ERGONOMIC RISK SIMULATION USING RAPID UPPER LIMB ASSESSMENT TOOL FOR THE SITTING POSTURE OF GARMENTS WORKERS: A CASE OF RIVATEX EAST AFRICA LIMITED, ELDORET, KENYA

[1, 2, 3]Abdalla Esmaeel*, [2]Sesan Peter Ayodeji, [3]Diana Starovoytova, and [3]Jerry Ochola.

[1]Department of Industrial Engineering, Faculty of Industries Engineering and Technology, University of Gezira P. O. Box 20, Wad Medani, Sudan

[2]Department of Industrial and Production Engineering, School of Engineering and Engineering Technology, Federal University of Technology, P.M.B 704, Akure, Ondo State, Nigeria.

[3]Department of Manufacturing, Industrial and Textile Engineering, School of Engineering, Moi University P. O. Box 3900, Eldoret, Kenya.

**Corresponding author: abdalla33065@gmail.com*

Esmaeel A., Ayodeji, S. P., Starovoytova D., Ochola J. (2026): Ergonomic Risk Simulation Using Rapid Upper Limb Assessment Tool for The Sitting Posture of Garments Workers: A Case of Rivatex East Africa Limited, Eldoret, Kenya. FUTA Journal of Engineering and Engineering Technology 20(special), 84-96

Received Date: 15.01.2026 **Accepted Date: 10.03.2026**

Abstract

Various research has investigated work risks and hazards using ergonomic analytical tools to prevent ergonomic risks and musculoskeletal disorders (MSDs). This paper simulated a human digital model of sitting posture using a rapid upper limb assessment tool for garment workers at Rivets East Africa Limited (REAL) factory, Eldoret, Kenya, to achieve a better score with an acceptable level of ergonomic risk. Anthropometric databases were used in the sewing workstation redesign, and digital human modeling aided the ergonomics simulation from the start of the product and workstation redesign process. Using the anthropometric data, a redesigned sewing workstation model was proposed. The proposed model was then simulated using computer-aided three-dimensional interactive application (CATIA V5) software based on rapid upper limb assessment (RULA). The redesigned sewing workstation had a final RULA score of 1, indicating that the ergonomic risk was negligible and the proposed redesign was acceptable. The outcomes of this study could therefore play a notable role in the growth of garment manufacturing by improving productivity and reducing worker fatigue.

Keywords: *RULA, Ergonomic Risk, Sitting Posture, Garments Workers, Kenya*

Introduction

The most common assessment tools include RULA, Rapid Entire Body Assessment (REBA), Ovako Working Posture Analysis System (OWAS), Occupational Repetitive Actions (OCRA) and Posture, Activity, Tools and Handling (PATH). On the other hand, these ergonomic risk assessment tools primarily focus on analysis of the upper limbs (Kong *et al.,* 2018). Therefore, the present work used RULA as one of the ergonomic risk assessment tools to simulate the human digital modelling sitting posture. An earlier study by Mcatamney & Corlett, (1993) defined RULA as a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported.

Series & Science, (2019) researched work posture analysis using RULA for rice milling in Malang, Indonesia and found that lifting sacks scored 7, indicating a high and dangerous ergonomic risk level. This should be investigated and changes implemented immediately when designing or redesigning the workstation/workplace for milling workers. Series, (2020) studied workload measurement of batik workers using EULA and found the highest physical workload occurred at the drying workstation with a score of 7, also indicating a high and dangerous ergonomic risk level. This should be investigated and changes implemented immediately when designing or redesigning the workstation/workplace for batik workers. Wibowo & Mawadati, (2021) researched working posture using RULA methods and found workers' postures presented a high and dangerous ergonomic risk level; therefore, workers need to improve their working posture immediately.

Dockrell et al., (2012) researched the assessment of children's computer sitting posture using the RULA ergonomic tool and found that RULA was more consistent when used for assessing ergonomic risk levels in children. They recommended that the RULA method may prove useful as part of an ergonomic assessment tool. Levanon et al., (2014) studied the validity of a modified RULA for computer workers and found the RULA valid for assessing computer workers; one observation was enough to assess the work-related ergonomic risk factor. Namwongsa et al., (2018) researched ergonomic risk assessment of smartphone users using the RULA analytical tool and found most smartphone users had a total RULA score of 6, indicating the need for further investigation and changes when designing or redesigning ergonomic interventions for smartphone users.

Nayak, (2021) studied the development of a fully automated RULA analytical assessment system based on computer vision. The study found that the system could reduce the time required for sitting postural evaluation while producing highly reliable RULA scores consistent with those generated by manual approaches. Thus, the researchers expected the study would aid ergonomic experts in conducting RULA analyses based on surveys of occupational sitting postures in workstation and workplace conditions. Yadi et al., (2019) researched an ergonomic intervention study using the RULA and REBA method in chemical industries for risk assessment to reduce the risk of MSDs for workers. The research performed an ergonomic assessment using CATIA software based on the RULA analytical method. The outcomes showed that work systems may be improved by adding specific tools, and that a chemical worker's sitting posture may be improved through application of ergonomic principles. Chidambaram *et al.,* (2023) developed a computer-based assessment model for novel dynamic postural evaluation using RULA. The results revealed the model achieved an accuracy of 94.12%, outperforming previously reported models. Yazdanirad *et al.,* (2018) compared three ergonomic risk analysis tools—RULA, Loading on the Upper Body Assessment (LUBA), and the New Ergonomic Posture Assessment (NERPA)—to predict upper-extremity musculoskeletal disorders. The study concluded that NERPA indicated low ergonomic risk levels, LUBA indicated medium risk levels, and RULA indicated high risk levels; overall, RULA was judged the best tool for assessing MSDs among the three. Norhidayah *et al.,* (2016) evaluated and validated physical ergonomic risk factors associated with work-related MSDs using RULA for mining workers. The analysis yielded a final RULA score of 7, indicating high ergonomic risk and a need for engineering changes to reduce risk. The study's outcomes were used to improve workstation postures and enhance mining workers' comfort. Massaccesi *et al.,* (2003) investigated work-related MSDs in sitting and standing postures for truck drivers using the RULA method. Results showed a significant neck score in both postures, reflecting high trunk and neck loading. Overall, RULA proved a suitable tool for rapid evaluation of trunk and neck loading in drivers.

