EFFECT OF THE CRITICAL ERGONOMICS PARAMETERS ON DOMESTIC CHAIRS FOR COMFORT USING THE HUMAN BASED PRODUCT DEVELOPMENT SOFTWARE

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Abstract

This study was carried out to evaluate the ergonomic suitability of 18 different types of domestic chairs by means of a human based product development software. Among the different chair designs, correlations among the seating depth, seating height and backrest inclination angle, which are the most influential factors on ergonomics of the seating furniture were analyzed. In the scope of study, 3 levels of seat depth (43, 45 and 47 cm), 3 levels of seat height (44, 45 and 46 cm) and 2 different backrest inclination angles (90º and 105º) were evaluated. Sitting postures were simulated in virtual environment using human-based product development software (AnyBody Modeling System). For the numerical analysis, the chairs which have different ergonomics characteristics and two different size of human models were created to represent musculoskeletal of male and female subjects in virtual environment as real size (1/1 scale). Average male and female subjects were utilized from the measured anthropometric data of 15 male and 15 female individuals. The musculoskeletal system taken from Anybody Managed Model Repository was scaled by length mass fat external measure law to match the average male and female subjects. Maximum muscle activity and joint forces that occurred on the musculoskeletal system of the human models were analyzed. Results show that most significant design parameter was the backrest angle in terms of minimum joint forces and muscular activity for both male and female figures. Other factors (seat height and seat depth) were not as effective compared to backrest angle factor. Seat height was found to be more effective than seat depth factor on legs and low back maximum muscle activity.

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1. INTRODUCTION

Ergonomics is one of the key components of furniture as in many areas. Often times the lack of in-depth analyses for the ergonomics aspect of furniture design results in problems such as negative customer feedback, erosion in brand image and decreased profits. Most of the available ergonomics studies depend on qualitative methods like surveys, which brings some uncertainty in ergonomics assessments due to lack of controlled measurements.

Nowadays, sitting furniture becomes more integral part of human life. More people spend their days sitting rather than performing activities whether at home, at work, at school etc. There are studies which have been performed about comfort of sitting in trains, offices, schools, sport centers etc. In such assessments of sitting furniture, various methods have been used to evaluate comfort: anthropometry, subjective assessments and objective measurements such as postural, biomechanical and physiological parameters. Anthropometry plays a crucial role to define dimensions of chairs, but it does not help with other features affecting comfort such as shape or inclination of seat pan and backrest (Bishu et al., 1991). In terms of chair design features, using a backrest may help reduce trunk muscle activation (Andersson, Jonsson, and Ortengren 1974; Kingma and van Dieen 2009) and low back discomfort (Vergara and Page 2000). However, backrest use can be limited among common seated tasks (Vergara and Page 2000). Thus, it is necessary to design the sitting furniture properly considering anthropometry and ergonomic guidelines together. Subjective assessment from users is the only way to explore user preferences and detect changes in comfort and pain.

However, these methods only provide qualitative information, so that their application is limited to comparing different models of chairs when they are evaluated simultaneously by the same group of subjects (Helander and Mukund, 1991). Zhanh et al. (1996) conducted investigations of sitting discomfort based on questionnaire surveys. However, sitting comfort alone does not equate health (Pynt et al., 2008). Objective measurements of postures and other biomechanical and physiological factors have been also widely used to analyze their relationship with different chair features (Anderson et al., 1979; Mandal, 1986; Nordin et al., 1986; Otun and Anderson, 1988; etc.). More quantitative information is needed on what happens inside the body when sitting in different ways. More recently, computer-based models have been presented, such as finite element models (e.g., Verver et al., 2004) and rigid body mechanical models (Lengsfeld et al., 2000). These studies were able to estimate parameters that are impossible or difficult to measure. So far, however, it has been possible to create a model that can calculate how muscular activity and joint forces are affected by changes in sitting conditions (Rasmussen et al., 2009).

