VIRTUALIZACIJA UDOBNOSTI SJEDENJA I PRIPADNOG BIOMEHANIČKOG OPTEREĆENJA ENTITETA STUDENTSKE POPULACIJE
VIRTUALIZATION OF SITTING COMFORT AND RELATED BIOMECHANICAL LOAD OF THE STUDENT POPULATION

S. Baksa[1], I. Vuk[1], I. Baksa[2],

[1] Međimursko veleučilište u Čakovcu, Bana J. Jelačića 22a, Čakovec, HRVATSKA, sarajko_baksa@yahoo.com, ivana.vuk@student.mev.hr

[2] *Saba*LAB, Vladimira Vidrića 10, Zagreb, HRVATSKA,

ines_baksa@yahoo.com

Sažetak: *Glede računalne prostorne virtualizacije udobnosti sjedenja, provedena je ergonomijska analiza djelatnih položaja, većeg broja antropometrijski relevantnih studentskih entiteta, muškog i ženskog spola. Unutar rada, računalnim metodama ergonomijske analize (CAEA) i izvedbom pripadnih digitalno generiranih računalnih 3D biomehaničkih modela istražena je antropometrijska i ergonomijska prilagođenost izvedenih studentskih radnih mjesta unutar istraživanih predavaona MEV-a, unutar domene suodnosa referentnih djelatnih tjelesnih položaja sjedenja. Oblikovanjem promatranog virtualnog 3D sustava omogućena je prostorna ergonomijska virtualizacija i detekcija pripadnog personaliziranog biomehaničkog opterećenja tijela i pojedinih tjelesnih segmenata.*
Ključne riječi: *ergonomija, biomehanika, znanstvena vizualizacija, virtualni humanoidni modeli*

Abstract: *With regard to computer spatial virtualization of sitting comfort, an ergonomic analysis of active positions was conducted on a large number of anthropometrically relevant student entities, of male and female gender. Within the paper, C*omputer Aided Ergonomy Analysis *(CAEA) and the performance of the associated digitally generated 3D biomechanical models, anthropometric and ergonomic adaptation of student workplaces was investigated within the MEV's lecture rooms, within the domain of correlation of reference active seating positions. Designing the observed virtual 3D system has enabled spatial ergonomic virtualization and detection of associated personalized biomechanical load of the body and individual body segments.*

Keywords: *ergonomics, biomechanics, scientific visualization, virtual humanoid models*

1. INTRODUCTION

Based on the results of the 3D Computer Characters and the associated 3D model of desks within student lecture rooms, the use of modern 3D graphics programs can determine the engagement dimensions of the body through anthropometric analysis of 3D character activity, and by knowing anthropometric measurements and applying computer virtualization, model the corresponding ergonomic shaped workplace. By applying such research of the author on the complete design of workplaces and places for leisure and free time, it is possible to establish and determine the harmony of furniture and furniture elements and the human body, as well as the proper physical position during work and rest, which puts the consumption of physical energy and energy balance of the body at the lowest possible measure. This, in turn, reduces human fatigue within the production process, humanizes the work, and increases efficiency, productivity and quality of work, which is a significant contributor of the author, especially since by using these methods of scientific computer virtualization optimal dimensions of furniture and the environment, in regards to the optimum loads, can be determined.

The paper presents the ergonomic and biomechanical contribution to designing and shaping a sitting workplace using computers and computer 3D programs. Computer spatial virtualization was used to consider the ergonomic effects of workplace design on the correct position of the student population at work, which reduces their energy consumption and fatigue to a minimum, while in the biomechanical context, the values of the biomechanical percentage of comfort are compared to the reference neutral position.

2. ANTHROPOMETRIC FACTORS OF THE HUMAN BODY

In living beings, including humans, there is an apparent harmony of the dimensions of certain parts of the body in correlation with gender, age and race. In this way, by knowing the dimension of a body part with a relatively high accuracy, the dimensions of any other part of the body can be determined [1].

From numerous anthropometric studies related to the definitions of the so called static anthropomeasures, there are also the differences that emerge from the constitutional differences between humans according to sex and age, as well as body structure. In this regard, according to the body structure, there are three distinct forms of body shape, namely: a) asthenic constitution, leptosome according to Kretschmer or respiratory according to Siguad, b) fibrous constitution, athletic according to Kretschmer, or athletic-muscular according to Siguad, and c) pyknic constitution, eurosomatic according Kretschmer or digestive towards Siguad as shown in figure 1 [2].

