

Automatic patient bed comfort structure analysis based on the RULA method

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Abstract. To improve patient care, reduce medical staff injuries, and increase the efficiency of the patient care process, automated patient beds are a very important innovation in the world of healthcare. However, there needs to be a study to find an ergonomic automatic bed design so that it is safe and comfortable when used by patients. This research concerns the study of the ergonomics of patient bed design using the Rapid Upper Limb Analysis (RULA) method. The patient bed that has been designed is then analyzed using RULA to obtain initial ergonomic data from a designed patient bed. There are 3 observations made, namely the patient's condition when sitting, the patient's condition when lying down, and the patient's condition when the bed can be adjusted low. When in the sitting position, the average RULA result is obtained at 3, when lying down, the average RULA result is obtained at 3, and when the bed is set low, the average RULA result is obtained at 3. This ergonomic value is an accumulation of the assessment of the structure of the upper arms and forearms, lower body, muscles, neck, torso, legs, wrists, and arms.

1 Introduction

The health and well-being of patients is a very important aspect of health services. One of the key factors in creating an optimal care environment is the ergonomic design of the patient bed. Ergonomics is an applied scientific discipline that focuses on the design and development of tools, including workplace settings, and optimal work strategies to maintain the health of the human body. Ergonomics aims to reduce fatigue, discomfort, risk of injury, and emotional stress [1]. Apart from that, ergonomics is a discipline that examines the limitations, strengths, and characteristics of humans, and utilizes this information in designing products, without ignoring the health, safety, and comfort aspects of the user [2]. A well-designed patient bed not only increases patient comfort but also makes it easier for medical staff to provide quality services. Patient beds are critical medical devices in hospitals and can be used by private individuals in caring for sick or recovering patients. The quality of the patient's bed is very important in ensuring

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patient comfort and ease of care. In hospitals, patient beds also play a role in providing the support necessary for optimal medical care. In addition, inappropriate work posture or position will result in work-related musculoskeletal disorders (MSDs)[3]. Therefore, designing and evaluating a good patient bed is very crucial. When someone is sick or in the process of recovery, comfort while lying in the patient's bed is an important factor in the healing and treatment process. A patient bed that is ergonomic and fits the patient's needs can help reduce the risk of pressure on the body, improve blood circulation, and reduce the discomfort that the patient may experience. Therefore, patient beds are needed that are designed with a structure that takes into account aspects of patient comfort and health as well as ease of care.

In this study, to analyze the comfort structure of the automatic patient bed, the RULA (Rapid Upper Limb Assessment) method was used. Even though there is a lot of previous research related to this field, the analysis of the comfort structure of automatic patient beds using the RULA method is still not optimal. This research contributes to this gap by developing an automated patient bed system in which a comfort structure analysis is obtained based on the RULA method. Results related to the automatic bed structure analysis in terms of comfort will be displayed. With this method, it will be shown how the system can be used to identify and measure factors that influence patient comfort and the ergonomics of the patient's bed. In this regard, this research can make an important contribution to improving the design of patient beds both for use in hospitals and for individual users.

2 Methods

This research method uses Rapid Upper Limb Assessment (RULA) which examines the ergonomics of the design of automatic patient beds. RULA is a method used to assess posture, strength, and movement of work activities related to upper limb activities[4, 5]. Apart from that, it is also a technique for evaluating and assessing body layout, strength, and movement transfer in work activities that touch the upper part of the body. This technique was also developed as a means of identifying possible risks of interference or injury experienced by workers as well as ergonomic factors related to upper extremity MSDs when carrying out certain activities[6]. The RULA ergonomic assessment instrument includes biomechanical loads, and task demands from the posture of the neck, trunk, and upper extremities which are measured and calculated using CATIA software. CATIA software is a tool that can be used for ergonomic analysis and design of workstations and environments. The steps in calculating RULA or the RULA assessment list are shown in Figure 1 below.

