of springs used. To accommodate different physical statures of individuals this mechanism must be adjustable. Users of greater physical stature require greater support force to maintain them in a supported position throughout articulation than users of lesser physical stature. Individuals will require a unique force pattern as they recline in different task chairs. This study recorded the force ranges and characteristics of five different seating mechanisms by four manufacturers. Comparisons were made between the actual force required to support a user in each chair, to the force provided by the chair's spring mechanism. These findings determined if the present spring force provided by these commercially available chairs could achieve the support level required by a diverse population range (5% female to 95% male).

Methods

In phase one, five task chairs were evaluated to determine the force range transmitted to the seat pan and backrest to support the user throughout articulation. Using the BIFMA Chair Measurement Device a point on the backrest eighteen inches above the compressed surface of the seat pan was located and marked on each chair. The chairs' recline "tension" was adjusted to the lowest setting. A load cell was applied at the marked point, perpendicular to the back. With the chair unoccupied the amount of force required to articulate the seating mechanism to the fully reclined position was recorded at five-degree intervals. Four articulation trials were recorded. The readings from each trial were averaged to calculate the lower limit of the force produced by the chair's mechanisms.

This procedure was repeated again at the upper limit of the "tension" adjustment range to establish the full range of force produced by the spring mechanism. The procedure was repeated for each chair in the investigation.

Twelve subjects were selected based on gender and two anthropometric dimensions, seated trunk height and weight. Two males and two females represented each of the following physical stature groups, 5th, 50th and 95th percentiles.

The second phase of the study removed the force producing devices (tension spring) from each chair. While the subjects were seated the seat pan height was adjusted to lower leg length. During testing subjects arms and hands remained relaxed on their laps.

A force via a load cell was applied at the same reference point from the back of the backrest. The backrest and subject were lowered from the chair's upright to reclined position while recording the force at five-degree intervals with zero indicating the chairs upright position. Three trials were recorded for each subject and the results averaged.

Averages for each subject were designated as the individuals "fingerprint" of force. These fingerprints are the force required to maintain a subject in equilibrium throughout their full range of articulation. Unique fingerprints of forces were recorded for all subjects in each of the chair samples.

The composite for all twelve fingerprints of force designates the minimum range that a chair's mechanisms must provide to support a wide range of subjects throughout articulation, and is referred to as the "range of force required by the user." For each sample the "range of force required by the user," which were measured without the tension spring (phase 2) were compared to the magnitude and slope of the "range force provided by the chair's mechanism" (phase 1).

Results

Figures 1-5 shows the "range of force provided by the chair's mechanism" and is indicated by the solid lines. Forces were recorded at the chair's lowest and highest force range. Recordings were collected at 5° intervals of recline angle as measured from the chair's upright position. The dittoed lines represents the "range of force required by the user" as determined by the composite of the fingerprints of force for all subjects. The data points represent the averages of three trials for each subject.