Anthropometric correlations of some of the body characteristics of a human population can be quantified by a statistical method of finding an average. It is possible to show it with the so-called Gaussian curve, in which the probability of distribution frequency is given on the ordinate, with the corresponding attribute of the body height on the abscissa, figure 2 [3].

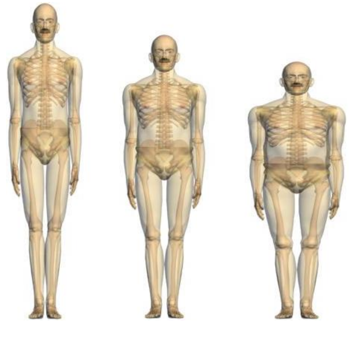

Figure 1: Types of body constitution

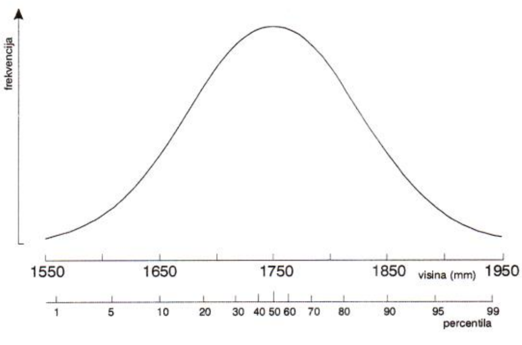

Figure 2: Frequency distribution of body height

3. CONSTRUCTION CHARACTERISTICS OF SITTING ERGONOMICS

With regard to the successful solution of the construction characteristics of the ergonomics of sitting, it is necessary to find an ergonomically functional, studied and shaped workplace, which facilitates work and improves efficiency while preventing damage to human health. Static and dynamic anthropometry shows the size and data measurements of the human body, depending on sex and age, for a particular population, which can be used to determine the ergonomic possibilities of adapting space and working environment to the human body. Also, the shapes of work surfaces can be customized, and determine more convenient work positions, forms and sizes of tools, equipment and devices, aids and environmental systems.

The working position of a person should provide good mobility of the extremities, ergonomically sound layout of the working and visual zones and a stable balance in the performance of work tasks. Unfavorable working positions are manifested through increased fatigue and increased time for performing technological operations. Conducted research and results have shown that the fatigue of a human organism is often increased due to an inappropriately shaped workplace, human work position, and non-compliance with ergonomic and biomechanical principles of work and workplace design.

The sitting position of a student can completely change the sagittal curvature of the spine, particularly the lumbar lordosis. This depends on figure 3, about the way of sitting and the construction of the sitting surface (according to Keegan Radke 1964). The most important role in this is the placement of the pelvis because the appearance of the lumbar spine depends on its inclination. For example, in the upright sitting without the back, the pelvis is inclined forward, similar to standing, and lumbar lordosis is expressed. Significant muscle activity is required to maintain such position, so rapid fatigue is visible. With (comfortably) relaxed seating with the back rest under different angles (90^o to 100^o), the sagittal and lumbar curve are completely straightened, or there is even lumbar kyphosis. It is important to note that for normal sitting it is necessary that both hips are movable because only in this way is the flexion required for the parallel position of upper legs possible whereat the pelvis is in the horizontal plane parallel to the backing. In this position, a normal flow of physiological sagittal curvatures of the spine is maintained, and the load is equally distributed over all its constituent elements [4].

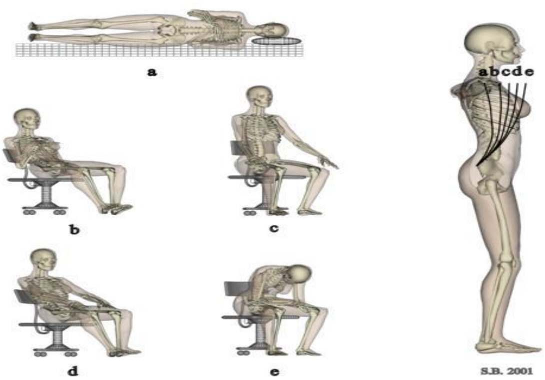

Figure 3: *The degree of spine curvature for different positions of the body*

4. COMPUTER 3D VIRTUALIZATION

Based on body height measurements of MEV students and their respective active positions within workplaces (student desks), 3D computer graphics programs were used for purposes of virtual design, modeling and visualization of elements of workplace in the lecture room and biomechanical models. On the acquired virtual 3D models of man and workplace, figure 4, computer scientific virtualization was use to perform a biomechanical analysis of movements based on actual correlation in the space of ergonomic interaction between the body of the student population and student desks as the environmental space.