Hussain, (2021) analyzed the HDM (manikin) working postures of manual workers in industries using the RULA ergonomic tool in CATIA V5 software. The study found that most working postures had a high ergonomic risk score of 7, indicating immediate changes were required. Ergonomic principles were proposed, and the improved working posture was re-evaluated using RULA, yielding a score of 3, which indicates a low ergonomic risk level and is acceptable. Overall, the results indicate that uncooperative working posture ergonomic risks should be minimized by effectively applying ergonomic principles. Sharan & Ajeesh, (2012) investigated the relationship between MSDs and sitting posture scores at computer workstations using RULA ergonomic analysis. The outcomes revealed that 30% of participants' sitting postures needed to be modified soon and 15% needed immediate modification. The results also showed a significant association between regional body pain and the final RULA score. Ergonomic recommendations were given to modify the computer workstation and sitting posture. Mohamad *et al.,* (2013) analyzed the sitting postures of industrial workers in the packaging industry using the RULA ergonomic assessment in CATIA P3 V5 software. The RULA analysis detected several uncomfortable postures that were high ergonomic risk factors. The study concluded that the RULA tool effectively detected awkward postures and that further improvements should be implemented to prevent long-term discomfort for workers.

Kusuma, (2020) analyzed the work activities of sandpaper machine finishing workers using the RULA ergonomic tool and designed a work aid to improve working postures and reduce long-term ergonomic risk of lower back injuries. The data analysis yielded a RULA score of 4, indicating an ergonomic risk of MSDs. Eswaramoorthi *et al.,* (2010) analyzed an assembly line from a lean perspective to identify human–system interaction areas that could generate waste, using RULA ergonomic analysis with the CATIA V5 software platform. Based on the results, the assembly line process stations were redesigned to prevent waste generation. Hambali *et al.,* (2019) analyzed working postures in the mechanical manufacturing industry and the effect of workstation improvements using RULA ergonomic simulation tools. The study concluded that the method and software were powerful analytical tools for designing and redesigning virtual improvements, and it aimed to create design guidelines incorporating ergonomic principles to assist mechanical assembly workstations.

Sohail, 2021) studied ergonomic risk factors leading to work-related MSDs in the garment industry using CATIA V5 software based on the RULA ergonomic tool. The study's results indicate a 45% high postural ergonomic risk among garment workers. It also concluded that garment workers face various occupational health and ergonomic deficiencies and recommended several ergonomic interventions to improve their occupational health and safety, thereby enhancing performance. Ansari & Sheikh, (2014) evaluated work posture in small-scale industries in India using the RULA ergonomic tool. The RULA analysis determined that the majority of workers were at high ergonomic risk and required immediate change, concluding a lack of ergonomics awareness and understanding in small-scale industries. Mahantesh *et al.,* (2023) designed a computer user chair for Indians based on anthropometric standard data and conducted a RULA ergonomic assessment on the sitting postures for the HDM manikin. The RULA results showed the model was acceptable with a final RULA score of 2, leading to the conclusion that the computer chair model was ergonomic based on Indian anthropometric data.

Mahantesh *et al.,* (2021) researched chair modeling based on Indian anthropometric data. The RULA ergonomic analysis was performed using CATIA-V5 with the HDM (manikin). The final RULA analysis score was 2 on both the right and left sides of the HDM (manikin), indicating that the sitting posture with respect to the computer-modeled chair was acceptable and ergonomically fit for computer users. Paul & Paul, (2019) studied ergonomic motorized wheelchair analysis using the HDM (manikin) based on Indian anthropometric data and used the RULA ergonomic tool to measure user comfort and discomfort. The study concluded that the ergonomic wheelchair provides a better fit for Indian users. Dianat & Salimi, (2014) researched safe working practices for hand-sewing tasks in small-scale industries to highlight potential ergonomic interventions to reduce MSDs among these workers. The research concluded that the traditional method may require further development based on anthropometric data to determine the optimum workstation design.

The previous study by Esmaeel *et al.,* (2024) reviewed research on work-related risks and hazards for garment workers at sewing workstations using both the RULA and REBA methods. In that review, it was explained that most studies show work-related musculoskeletal disorders are a major problem worldwide. Strategies to control this risk typically focus on redesigning sewing workstations to reduce the ergonomic hazards workers experience during their tasks. The best way to achieve a safer workstation and prevent injuries is to assess the risks and hazards comprehensively. For ergonomic assessment, RULA and REBA are commonly used by different researchers; both observational methods are significant, suitable, and accurate for assessing ergonomic risks and hazards in the workplace. This review therefore suggested both methods as the most popular and widely used observational ergonomic assessment tools across various industries and services.

Hambali et al., (2021) studied an ergonomic design of an industrial assembly workplace using CATIA V5 based on the RULA ergonomic tool. The study showed that the final RULA score of the proposed workplace design was better than that of the existing design. This indicates that the CATIA V5 software, based on RULA, is a powerful predictive ergonomic tool for measuring ergonomic risk and improving workplace design. A previous study by Esmaeel *et .,* (2025) reported that analysis of employee posture in the existing sewing workplace at REAL Factory, Eldest, Kenya produced a final REBA score of 5, indicating a medium ergonomic risk of musculoskeletal disorders and the need for changes. Therefore, the goal of this paper was to simulate human digital modeling of sitting posture using CATIA V5 based on the RULA ergonomic tool for garment workers at REAL Factory, Eldest, Kenya, to achieve a better score with an acceptable level of ergonomic risk.

Materials and methods

Introduction

The RULA ergonomic analytical tool assesses the biomechanical and postural load demands of job tasks on the neck, trunk, and upper extremities (Manzoor Hussain et al., 2019). Moreover, ergonomic principles can be understood as the science of adapting tools and environments to user needs to reduce discomfort during use. Additionally,ergonomics seeks to achieve the best possible match between a product and its user within the context of the intended application (Romli & Aminian, 2018). The main steps for simulating an

HDM (manikin) in a seated posture using CATIA V5 ergonomic 3D CAD software based on RULA analysis are shown in Figure 1.