The aim of this study was evaluation of the ergonomic suitability of 18 different types of domestic chairs by using ergonomics software. In these chairs, correlations among the seating depth, seating height and backrest inclination angle which are the most influential factors on ergonomic of the seating furniture were analyzed.

2. METHOD

The effect of seat depth (43, 45, 47 cm), seat height (44, 45, 46 cm) and backrest angle (90 and 105 degree) were analyzed with a musculoskeletal modeling software (AnyBody Modeling System). The 18 different types of chairs used were showed in Figure 1.

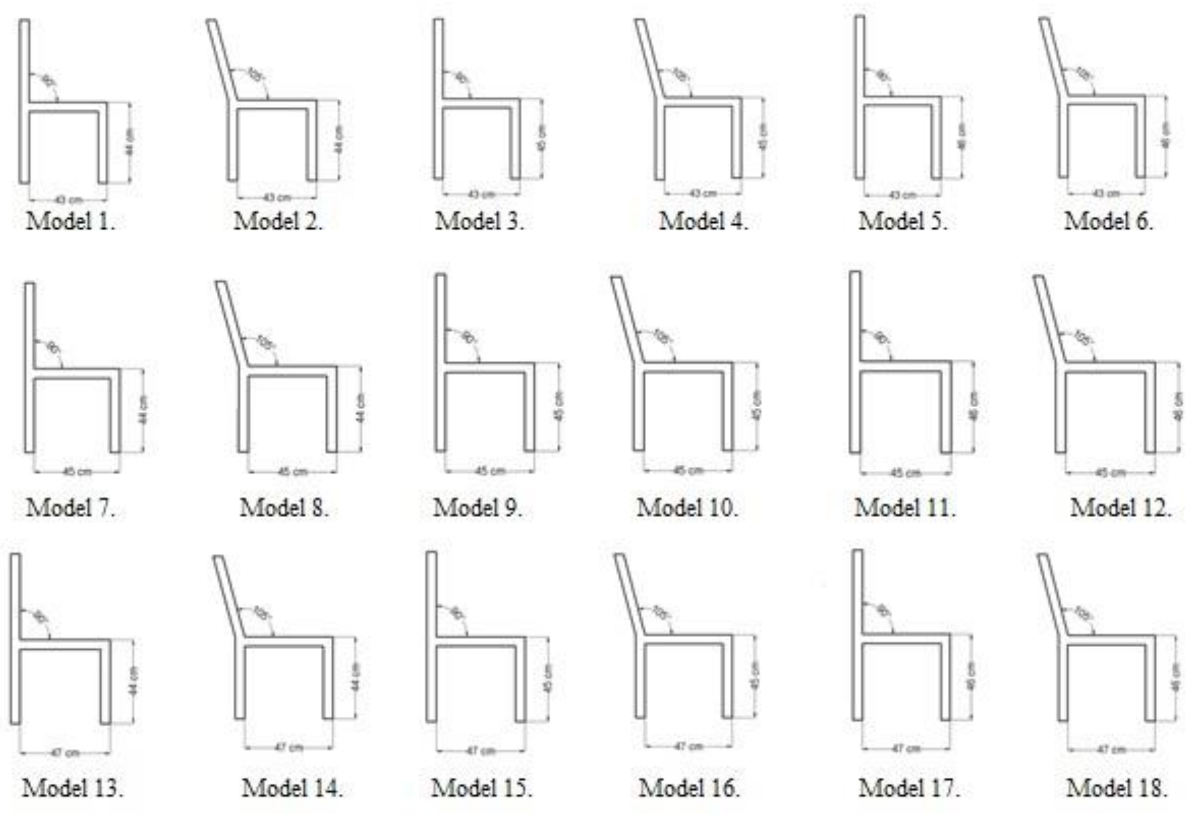

Figure 1. The chair types evaluated in this study

Initially, 10 different static anthropometric length measurements were collected from 30 healthy subjects (15 male, 15 female aged 18-25 years old) using anthropometric measuring sets. These data were then used in the software to scale available human model from AnyBody Managed Model Repository (AMMR) which represent average of anthropometric data of healthy subjects. Scaling was performed using the ScalingLengthMassFatExt scaling law. This scaling law takes external body and limb measurements and mass into account. The size of the bones was scaled considering these length measurements and mass. Muscle strength was scaled by considering fat percentage using an empirical formula. A seated human model was built by modification of Seated