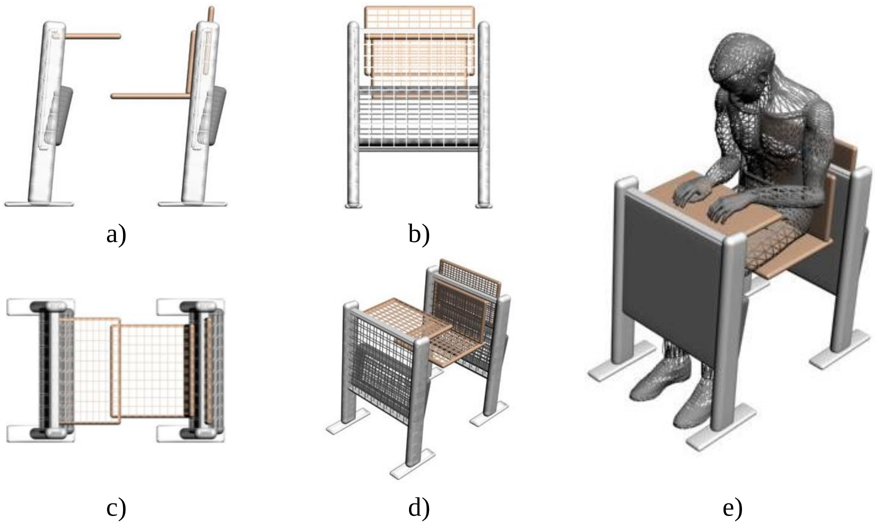

Figure 4: *Virtualization front view (a), side view (b), top view (c), and perspective view (d) of analyzed student desks with the associated 3D humanoid model (e)*

5. RESEARCH RESULTS

From the point of view of ergonomics and biomechanical analyzes it is possible to accurately determine the dimensions of the ideal form of space and body load for each person individually. The results of the evaluation of the biomechanical comfort of the spine and the angles of the body's extremities within this paper were taken for three anthropometric heights; of male students: 194 cm, 184 cm, 174 cm and female students: 174 cm, 164 cm, 154 cm. The computer 3D anthropometric motion analysis determined the dimensions of the body's area of engagement. By knowing anthropometric measurements and using computer equipment and computer 3D generated virtual models, it is possible to efficiently and quickly perform ergonomic modeling of dimensions and forms of environmental elements as well as related biomechanical analysis of the curvature angles of the spinal column spatial in the cervical, chest and lumbar spine, as well as the shift angles of hands, elbows, shoulders, hips, knees and feet, showing the biomechanical percentage of comfort expressed in percentages, and in relation to the reference body position for men and women, table 1.

Table 1: Tabular representation of the biomechanical percentage of comfort (%)

Body position		Male			Female			Reference Male	Reference Female
		194 cm	184 cm	174 cm	174 cm	164 cm	154 cm	174 cm	174 cm
Spine	Cervical S1	60	54	82	81	82	72	72	71
	Cervical S2	56	51	78	77	77	67	68	67
	Cervical S3	51	47	74	73	73	63	64	63
	Cervical S4	46	42	70	69	69	59	60	59
	Cervical S5	40	37	65	64	65	54	56	54
	Cervical S6	34	31	60	59	60	50	52	50
	Cervical S7	29	26	56	55	57	46	48	47
	Dorsal S1	35	37	59	52	47	51	60	57
	Dorsal S2	28	31	54	46	42	47	57	54
	Dorsal S3	22	26	49	42	39	44	55	52
	Dorsal S4	16	21	46	39	36	42	53	50
	Dorsal S5	11	15	43	37	34	40	52	49
	Dorsal S6	7	13	41	35	33	38	51	49
	Dorsal S7	4	10	39	35	32	38	52	50
	Dorsal S8	0	8	39	35	32	38	52	51
	Dorsal S9	0	6	38	36	33	38	53	53
	Dorsal S10	0	5	39	37	34	39	55	55
	Dorsal S11	0	4	40	39	35	40	56	57
	Dorsal S12	0	5	41	41	37	42	58	60
	Lumbar S1	0	0	24	25	20	26	32	34
	Lumbar S2	0	0	26	26	21	26	34	36
	Lumbar S3	0	0	26	26	21	27	34	36
	Lumbar S4	0	0	25	25	21	27	35	36
	Lumbar S5	0	0	28	29	26	31	37	39
Arms	Hand R	91	98	31	32	33	24	31	32
	Lower ArmR	0	0	0	0	0	0	0	0
	Upper ArmR	0	0	39	21	8	39	70	70
	Clavicle R	19	24	22	31	22	37	47	49
	Hand L	78	78	85	40	93	41	39	40
	Lower ArmL	0	0	0	0	0	12	0	0
	Upper ArmL	40	34	80	73	30	34	42	42
	Clavicle L	48	56	48	47	48	55	50	53
Legs	Toe R	100	100	100	100	100	100	100	100
	Foot R	46	21	41	54	47	71	68	67
	Lower Leg R	43	0	32	49	49	58	62	62
	Thigh R	0	0	0	0	0	0	0	0
	Toe L	100	100	100	90	100	100	100	100
	Foot L	55	0	37	56	48	60	58	56
	Lower Leg L	42	14	45	57	47	57	61	61
	Thigh L	0	0	0	0	0	0	0	0