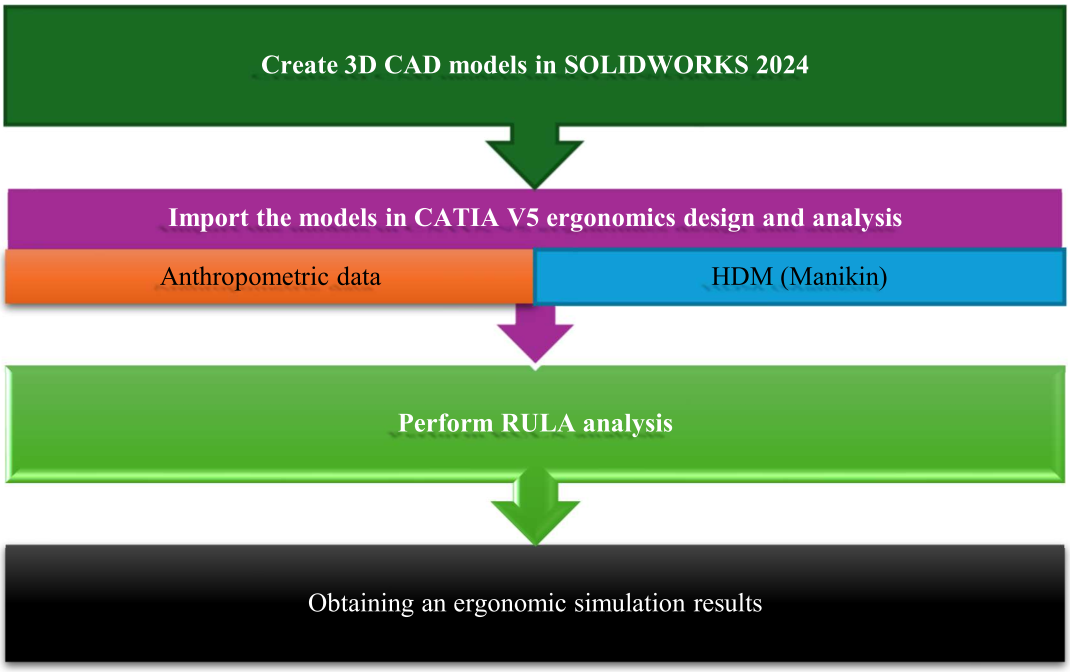


Figure 1: Main steps of the ergonomic simulation of HDM using RULA analysis

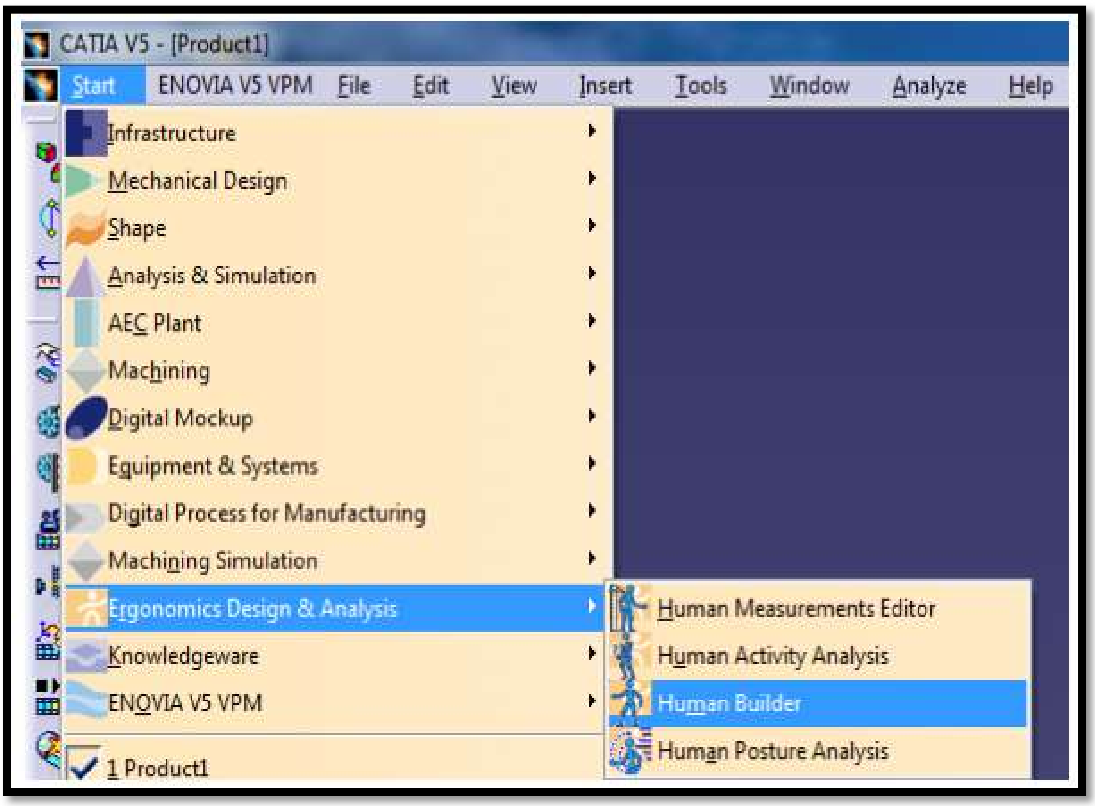


Figure 2: Ergonomics model in CATIA V5

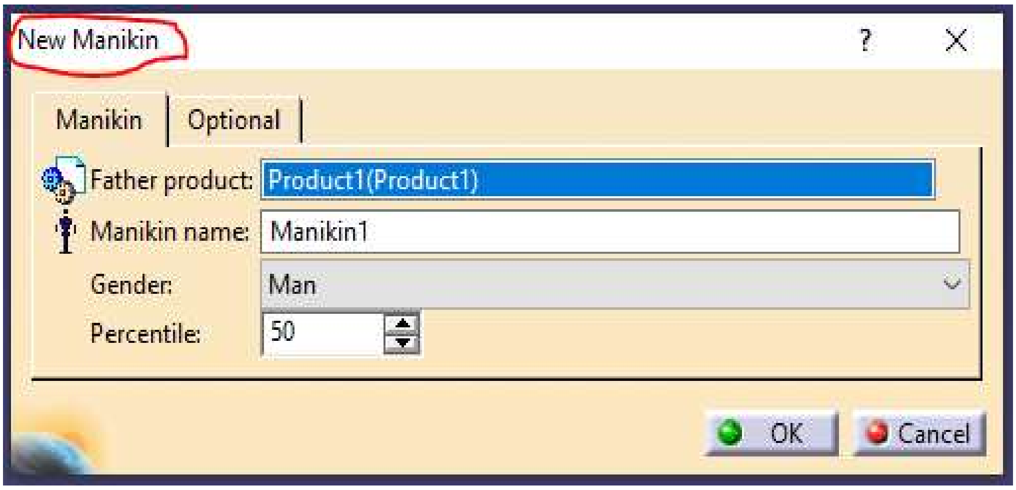


Figure 3: Manikin insertion for this present study

Create 3D CAD models with the 3D SolidWorks 2024 CAD software

The 3D models of the sewing workstation (selected sewing chair and adjustable sewing machine table) were created in the 3D engineering CAD software for ergonomic simulation of the sitting posture of the HDM.