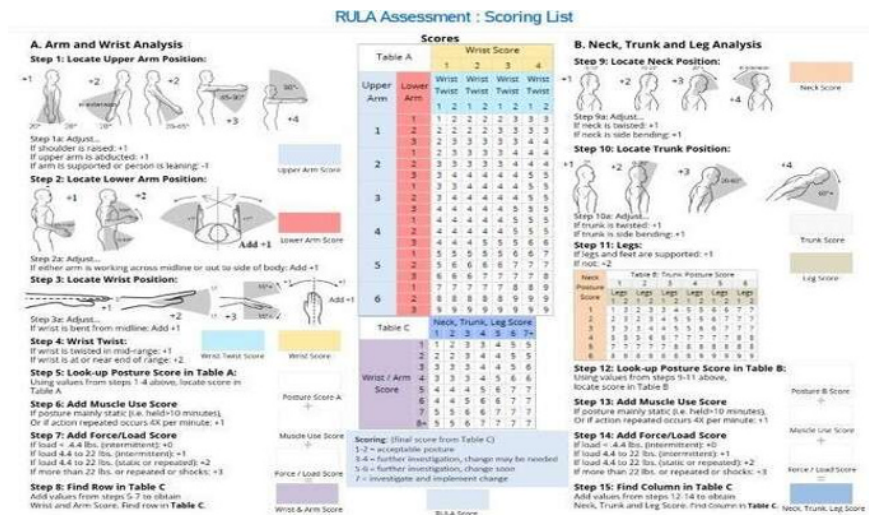


Fig. 1. RULA Assessment: Scoring List

RULA analysis was carried out on the upper limbs of the mannequin by taking into account factors such as weight, distance, and frequency. RULA is a survey method designed as a means of investigating human factors or ergonomics in the work environment regarding work disorders in the upper extremities. RULA is a screening tool that assesses the biomechanical load and posture of the entire body with a particular focus on the neck, trunk, and upper limbs. RULA is intended to be used as part of a more comprehensive ergonomics study [7].

In this case, RULA was developed and used specifically to evaluate the risks for patients who are treated using a patient bed that involves sitting, lying, right or left tilt, such as patients in hospitals who experience mobility problems. as well as risks for patients where patients lie down for long periods of time. Input data in RULA analysis includes body posture (head, torso, and upper limbs), force used, and types of movements or actions performed repeatedly. This RULA analysis is used for various aspects of a mannequin's posture automatically from a combination of visible variables and user data. In this study, some parts of the mannequin's body were adjusted according to the design of the patient's bed. assessment of the structural position of the upper arm, forearm, muscles, neck, trunk, legs, wrists, and arms. The patient bed that has been designed is then analyzed using RULA to obtain initial ergonomic data for the designed patient bed. There are 3 reviews carried out, namely the patient's condition when sitting, the patient's condition when lying down, and the patient's condition when the bed can be set low. The following is a simulation scenario of a patient bed for RULA assessment as seen in Figure 2.

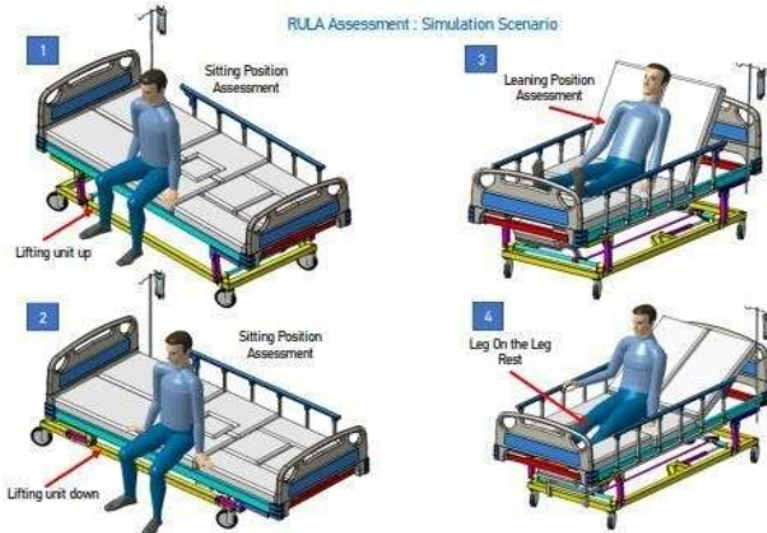


Fig. 2. RULA Assessment Simulation Scenario

Table 1. RULA Scoring and descriptions

Action Levels	RULA Score	MSD Risk Level	Descriptions
1	1-2	Negligible risk, no action required	The individual is operating in an optimal posture, with no potential risk of injury from their work position.
2	3-4	Low risk, some adjustments may be needed	The individual is working in a posture that could pose some risk of injury due to their work position, and this score is likely due to one specific aspect of the task.
3	5-6	Medium risk, further investigation, changes needed soon	The individual is working in a suboptimal posture, which carries a medium risk of injury from their work position. It's crucial to investigate and implement changes in the near future to prevent injuries.
4	7+	Very high risk, immediate changes required	The individual is operating in the poorest posture, with an imminent risk of injury from their work position. Immediate

			investigation and changes are necessary to prevent injury.
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Table 1 displays the RULA action levels along with their respective descriptions. The score is represented on a numerical scale, ranging from 1 (the lowest score) to 7 (the highest score). Each action level is accompanied by its own set of descriptions, which elucidate the potential outcomes when the analysis aligns with the assigned score [5].