6. DISCUSSION AND CONCLUSIONS

According to the results of the biomechanical percentage of comfort shown in table 1, there is a significant visible departure from the real percentage of comfort of individual segments of the body compared to the reference sitting position. Given the biomechanical percentage of comfort, the results can be grouped into three segments of physiological acceptability; unacceptable from 0 to 15%, moderately acceptable from 16 to 50% and acceptable from 50 to 100%. In the observed entities of the student population, there is a noticeable strain on the individual muscle groups (cervical muscles, paravertebral and lower pelvic muscles) caused by irregular and uncomfortable sitting, which, it is established, inevitably leads to muscle fatigue, reflexes and motor weakness, and over time reduction in the possibilities of precision work.

Due to the long-term and forced work position, though it may be even comfortable, musculoskeletal problems and spinal problems often appear, although this work position can be classified as lightweight by the energy consumption criterion. Damage and degenerative changes in bone and joint structures are the consequence of a disparity between the demands on the body's load and the ability of the organism to respond to these requirements [5]. The unfavorable body positions are manifested through an increased fatigue coefficient. These unfavorable positions can also be professionally dangerous where the spinal loads are exaggerated and are at the edge of physiologically acceptable values [6]. Mental discomforts, along with fatigue, lethargy and exhaustion are often associated with an inappropriately shaped environmental system in relation to a person or the result of neglecting the application of ergonomic and biomechanical principles.

When sitting, students usually have a sagittal spine curve deformity, especially in the cervical and lumbar region and legs in an uncomfortable position, but unlike standing, one can sit right or wrong, not just comfortably or uncomfortably. In the ergonomic design of the workplace, it is necessary to establish a proper relationship between the working environment and the biomechanical position of the body in order to lessen the strain on body musculature, which is determined by body height, working environment and technological operation of the work.

REFERENCES

[1] Muftić, O.; Milčić, D.: *Ergonomija u sigurnosti*, Visoka škola za sigurnost na radu, Zagreb, Iproz, Zagreb, (2001)

[2] Jurum - Kipke, J.; Baksa, S. & Kavran, Z.: Anthropometric Relations of Human Body in the Function of Traffic Environment Analysis, *The 3rd International Ergonomics Conference, ERGONOMICS 2007.*, June 13th – 16th, 2007, Stubičke Toplice, Zagreb, Croatia, 239 – 248., (2007)

[3] Lange, W.: *Kleine Ergonomische Datensammlung*, Bundesanstalt für Arbeitsschultz 6. überarbeitete auflage, Verlag TÜV Rheinland, (1991), ISBN 3-921059-63-1

[4] Baksa, S.; Muftić, O. & Baksa, I.: Virtual 3D Human Model in Investigations in Computer Interior Design, *3D Modelling 2006, Virtual mockups & Ergonomy, Harbour Conferences*, Paris, June 63 – 66, (2006)

[5] Bailey, R. - W.: *Human performance engineering: A guide for system designers*, Prentice-Hall, Englewood Cliffs, NJ, (1982)

[6] Radwin, R.G. & Lin, M.L.: An analytical method for characterizing repetive motion and postural stress using spectral analysis, *Ergonomics 34*, 4, 1993., 379 - 389.