Figure 1

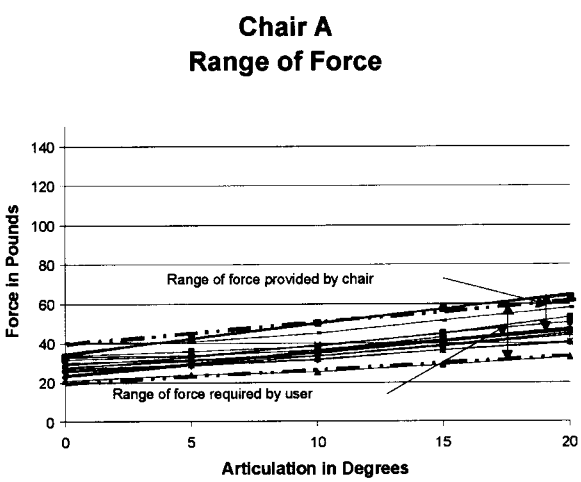


Figure 2

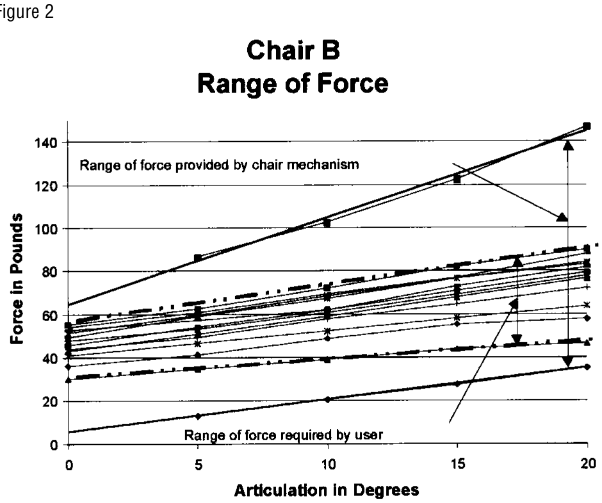


Figure 3

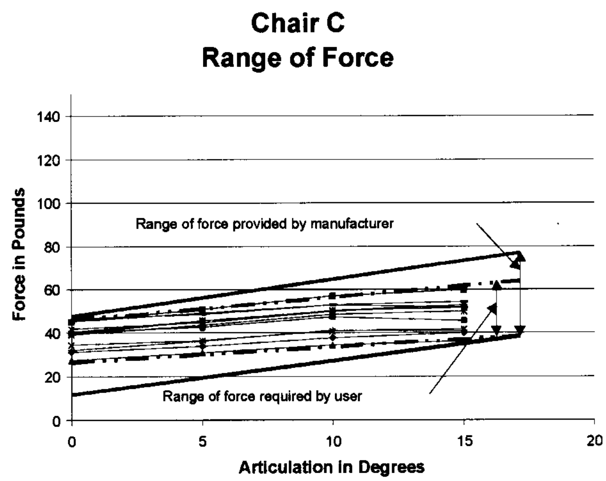


Figure 4

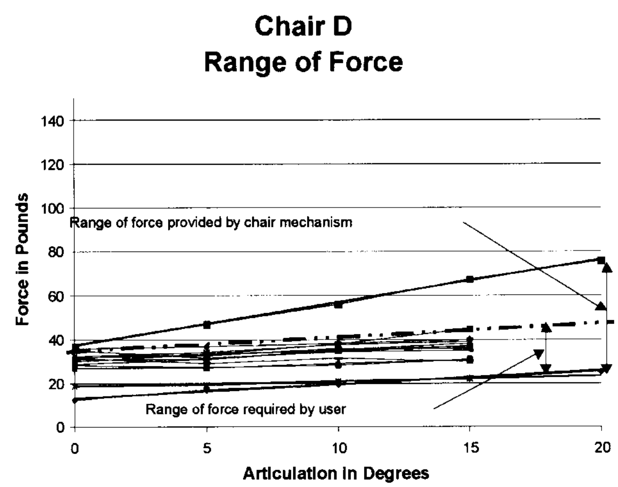
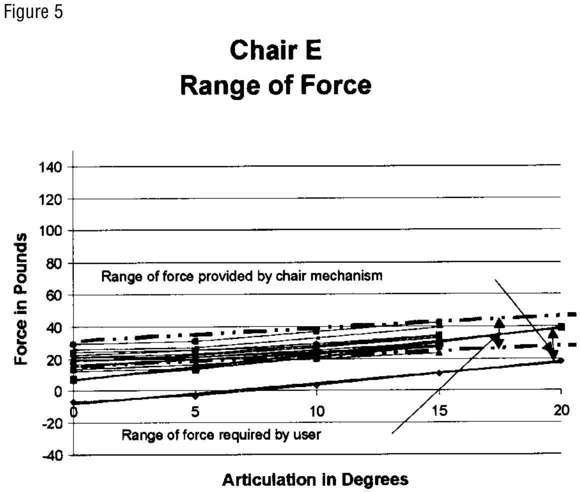


Figure 5



Figures 6-10 show the forces needed by the 5th and 95th percentile subjects for full articulation. These graphs allow the investigator to compare the relationship between the force required by the user and the force produced by the chair mechanism at the 20 degree-articulation position. In the following graphs the amount of force produced by the chair mechanism is adjusted to the point that a 5th and 95th percentile subject would adjust the chair to achieve upright support. The solid line represents the force produced by the chair and the dittoed line represents the force required by the user.