Import the models in CATIA V5 ergonomics design and analysis

After the 3D CAD modeling was completed in the ergonomic simulation software, the sewing workstation models were imported into CATIA V5 ergonomics design and analysis as 3D CAD software to perform the RULA ergonomic simulation. Furthermore, sewing workstation comfort depends on aesthetics, maintainability, material quality, ergonomics and safety, structure, ease of manufacture, shape, utility and function, handling, durability, and stability. Moreover, the structure and shape in the design or redesign of a sewing workstation depend on the available anthropometric data of the users. Figure 2 shows the method adopted for the redesign of a sewing workstation using an HDM and CATIA V5 ergonomics design and analysis software.

Anthropometric data

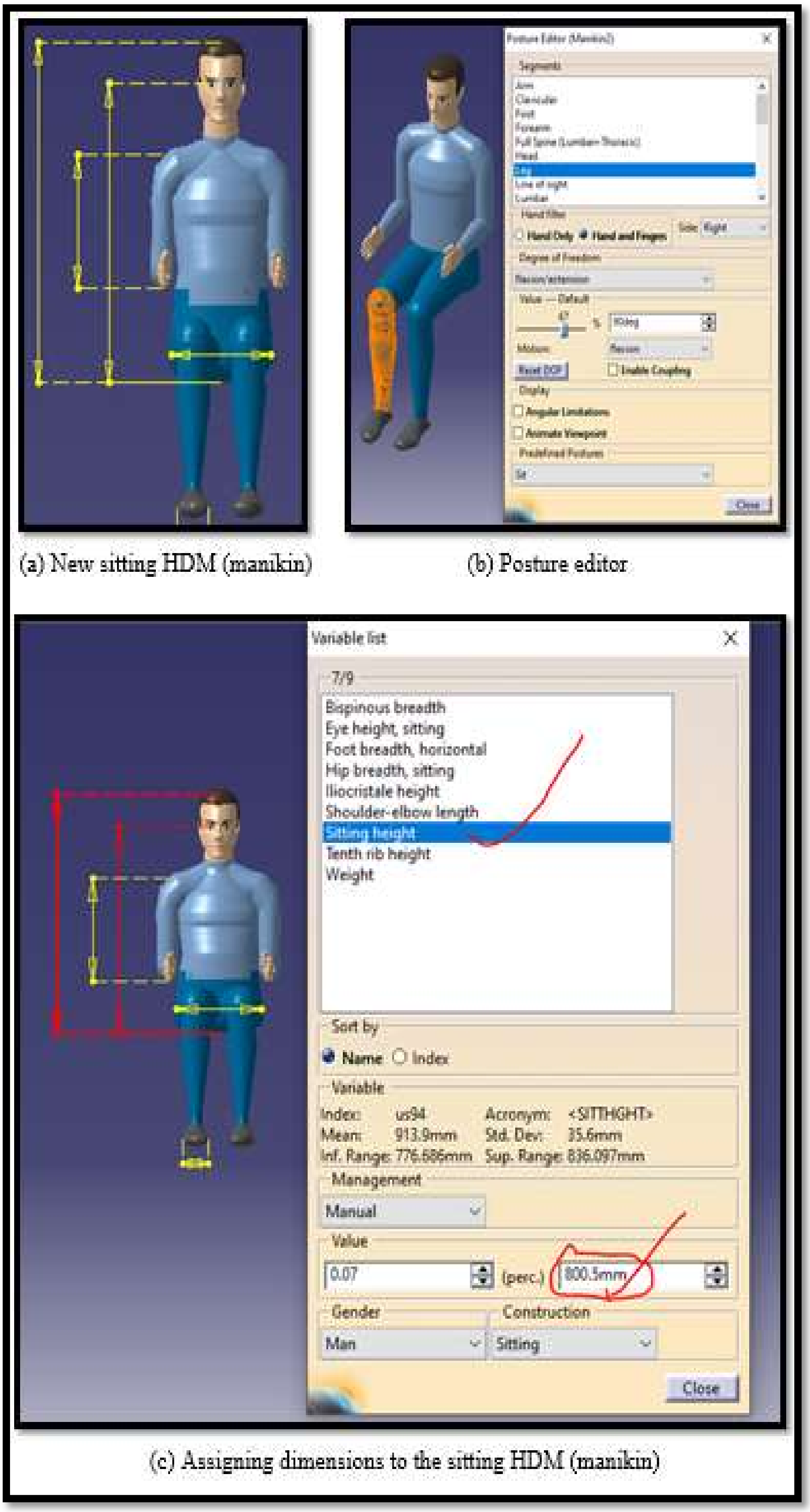
An anthropometric measurement is the collection of physical characteristics of the human body that are relevant to ergonomic design/redesign, physical anthropology, clothing sizing, consumer product design, tool and equipment design, among other fields. These characteristics therefore include size, body shape, strength in static and dynamic conditions, and the ability to perform tasks or work. When anthropometric measurements are considered for the design/redesign of sewing workstation furniture, they help improve comfort, reduce low back pain and MSDs, and increase user performance. In addition, Table 1 lists the essential anthropometric data inputs used in developing the manikin in CATIA V5 ergonomics design and analysis software.

Table 1: 50th percentile of the workers' anthropometric data for manikin

Variables (Sitting)	50th percentile	Units	Input method
Sitting height	800.5	mm	Manual
Eye height, sitting	685.5	mm	Manual
Hip breadth, sitting	355.4	mm	Manual

Manikin

The focus of the manikin is creating an anthropomorphically detailed digital human for advanced ergonomics design/redesign, analysis, and accommodation of the global target audience. For this ergonomics analysis, the manikin was generated to represent the 50th percentile of sewing workers' (male and female) anthropometric data. This research therefore applied a manikin. Furthermore, the specific postural analysis in CATIA V5 ergonomics design and analysis 3D CAD software was based on the RULA ergonomics body posture analysis. Besides, two steps needed to be addressed before the final evaluation could be made: (1) develop a manikin and (2) assess the recommended redesign of the sewing workstation through ergonomic body posture and design analysis.