3 Results and discussion

Based on the results of the automatic patient bed design, the dimensions and geometry of the patient bed product are obtained as shown in Figure 3 below:

3.1 Product geometry & dimension

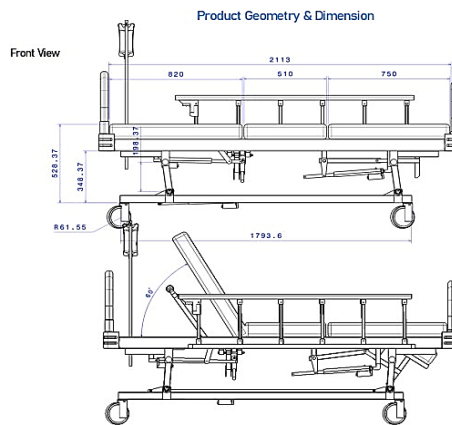


Fig. 3. Product Geometry and dimension of the patient bed

3.2 Structural study designed patient bed lifting unit

Based on the results of a structural study of the designed lifting unit for the patient's bed, in this simulation scenario the bed will be given a load of 1471 N (-150 kgf), where the results show that the stress distribution in the frame is less than 250 MPa or does not exceed the Yield Strength Then, the safety factor value is 15 so it can be said that this patient's bed frame is safe. In Figures 4 to Figure 7, the results of the structural analysis of the patient bed lifting frame unit are presented.