Figure 6

Chair A

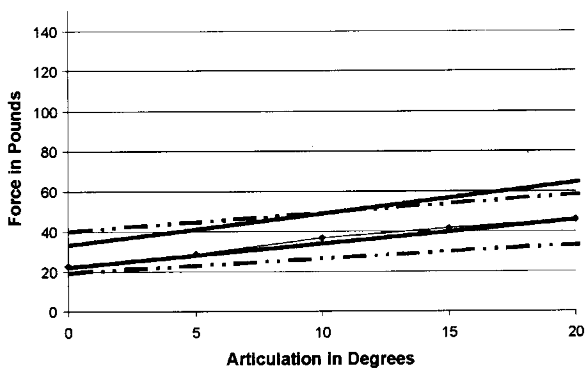


Figure 7

Chair B

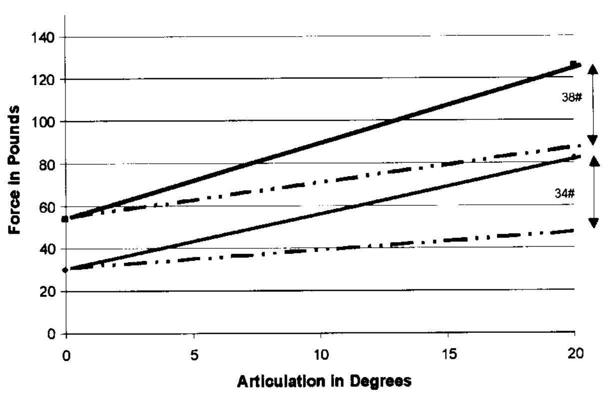


Figure 8

Chair C

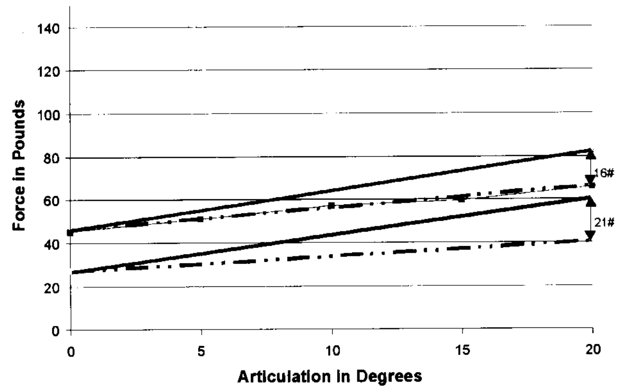


Figure 9

Chair D

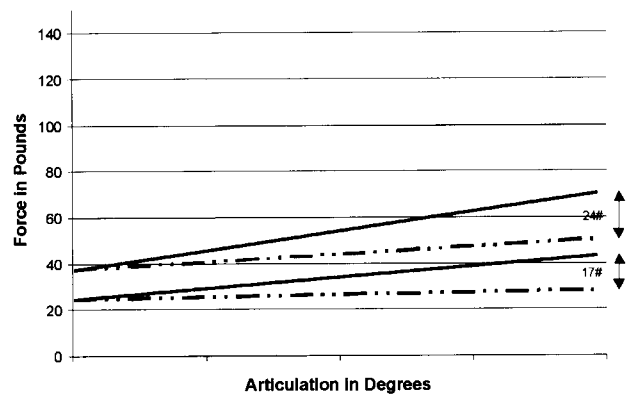
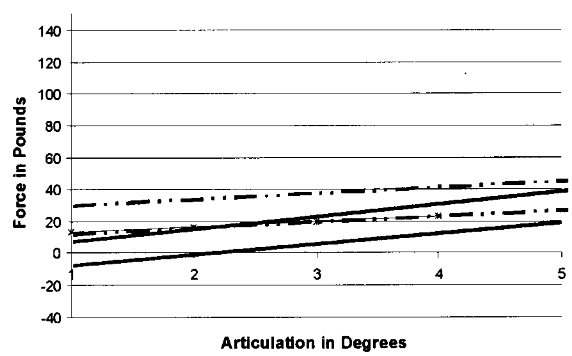


Figure 10

Chair E



Discussion

As can be determined by the graphs, every chair has its own unique force requirements due to different recline mechanisms. The force profile required by one mechanism cannot be directly compared to the force profile of another mechanism. Each chair's force profile must be compared to the force profile required by the user. The user profile is determined by establishing the composite of individual "fingerprints" of forces from a diverse subject base over the full range of articulation, which is unique to that particular chair.

The purpose of this paper is to make such comparisons and to suggest certain guidelines in determining the force profile in chair designs. In making this comparison certain hypotheses have been established.

Hypothesis One

The force provided by a chair mechanism should be adjustable to support the 5th through 95th percentile population in an upright task position.

Chair A and chair E did not meet this requirement (see fig.1&5). The low range of chair A could not adjust low enough to meet the requirements of the 5th percentile subject. The high range of chair A could not adjust high enough to meet the requirements of the 95th percentile subject.

When chair E was adjusted to its highest range it did not meet the requirements of supporting the 5th percentile subject. This condition resulted in both the 5th and 95th percentile subjects being insufficiently supported in the upright task position.

Chairs B, C and D could be adjusted to meet the upright task position requirements of the entire population tested.