(a) New sitting HDM (manikin)

(b) Posture editor

(c) Assigning dimensions to the sitting HDM (manikin)

Figure 4: Manikin in the sitting posture using workers' anthropometric data

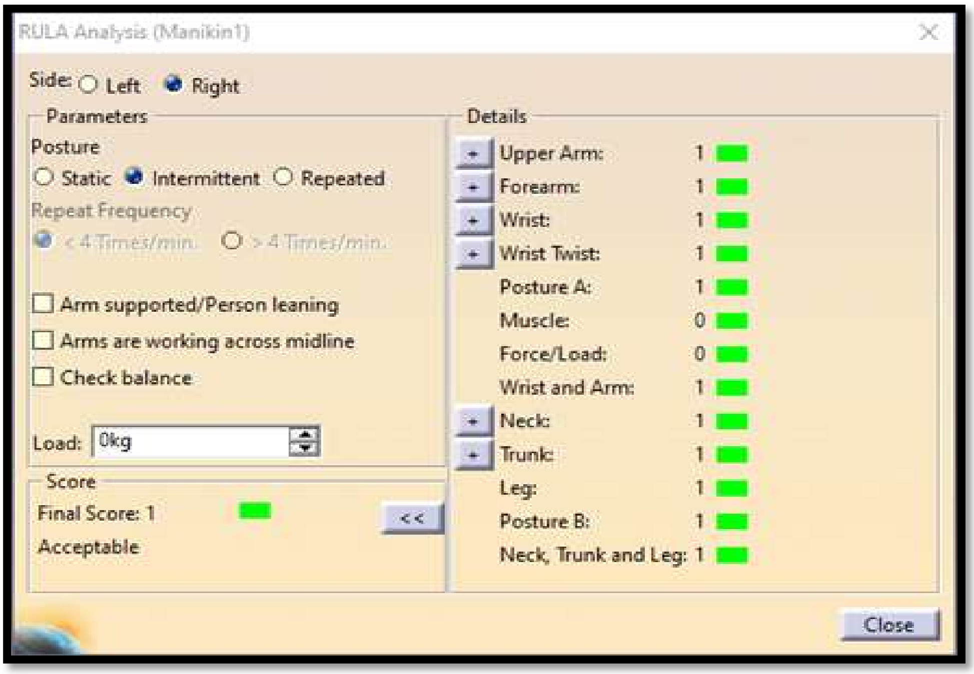


Figure 5: The RULA dialog box in CATIA V5

Table 2: RULA ergonomic and design analysis score description

RULA Score	Risk Level	Action
1 - 2	Negligible	Acceptable
3 - 4	Low	Further investigation and changes may be needed
5 - 6	Medium	Investigation and changes required soon
7	High	Investigation and changes required immediately

Table 3: The evaluation analysis results of the upper limb analysis

Place	Scores and colors		Recommendation
Upper arm	1		Based on the anthropometric data of the sewing workers, the upper limp analysis results for the manikin's sitting body posture fell within the proper range. Consequently, the final RULA score of 1 indicated a very low risk of MSDs. After that, the proposed sewing workstation's proportions were decided upon and the redesign was approved.
Forearm	1		
Wrist	1		
Wrist twist	1		
Posture A	1		
Muscle	0		
Force/load	0		
Wrist and arm	1		
Neck	1		
Trunk	1		
Legs	1		
Posture B	1		
Neck, trunk and leg	1		
Final/total score	1		

Development of a manikin

CATIA V5 was used to design a manikin. As shown in Figure 3, the manikin creation, gender specification, and percentile specification were additional tools in the human builder. Additionally, Figure 4 depicted the manikin in the sitting position, which was created using the anthropometric data of the sewing worker. Furthermore, Figure 4(a) displayed the created manikin, and Figure 4(b) displays a body posture editor. Additionally, Figure 4(c) shows how the manikin's variables were assigned dimensions.

Assessment of the recommended sewing workstation

The assembly of the sewing workstation for making workers at the garment manufacturing facility was developed by integrating the measurements of the manikin and the chosen sewing chair and adjustable sewing machine table.

Perform RULA analysis

The rapid upper limb assessment, or RULA ergonomics and design analysis, examines the ergonomic risk associated with the upper limb extremity. As a result, it is a technique used to examine upper limb disorders in work settings. Additionally, the primary goal of the RULA ergonomic analysis is to investigate the postural load needs for the manikin's body parts. Additionally, it produces a scorecard with numbers ranging from 1 to 7 and a color code from green to red. Thus, the upper limb problem should be examined using this scoring. Furthermore, if the score is 1 or 2, the work body posture is appropriate; if not, more research into the body posture will be necessary. In addition, to perform RULA ergonomic analysis the following section can be discussed:

RULA method and RULA score

Ergonomics and design/redesign analysis are features offered by the CATIA V5 software. Additionally, SolidWorks, an engineering design/modify program, was used to redesign the sewing workstation models. The models were then accessed in CATIA V5 software for the ergonomic study after being converted into a STEP file. Additionally, the sewing worker's anthropometric data was used to digitally build manikins of the 50th percentile of men and women. Therefore, the manikin has been created for the 50th percentile of the anthropometric data of the male and female sewing workers for this ergonomics design and study. As a result, this configuration was selected to redesign or design for average, which is suitable for all sewing workers.

To choose a manikin, the RULA analysis tool is also deployed. Additionally, the RULA dialog box opens when you click on the matching symbol in the toolbar. Furthermore, the CATIA V5 software's RULA dialog box was displayed in Figure 5. The manikin's side was chosen for the analysis and the body posture that was found to be most appropriate. Additionally, there are three different kinds of posture: repetitive, intermittent, and static. Additionally, the activities are repeated fewer than or equal to four times in a minute by the intermittent. Therefore, the body posture performs the work more than four times in a minute for the static and repeating choice. The load of the object that the person is manipulating is specified by filling out the parameters in the same body posture choice. As a result, the intermittent position was chosen for this predetermined study.

Additionally, the score and colors are the foundation of the RULA ergonomic and design analysis technique. Consequently, there is a relationship between the colors and the score. In addition, the hues are orange, red, yellow, and green. Additionally, the color green denotes a healthy and appropriate sitting body posture, whereas the color red denotes a poor sitting body posture that requires quick correction. Additionally, the scores are separated into four (4) scales, each of which has a description. Furthermore, the RULA ergonomic and design analysis score description was shown in Table 2.

Obtaining an Ergonomic Simulation Results

The sewing workstation redesign based on anthropometric data was completed once the RULA ergonomic simulation findings were acquired.

Results and discussions

Introduction

The following specifics were covered in the ergonomic analysis of the manikin's sitting body posture utilizing the RULA ergonomic analytical tool:

The Evaluation Results of the Upper Limb Analysis

A manikin representing the 50th percentile of the male and female sewing workers was used to assess the sewing workstation assembly. Additionally, the RULA ergonomic analytical tool was used when a sewing worker was seated and carrying out a task in the sewing workstation. Furthermore, the RULA analysis approach analyzes using a linked score and color. The hues are also orange, red, yellow, and green. Additionally, the color green denotes healthy and appropriate body posture, but the color red denotes poor body posture that needs to be corrected right away. Additionally, the RULA analysis combines postural analysis of the various muscle groups, which are classified as: muscle group B (which includes the neck, trunk, and leg) and muscle group A (which includes the upper arm, lower arm, and wrist).