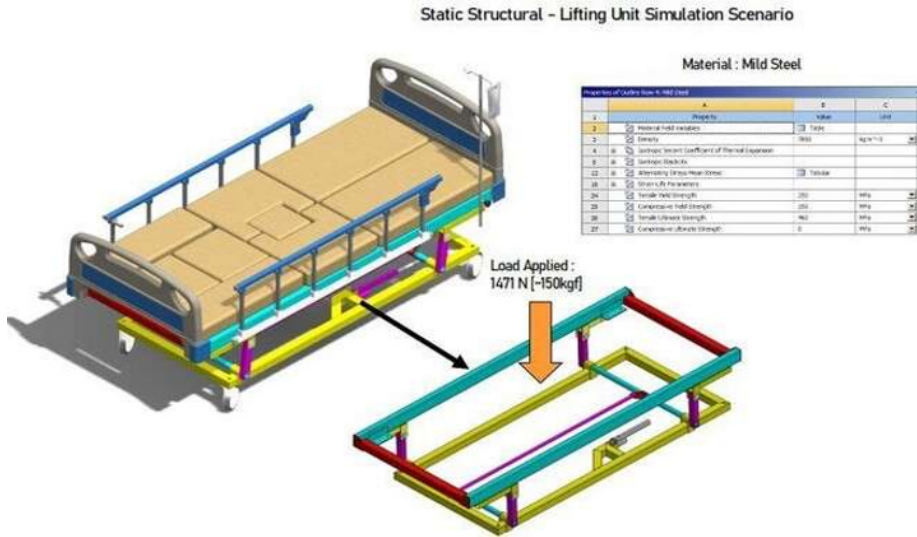


Fig. 4. Static Structural – Lifting unit simulation scenario

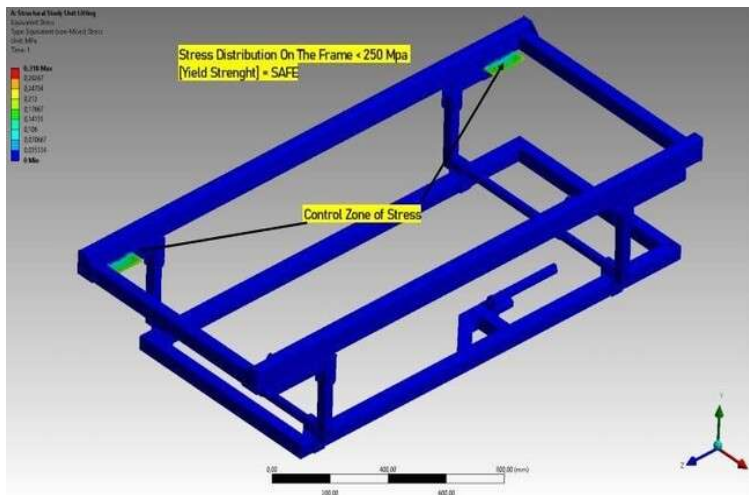


Fig. 5. Structural analysis of the patient bed lifting unit

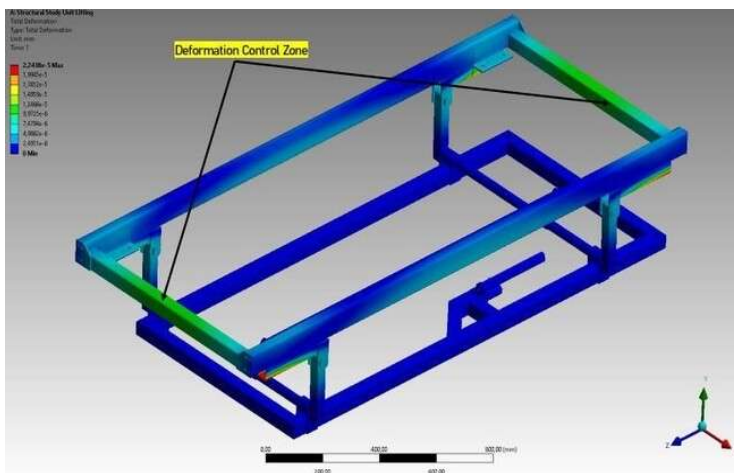


Fig. 6. Structural analysis of deformation control zone

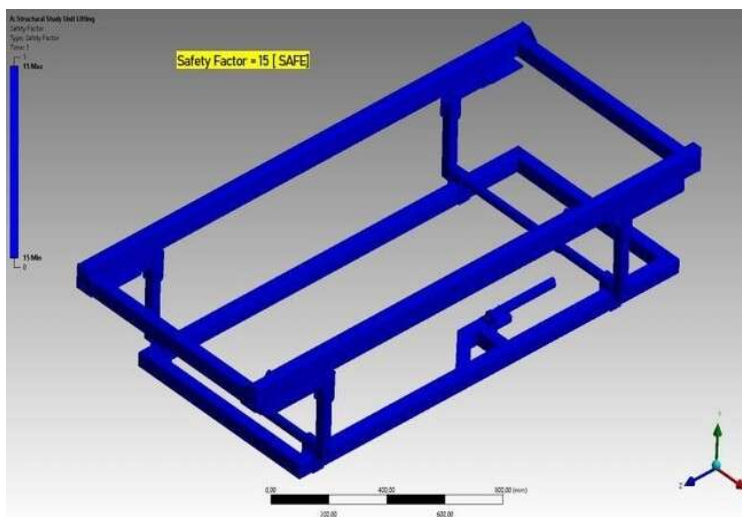


Fig. 7. Analysis of safety factors for patient bed frames

3.3 Structural analysis of patient beds with rapid upper limb assessment (RULA)

Based on the patient bed simulation scenario for RULA assessment as seen in Figure 2, above, the following results were obtained.



Fig. 8. Sitting Position (lifting unit) RULA Assessment

Referring to the results of structural analysis in the sitting position, namely when lifting the unit, the DOF of the leg or the degree of body posture of a person's legs when sitting with the lifting bed up is 75.84 deg, the DOF of the hand is -58.19 deg, the DOF of the forearm is 15.73 deg, and DOF of the arm is 2 deg, resulting in a final score in the sitting position of 3 or still in the safe category and can be investigated further or can be said to be at level Low risk, change may be needed, if based on MSD risk.



Fig. 9 Sitting Position (lifting unit down) RULA Assessment

Referring to the results of structural analysis in the sitting position, namely when the lifting unit is down, the DOF of legs or the degree of the body posture of a person's legs when sitting with the lifting bed down is 65.21 deg, DOF of hand is -61.83 deg, DOF of forearm is 7.87 deg, and DOF of arm is 4.60 deg, DOF of thigh is 71.78 deg resulting in a final score in the sitting position when lifting down which is 3 or still in the safe category and can be investigated further or can be said in level is low risk, change may be needed,



if based on MSD risk.