Hypothesis Two

The rate of force provided by the chair mechanism should increase over the rate of force required by the user as the chair is articulated. This increase in rate provides stability for the user. If the rate of force provided by the mechanism decreases during articulation the subject will be unstable and unsupported while reclining. If the rate of force increases at a high rate the subject will not be able to overcome the increase of force and therefore be prevented from fully utilizing the articulation feature of the chair. The actual values, which meet these requirements, are dependent on the specific chair mechanism.

Chair B's rate of force (Fig.7) for the 5th percentile subject produced an increase of 34 lbs. as the subject reclined from the supported upright position to the fully reclined position. The rate of force for the 95th percentile subject increased 38 lbs. as the subject reclined from the supported upright position to the fully reclined position.

Chair C's rate of force (Fig.8) for the 5th percentile subject produced an increase of 21 lbs. as the subject reclined from the supported upright position to fully reclined position. The rate of force for the 95th percentile subject increased 16 lbs. as the subject reclined from the supported upright position to the fully reclined position.

Chair D's rate of force (Fig.9) for the 5th percentile subject produced an increase of 17 lbs. as the subject reclined from the supported upright position to fully reclined position. The rate of force for the 95th percentile subject increased 24 lbs. as the subject reclined from the supported upright position to the fully reclined position.

Chairs B, C and D's rate of force all increased as the user reclined, thereby providing support and stability as the person changes their position and posture in the seat. The high level of force for chair B however may provide too much resistance, limiting the users ability to recline. This chair would require further subjective evaluation.

Chairs A and E were not further evaluated because they could not be adjusted to meet the needs of the users in the upright position as established in hypothesis one.

Hypothesis Three

The force difference at 20 degrees articulation, between that required by the user and that provided by the chair mechanism should increase proportionally between the 5th and 95th percentile subject. Each chair's mechanism will have it's own proportion of rate increase depending on the design of the chair.

Chair B produced a force of 34# at the reclined position for the 5th percentile user and a force of 38# for the 95th percentile user for a 12% increase.

Chair C produced a force of 21# at the reclined position for the 5th percentile user and a force of 16# for the 95th percentile user for a 24% decrease.

Chair D produced a force of 17# at the reclined position for the 5th percentile user and a force of 24# for the 95th percentile user for a 41% increase.

Both Chair B and chair D recorded an increase of force of 12% and 41% respectively providing a proportionally higher rate of support for the 95th percentile user. Chair C recorded a decrease of force of 24% for the 95th percentile user. It is unknown at this time what the appropriate increase in magnitude of force would be required for these chairs and warrants further investigation, but the level of support should not decrease as exhibited with Chair C.

Conclusion

This study was specifically designed to evaluate the force requirements of task chairs. It is the function of task chairs to support the full range of users throughout the entire range of articulation. If the chair is unable to provide the proper amount of support it can limit the users ability to easily change their posture. Chairs providing too much force will limit the user from using the full range of articulation. A force to low will provide limited support and lack of stability.

The guidelines set forth by these hypotheses are intended to be a starting point for the designers of chairs. They should be used in establishing the initial force profile of a chair to support the full range of users throughout the entire range of articulation. Once this has been established the final force profiles can be established by subjective evaluation.

It has not been the intent of this paper to "rate" the different task chairs in this study but to explore a cross section of task chairs against these hypotheses. Only one chair was tested for each sample. Manufacturing variance could affect the results and additional testing would be required to determine the significance of this variable.

The authors encourage additional work in this area to test the hypotheses put forth to continue to build a knowledge base in this area of research.

References

Chaffin D.B., Andersson G.B.J. Occupational Biomechanics, New York, John Wiley & Sons, 1984.

Faiks[1] F.S., Reinecke S.M., Investigation of spinal curvature while changing one's posture during sitting. Contemporary Ergonomics 1998, Edited by M.A. Hanson, Taylor & Francis.

Faiks[2] F., and Reinecke S., Supporting the lumbar and thoracic regions of the back during sitting, ASB-NACOB, June 1998.

Kroemar R., Sitting (or Standing?) at the Computer Workplace. Hard Facts about Soft Machines: The Ergonomics of Seating. Edited by R. Lueder and K. Noro, Taylor & Francis, p. 181-191, 1994.

Lueder R. et. al., Does it Matter that People are Shaped Differently, yet Backrest are Built the Same. Hard Facts about Soft Machines: The Ergonomics of Seating. Edited by R. Lueder and K. Noro, Taylor & Francis, p. 205-217, 1994.