Human Full with Neck Model available in AMMR and used for calculating maximum muscle activity (%) and L5-sacrum joint reaction (N). The model was constrained to contact its back to back rest and feet to be on the ground parallel. Pelvis was set to constant position from the backrest where the distance between femur and chair edge was set to be constant 5 cm at all times. Contact between back/thigh of the figure and chair was resolved by contact forces. Similarly contact reaction forces between feet and ground were calculated (Figure 2). The muscular forces and joint reactions were then solved by performing an Inverse-Dynamics analysis. Muscle forces were summed up and reported in following groups: shoulder-arm, leg and lower back erector spinae muscle group. All 36 analyses were performed by calling AnyBody Modeling System using AnyPyTools Python library. Results data was processed using Python libraries, as well.

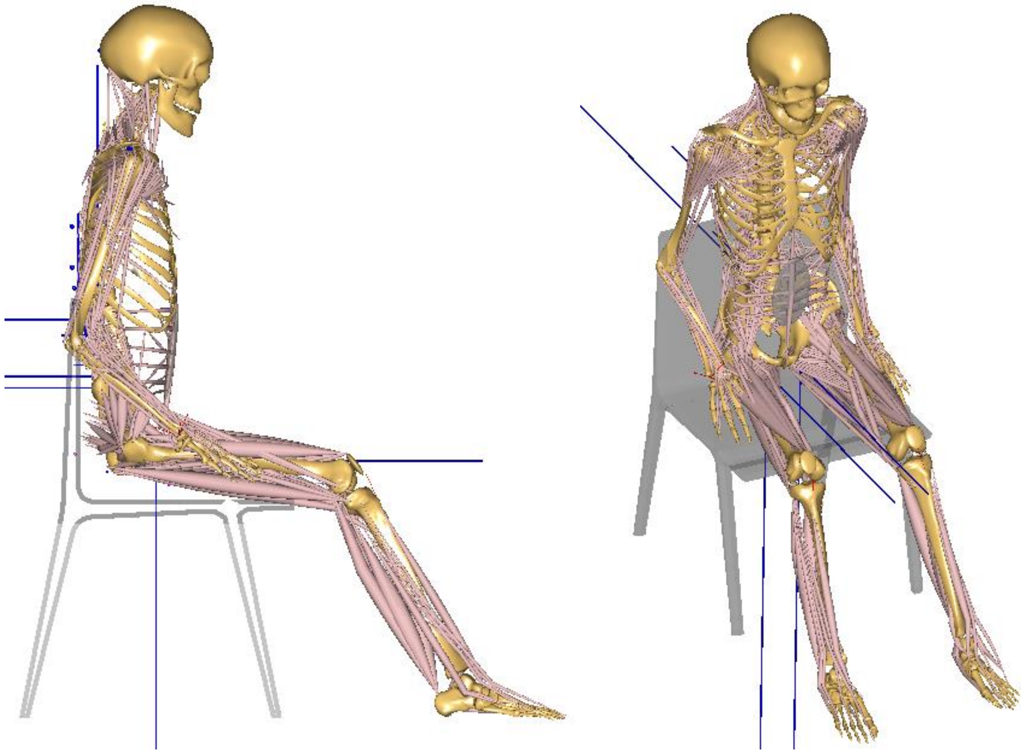

Figure 2. AnyBody Model (a) Side view (b) Iso view

3. RESULTS AND DISCUSSION

Variation of lumbar region of joint load levels according to chair design parameters: High joint loads can cause pressure on muscle groups and time-dependent stretch on intervertebral discs. Pressure on muscle groups can cause pain. Results show that most significant effect is backrest angle and the effect of seat depth and seat height do not cause much differences (Figure 3).