Fig. 10. Leaning Position RULA Assessment

Referring to the results of structural analysis in the lying position, namely when the DOF of thigh is 64.42 deg, DOF of hand is -29.54 deg, DOF of forearm is 23.59 deg, and DOF of full spine is 0 deg, resulting in a final score in a sitting position when lifting down, namely 3 or still in the safe category and further investigation can be carried out or can be said to be at level low risk, change may be needed, if based on MSD risk.

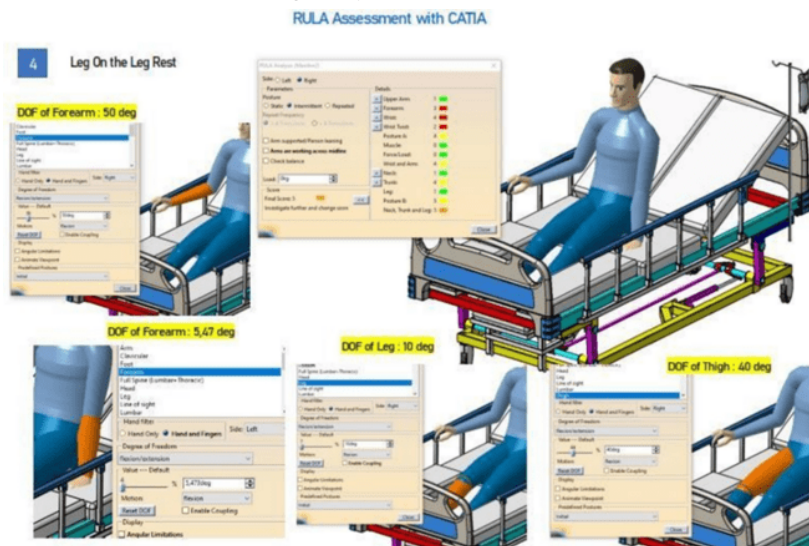


Fig. 11. Leg On the Leg Rest RULA Assessment

Referring to the results of structural analysis in the position of the foot on the footrest or leg on the leg rest, namely when the DOF of the thigh is 40 deg, DOF of right forearm is 50 deg, the DOF of left forearm is 5.47 deg, and DOF of the leg is 10 deg, produces a final score in a sitting position when leg on the leg rest, namely 5 or investigate further change soon or can be said in medium-risk, further investigation, change soon, if based on MSD risk.

Based on these results, it can be seen that several positions that were analyzed when the automatic patient bed was operating, in 3 conditions, namely the sitting position when lifting up, the sitting position when lifting down, and the lying position received a final score of 3 or in the low-risk category which can be said to be still in the safe and comfortable category. However, when the foot is in the final leg rest, the RULA score is 5, which is in the medium risk category, which can be said to require further investigation to avoid serious risks. Analysis using the RULA method was also carried out by M. Massaccesi et.al (2003) in analyzing the position of truck drivers where drivers often experience complaints due to inappropriate work postures[8]. Apart from that, research by Nelfiyanti, et.al (2022) regarding MSD analysis using the RULA approach for chassis assembly workers where there are several groups analyzed and there are groups analyzed that have a high risk so corrective action needs to be taken as soon as possible [5]. Therefore, it can be seen that evaluating or assessing work posture is very important, especially for several products and work positions to avoid injury or problems with body posture [9, 10].

This is also supported by research by Widiyawati, et.al. (2020), regarding the risks of hunched work postures, using maximum reach and the position of certain body parts is uncomfortable, resulting in decreased worker productivity. Therefore, this analysis evaluates employee work postures to identify problems with the work postures used. The RULA method is also used to evaluate musculoskeletal loads in a job where a person has risks to upper body activities. The samples used in this research were workers who worked in a sitting position and used computers in their activities. Based on the analysis, it is known that worker activities received a score indicating that the workplace requires changes to improve ergonomic aspects[11].

4 Conclusion

Based on the structural analysis carried out on the patient's bed, there are several conclusions, namely: (1) The results of the analysis of the comfort structure of the patient's bed automatically obtain an average RULA score of 3 or low risk and are

included in the safe category which is carried out in the structural analysis when sitting in a lifting up, lifting down position, then when lying down, and also when in a sitting position feet are on the leg rest; (2) There needs to be further improvement and investigation into the leg on the leg rest condition because it is in the medium risk category; (3) The designed patient bed has been evaluated and used as a consideration for the mass production process of automatic patient beds.

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