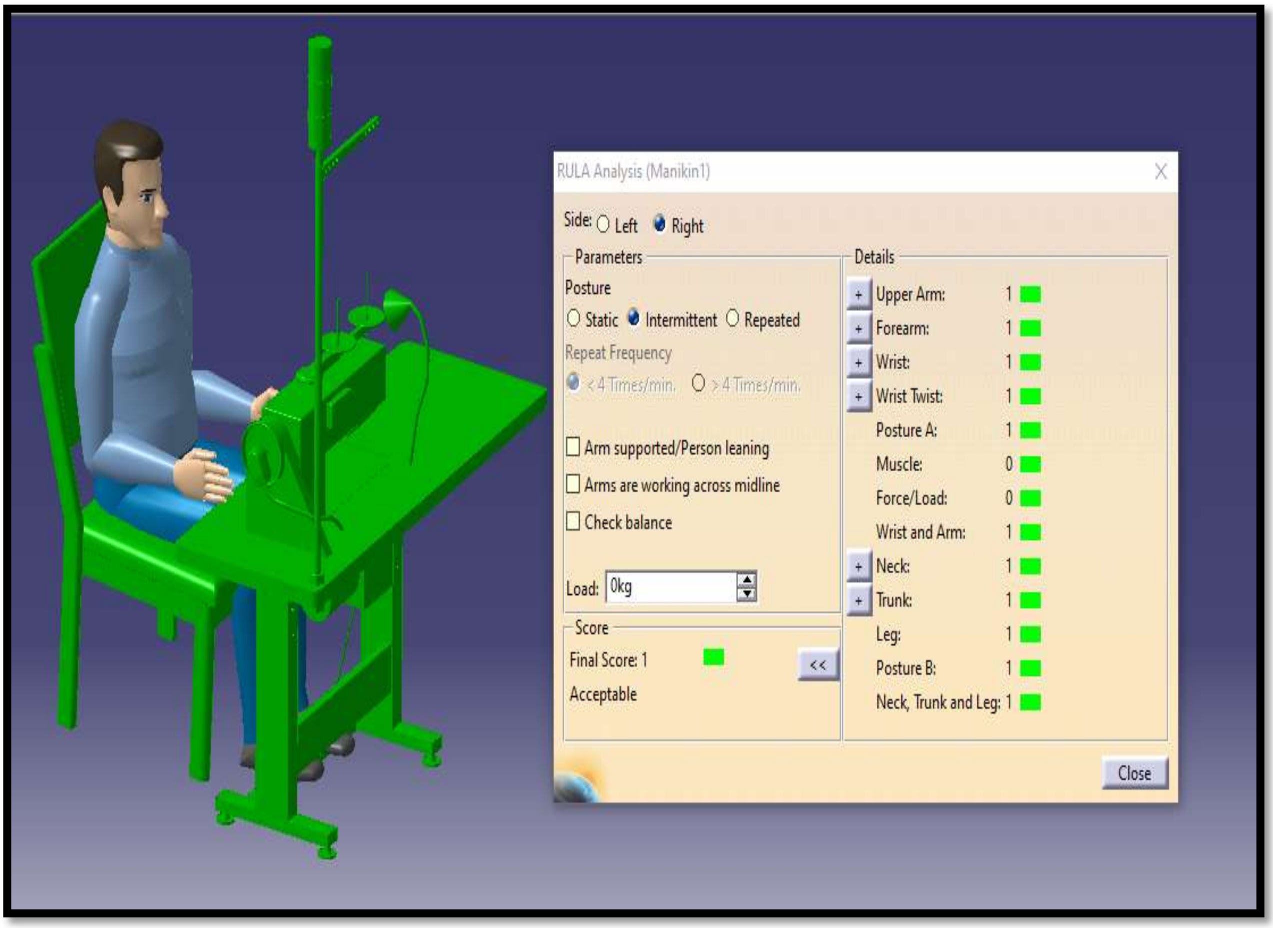


Figure 6: Simulation results of the RULA ergonomic analysis for manikin sitting posture

Additionally, the overall score was determined by combining the two muscle groups. Additionally, the upper limp analysis results for the manikin's sitting body position based on the anthropometric data of the sewing workers fell within the proper range. As a result, the suggested redesign of the sewing workstation is acceptable, as shown in Table 3, and the final/total RULA score of 1 indicated that there was very little ergonomic risk of MSDs.

Simulation results of the RULA ergonomic analysis

By simulating a manikin utilizing an ergonomically creative appropriate sewing workstation redesign based on the anthropometric data of the sewing worker, a final RULA score of 1 was obtained. The ultimate RULA score of the outcomes was displayed in Figure 6.

Comparison of RULA results of this study with the previous studies

Table 4 shows a comparison of the RULA results from this study with those from earlier research on the analysis of manikin sitting position at the sewing workstation. According to previous studies by Upasana & Vinay, (2017) on work body posture of tailors and Öztürk & Esin, (2011) on ergonomic risk factors among female sewing machine operators. As a result, these research discovered a final RULA score of 7, indicating a high degree of risk and the need for quick adjustments.

Also, according to prior researches by Saguyod *et al.,* 2021) on an ergonomic workstation design for clothing manufacturing sewing workers and Shah et al., (2016b) on an inconvenient body position in a garments manufacturing industry. These studies verified the final RULA score of 5, indicating a medium level of risk and the need for immediate adjustments.

Therefore, the current study is consistent with earlier research that indicates a final RULA score of 1 can yield the best outcomes when imitating a manikin sitting posture in the suggested redesign of an ergonomically revolutionary suited sewing workstation for clothing manufacture.

Therefore, the current study supports earlier research by Wibowo & Mawadati, (2021) as stated that the RULA score results are a technique that can offer thorough results when imitating a manikin

sitting posture. Employing ergonomic principles to determine whether or not the redesign of the sewing workstation is appropriate.
According to a previous study by Profile & Profile, (2020), RULA can be applied to workers in a variety of fields, typically in conjunction with other techniques, and its implementation benefits from technological innovation.