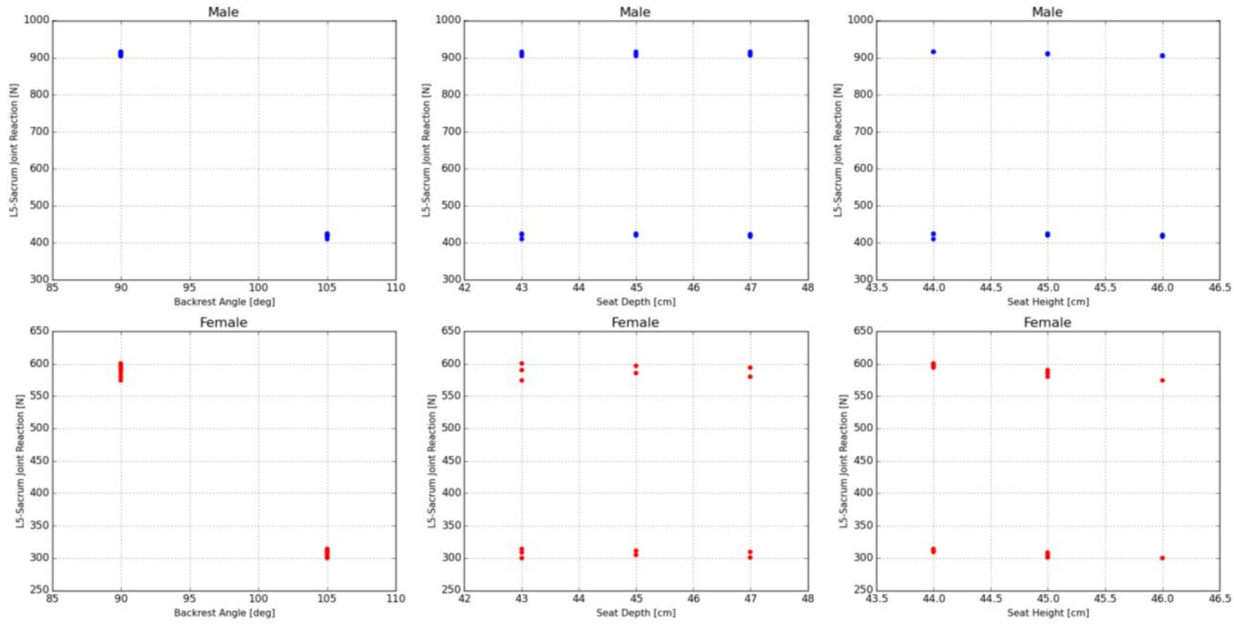

Figure 3. L5 Sacrum joint pressure loads on male and female.

Variation of muscle activation levels on lumber region (erector spinae) muscle groups according to chair design parameters: High muscle activation cause early fatigue, thus it should cause discomfort. Results show that most significant factor is backrest angle. Seat height causes a negative effect on female group. High chair causes a little more discomfort (Figure 4).

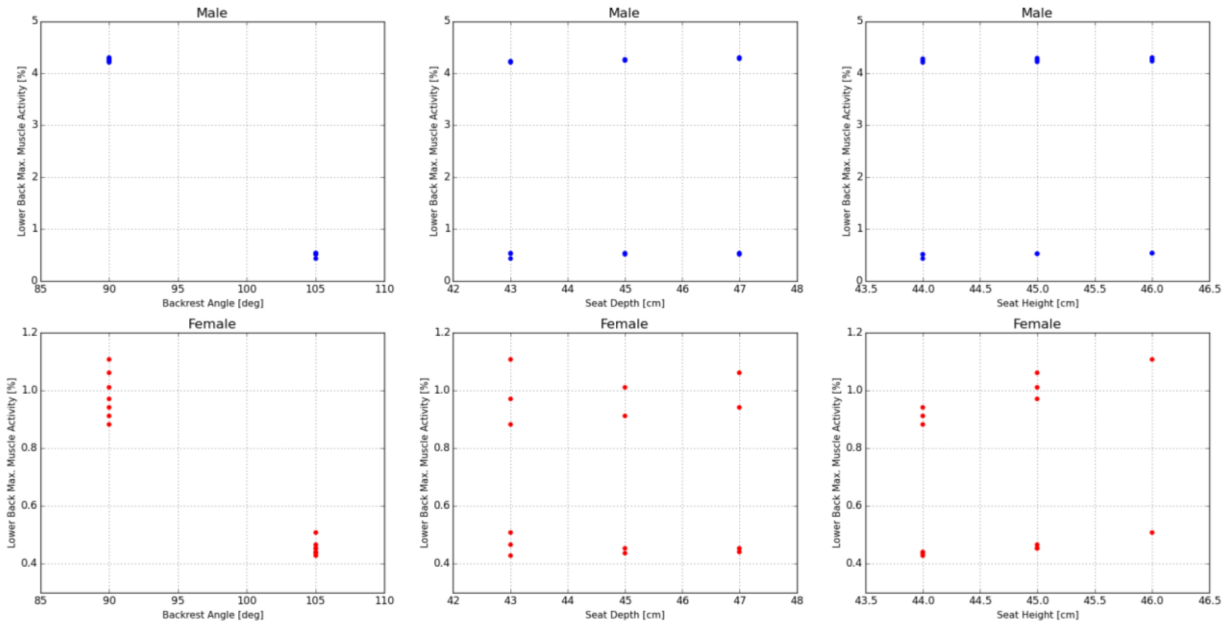

Figure 4. Lower back maximum muscle activity on male and female.

Variation of muscle activation levels on leg muscle groups according to chair design parameters: High muscle activation cause early fatigue, thus it should cause discomfort. Results show that most significant factor is backrest angle and seat height and seat depth parameters have showed limited effect on musculoskeletal system (Figure 5).

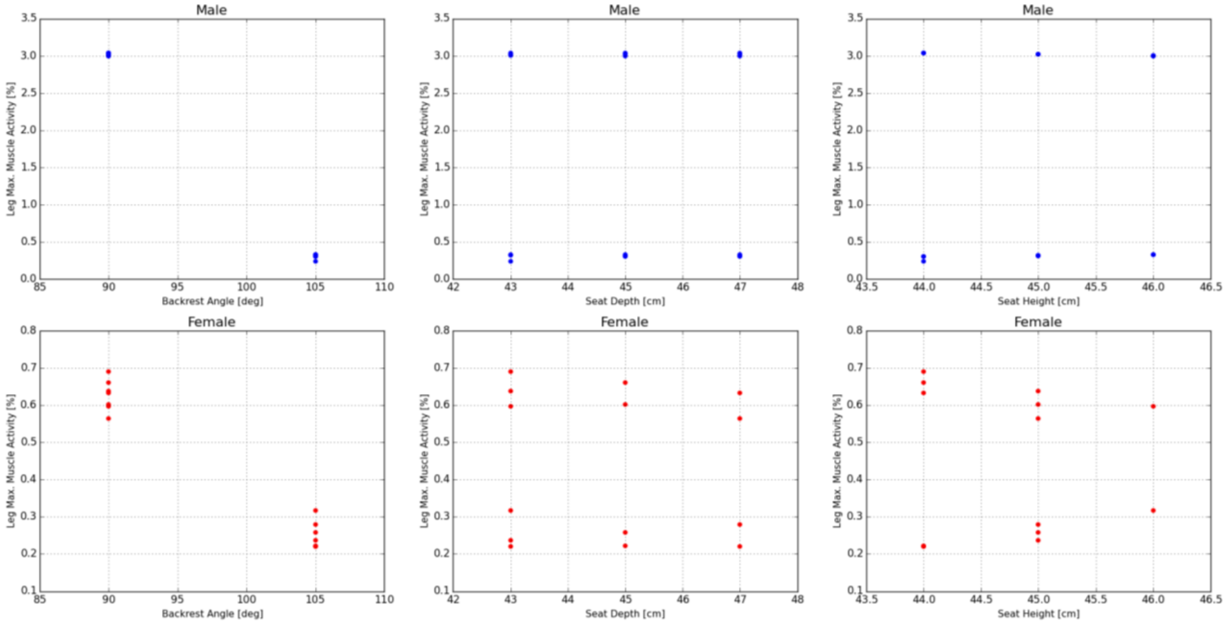

Figure 5. Leg maximum muscle activity on male and female.