Table 4: Comparison of RULA ergonomic analysis results of this present study with the previous studies

Titles of the Studies	Final RULA score	Risk Level	Recommendation	References
Work-Posture-Assessment-of-Tailors-By-RULA-and REBA-Analysis.	7	High	Investigation-and changes-required immediately	(Upasana & Vinay, 2017)
Investigation-of-Musculoskeletal-Symptoms-and Ergonomic-risk-Factors-among-Female-Sewing-Machine Operators-in-Turkey.	7			(Öztürk & Esin, 2011)
Working-Conditions-of-Iranian-Hand-Sewn-shoe-Workers and Associations with Musculoskeletal-Symptoms.	6	Medium	Investigation-and changes-required soon	(Dianat & Salimi, 2014)
Analysis-of-Working-Posture-on-Musculoskeletal Disorders-of-Vocational-Garment-Student's-in-Garment Assembly-Operations-Practice.	5			(Aribowo et al., 2020)
An-Ergonomic-Workstation-Design-for-Apparel Manufacturing-Workers-in-the-Philippines.	5			(Saguyod et al., 2021)
Ergonomic-Risk-Factors-for-Workers-in-Garments Manufacturing: A-Case-Study-from-Pakistan.	5			(Shah et al., 2016a)
Prevalence-of-Musculoskeletal-Problems and-Awkward Posture-in-a-Pakistani-Garments-Manufacturing-Industry.	5			
An-Ergonomic-Analysis-of-the-Seat-Sewing.	4	Low	Further-investigation-and changes-may-be needed	(Rittel, 2010)
Ergonomic-Risk-Simulation-Using-Rapid-Upper-Limb Assessment-Tool-for-the-Sitting-Posture-of-Garments Workers: A-Case-of-Rivatex-East-Africa-Limited, Eldoret,-Kenya	1*	Negligible	Acceptable	Present study

*RULA score of the present study

Conclusion
In conclusion, the goal of this paper was to simulate the human digital modelling sitting posture using CATIA V5 based on the RULA ergonomic tool of garment workers at the REAL factory in Eldoret, Kenya. In order to achieve a better score with an acceptable level of ergonomic risks. And the analysis of the sitting body posture of the manikin for the proposed ergonomically sewing workstation had a final RULA score of 1, meaning that the ergonomic risk for MSDs was negligible. And this result, therefore, shows that the proposed model was acceptable in reducing the ergonomic risk of injury to the low back pain of the sewing workers. The outcomes of this present study, therefore, can play a phenomenal role in the growth of garment manufacturing for enhancing productivity and reducing fatigue of the sewing workers.

Acknowledgment
In particular, the authors would like to thank **RUFORUM** for providing complete support for this work. The assistance is much appreciated and recognized. The authors would like to express their gratitude to the REAL Company, whose dedication to producing high-quality products and a safe setting made the research fun and instructive, as well as to all of the employees who helped with the anthropometric assessment. We also thank Monica

Achieng, our helper, for helping to measure the female research subjects.

References

Ansari, N. A., & Sheikh, D. M. J. (2014). Evaluation of work Posture by RULA and REBA: A Case Study. *IOSR Journal of Mechanical and Civil Engineering*, *11*(4), 18–23. https://doi.org/10.9790/1684-11431823

Aribowo, I., Suhardi, B., & Pujiyanto, E. (2020). Analysis of working posture on musculoskeletal disorders of vocational garment student's in garment assembly operations practice. *AIP Conference Proceedings*, *2217*(April). https://doi.org/10.1063/5.0000602

Chidambaram, V., Gopalsamy, M. M., Vignesh Raja, M., & Kanchan, B. K. (2023). Ergonomic investigations on novel dynamic postural estimator using blaze pose and transfer learning. *Ergonomics*, *0*(0), 1–17. https://doi.org/10.1080/00140139.2023.2221411

Dianat, I., & Salimi, A. (2014). Working conditions of Iranian hand-sewn shoe workers and associations with musculoskeletal symptoms. In *Ergonomics* (Vol. 57, Issue 4, pp. 602–611). Taylor & Francis. https://doi.org/10.1080/00140139.2014.891053

Dockrell, S., Grady, E. O., Bennett, K., Mullarkey, C., Connell, R. M., Ruddy, R., Twomey, S., & Flannery, C. (2012). *An investigation of the reliability of Rapid Upper Limb Assessment (RULA) as a method of assessment of children ' s computing posture*. *43*, 2011–2013. https://doi.org/10.1016/j.apergo.2011.09.009

Esmaeel, A., Starovoytova, D., Nziu, P., & Ochola, J. (2024). *Work-Related Risks and Hazards for Garment Making Workers at Sewing Workstations : A Review* . *14*(1), 48–66. https://doi.org/10.7176/ISDE/14-1-06

Esmaeel, A., Starovoytova, D., & Ochola, J. (2025). *Risk Assessment and Management Decisions Work-Related Musculoskeletal Disorders for Garments- Making Employees at Sewing Workplace*. *2*(2), 87–103.

Eswaramoorthi, M., John, M., Rajagopal, C. A., Prasad, P. S. S., & Mohanram, P. V. (2010). Redesigning assembly stations using ergonomic methods as a lean tool. *Work*, *35*(2), 231–240. https://doi.org/10.3233/WOR-2010-0975

Hambali, R. H., Mohamad, E., & Ito, T. (2021). Ergonomic Design for Assembly Manufacturing Workstation Based on Universal Design Principles. In *Lecture Notes in Networks and Systems* (Vol. 260, Issue July). Springer International Publishing. https://doi.org/10.1007/978-3-030-80829-7_106

Hambali, R. H., Rahim, S. A. A., Azizan, N., Zali, Z., Akmal, S., & Zin, M. H. (2019). Analysis the Awkward Posture Ergonomic Risk and Workstation Improvement Simulation in Mechanical Assembly Manufacturing Industry using DelmiaV5. *IOP Conference Series: Materials Science and Engineering*, *705*(1), 0–6. https://doi.org/10.1088/1757-899X/705/1/012044

Hussain, M. M. (2021). *Digital Human Modeling in Ergonomic Risk Assessment of Working Postures using RULA Digital Human Modeling in Ergonomic Risk Assessment of Working Postures using RULA*. *June*.

Kong, Y., Lee, S., Lee, K., & Kim, D. (2018). *Comparisons of ergonomic evaluation tools (ALLA , RULA , REBA and OWAS) for farm work*. https://doi.org/10.1080/10803548.2017.1306960

Kusuma, T. Y. T. (2020). Analysis of Body Posture using Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) to Improve the Posture of Sand Paper Machine Operators and Reduce the Risk of Low Back Pain. *Biology, Medicine, & Natural Product Chemistry*, *9*(1), 21–25. https://doi.org/10.14421/biomedich.2020.91.21-25

Levanon, Y., Lerman, Y., Gefen, A., & Ratzon, N. Z. (2014). Validity of the modified RULA for computer workers and reliability of one observation compared to six. *Ergonomics*, *57*(12), 1856–1863. https://doi.org/10.1080/00140139.2014.952350

Mahantesh, M. M., Rao, K. V. S. R., Chandra, A. C. P., Vijayakumar, M. N., Nandini, B., Prasad, C. D., & Vasudev, H. (2023). Design and modeling using finite element analysis for the sitting posture of computer users based on ergonomic perspective. *International Journal on Interactive Design and Manufacturing*. https://doi.org/10.1007/s12008-023-01383-9

Mahantesh, M. M., Rao, K. V. S. R., & Mandal, J. (2021). Human digital modeling and RULA analysis for an office chair user in computer work environment - A case study in Indian context. *AIP Conference Proceedings*, *2316*(September). https://doi.org/10.1063/5.0036414

Manzoor Hussain, M., Qutubuddin, S. M., Kumar, K. P. R., & Reddy, C. K. (2019). Digital human modeling in ergonomic risk assessment of working postures using RULA. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *2019*(MAR), 2714–2725.

Massaccesi, M., Pagnotta, A., Soccetti, A., Masali, M., Masiero, C., & Greco, F. (2003). *Investigation of work-related disorders in truck drivers using RULA method*. *34*, 303–307. https://doi.org/10.1016/S0003-6870(03)00052-8

Mcatamney, L., & Corlett, E. N. (1993). *RULA : a survey method for the investigation of work-related upper limb disorders*. *24*(2), 91–99.

Mohamad, D., Md Deros, B., Ismail, A. R., Daruis, D. D. I., & Sukadarin, E. H. (2013). RULA Analysis of Work-Related Disorder among Packaging Industry Worker Using Digital Human Modeling (DHM). *Advanced Engineering Forum*, *10*(December 2014), 9–15. https://doi.org/10.4028/www.scientific.net/aef.10.9

Namwongsa, S., Puntumetakul, R., & Neubert, M. S. (2018). *Ergonomic risk assessment of smartphone users using the Rapid Upper Limb Assessment (RULA) tool*. 1–16.

Nayak, G. K. (2021). *Scholarship at UWindsor The development of fully automated RULA assessment system based on Computer Vision*.

Norhidayah, M. S., Nik Mohamed, N. M. Z., Mansor, M. A., & Ismail, A. R. (2016). RULA: Postural loading assessment tools for Malaysia mining industry. *Journal of Engineering Science and Technology*, *11*(April), 1–8.

Öztürk, N., & Esin, M. N. (2011). Investigation of musculoskeletal symptoms and ergonomic risk factors among female sewing machine operators in Turkey. *International Journal of Industrial Ergonomics*, *41*(6), 585–591. https://doi.org/10.1016/j.ergon.2011.07.001

Paul, B. P., Darius Gnanaraj, S., & Paul, S. (2019). Ergonomic design and RULA analysis of a motorised wheelchair for disabled and elderly. *International Journal of Mechanical Engineering and Technology*, *10*(1), 1014–1025.

Paul, B., & Paul, S. (2019). *ERGONOMIC DESIGN AND RULA ANALYSIS OF A MOTORISED WHEELCHAIR FOR*. *January*.

Profile, S. E. E., & Profile, S. E. E. (2020). *Musculoskeletal Risks : RULA Bibliometric Review Musculoskeletal Risks : RULA Bibliometric Review* (Issue June). https://doi.org/10.3390/ijerph17124354

Rittel, A. (2010). Risk Con:trol The Graduate School University of Wisconsin-Stout April,2010. *How to Overcome Resistance to Behavioral-Based Safety*, 1–45.

Romli, F. I., & Aminian, N. O. (2018). Ergonomic analysis of aircraft passenger seat: A malaysian case study. *International Journal of Pure and Applied Mathematics*, *119*(15 Special Issue B), 3749–3754.

Saguyod, P. J. V., Villapando, A. C., & Gumasing, M. J. J. (2021). An ergonomic workstation design for apparel manufacturing workers in the Philippines. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2497–2504.

Series, C. (2020). *Workload measurement of batik workers at UKM batik jumputan Yogyakarta using RULA and NASA-TLX Workload measurement of batik workers at UKM batik jumputan Yogyakarta using RULA and NASA-TLX*. https://doi.org/10.1088/1742-6596/1456/1/012032

Series, I. O. P. C., & Science, M. (2019). *Work Posture Analysis by Using Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) Methods (Case Study : Rice Milling In Malang - East Java of Indonesia) Work Posture Analysis by Using Rapid Upper Limb Assessment (RULA) and* . https://doi.org/10.1088/1757-899X/469/1/012012

Shah, Z. A., Amjad, A., Ashraf, M., Mushtaq, F., & Sheikh, I. A. (2016a). Ergonomic risk factors for workers in garments manufacturing - A case study from pakistan. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *8–10 March*, 2580–2584.

Shah, Z. A., Amjad, A., Ashraf, M., Mushtaq, F., & Sheikh, I. A. (2016b). Prevalence of musculoskeletal problems and awkward posture in a Pakistani garments manufacturing industry. *Malaysian Journal of Public Health Medicine*, *1*(Specialissue1), 75–79.

Sharan, D., & Ajeesh, P. S. (2012). Correlation of ergonomic risk factors with RULA in IT professionals from India. *Work*, *41*(SUPPL.1), 512–515. https://doi.org/10.3233/WOR-2012-0205-512

Sohail, A. (2021). *Ergonomic Risk Assessment and Postural Analysis of Workers in Small Garment Industries by RULA using Digital Human Modeling*. 253–264.

Upasana, & Vinay, D. (2017). Work Posture Assessment of Tailors By RULA and REBA Analysis. *International Journal of Science, Environment and Technology*, *6*(4), 2469–2474. http://www.ijset.net/journal/1849.pdf

Wibowo, A. H., & Mawadati, A. (2021). The analysis of employees' work posture by using Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA). *IOP Conference Series: Earth and Environmental Science*, *704*(1). https://doi.org/10.1088/1755-1315/704/1/012022

Yadi, Y. H., Kurniawidjaja, L. M., & Susilowati, I. H. (2019). *Ergonomics Intervention Study of the RULA / REBA Method in Chemical Industries for MSDs ' Risk Assessment*. *June 2018*. https://doi.org/10.18502/kls.v4i5.2551

Yazdanirad, S., Habibi, E., Zare, A., & Dehghani, F. (2018). *Comparing the Effectiveness of Three Ergonomic Risk Assessment Methods — RULA , LUBA , and NERPA — to Predict the Upper Extremity Musculoskeletal Disorders*. *September*. https://doi.org/10.4103/ijoem.IJOEM

Ye, Z., Li, X., & Li, Y. (2013). The Virtual Prototyping Design and Evaluation of Ergonomic Gymnastic Based on CATIA. *International Journal of Hybrid Information Technology*, *6*(5), 67–78. https://doi.org/10.14257/ijhit.2013.6.5.07