Variation of muscle activation levels on shoulder-arm muscle groups according to chair design parameters: High muscle activation cause early fatigue, thus it should cause discomfort. Results show that most significant factor is backrest angle and seat height and seat depth parameters have had limited effect on musculoskeletal system (Figure 6)

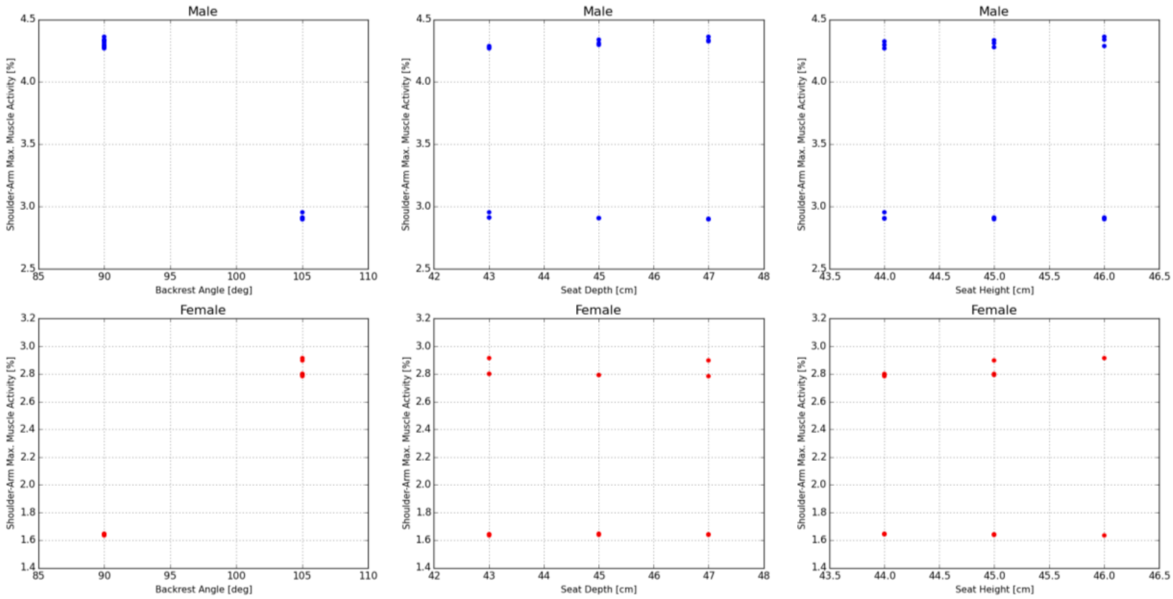

Figure 6. Shoulder-Arm maximum muscle activity on male and female.

5. CONCLUSION

It can be concluded that most significant chair design parameter is backrest angle for both male and female figures. Increasing backrest angle from 90 to 105 degrees result in 50% decrease in L5-sacrum joint reactions for both figures which is a significant change in terms of comfort. Maximum muscle activity level comparisons follow the same for backrest angle effects expect Shoulder-Arm muscle activity for females. This is due to lack of input posture information to simulation and not related with the chair design. Seat height and seat depth factors were not critical for both male and female figures. For females increased seat height seems to cause discomfort in the legs. We think this is due to our imposed boundary condition of having both feet parallel on ground. In general, our study shows it is possible to analyze seating furniture design alternatives for ergonomics before building any prototype and get meaningful quantitative data. The study can be extended to analyze each individual in certain population and optimize furniture design further for targeted customers.

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