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Ergonomic redesign of transportation fleet driver seats using anthropometric approaches to minimize musculoskeletal disorders

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Abstract

The operation of public transportation fleets demands competent drivers to ensure passenger safety and operational reliability. Maintaining an optimal driving posture is a critical factor in supporting driver performance; however, mismatches between seat design and driver anthropometry can result in musculoskeletal disorders (MSDs), reducing driver focus and increasing the risk of traffic accidents. This study aims to determine the ergonomic dimensions of driver seats based on anthropometric data. The methodology integrates anthropometric measurements, percentile analysis, statistical validation, and ergonomic modeling utilizing CATIA software. Key anthropometric dimensions considered include sitting upright height (TDT), chin-to-top-of-head distance (DPK), shoulder width (LB), popliteal-buttock length (PPO), popliteal height (TPO), thigh thickness (TP), and hip width (LP). Data uniformity and adequacy tests confirmed the reliability of the dataset, while normality tests verified that the measurements were normally distributed. Subsequent analysis applied the 50th and 95th percentile values to guide design decisions, ensuring broad user accommodation. Ergonomic modeling was conducted using CATIA software to develop an optimized driver's seat. The resulting design specifications include a seat base height of 92.63 cm, headrest height of 21.7 cm, seat width of 62 cm, seat base length of 46.90 cm, seat height from the floor of 44.00 cm, seat base thickness of 15.07 cm, and seat base width of 38.33 cm. These dimensions are intended to support optimal driver posture, reduce the incidence of MSDs, and enhance overall driving safety and comfort in public transportation fleets.

Keywords:
Anthropometrics, ergonomics, design, percentiles, drivers.

1 Introduction

Public transportation necessitates a skilled driver to ensure the safety and security of passengers. It plays a vital role in facilitating daily activities by transporting goods and individuals from their point of origin to their final destination [1]. Important factors and habits that support effective work activities as a driver include maintaining an ergonomic driving position. An ergonomic posture is essential for everyone in performing daily activities to prevent issues associated with poor posture. The goal of ergonomics is to create a comfortable working environment [2] and following the workers' abilities to meet optimal production targets and high work productivity [3]. The driving position has a big influence in determining the occupational health of bus drivers [4].

Paying attention to ergonomic factors, particularly maintaining an appropriate driving posture, is crucial for drivers as it can significantly reduce discomfort and pain [5], reduce muscle fatigue, and prevent traffic accidents. Driver fatigue is a critical factor to monitor, as it can lead to traffic accidents. Fatigue is a natural physiological response indicating that the body requires rest to replenish the stamina expended during work [6]. Complaints of Musculoskeletal Disorders (MSDs) are one of the factors that can affect a person's ability to drive [7] Complaints of Musculoskeletal Disorders (MSDs) are one of the factors that can affect a person's ability to drive [8], work duration, and frequency of repetitive movements [9]. Complaints in the form of damage to joints, ligaments, and tendons will occur if the muscles receive static loads repeatedly and for a long time, usually termed MSDs or injuries to the *musculoskeletal* system [10].

Musculoskeletal Disorders (MSDs) can adversely affect workers. When workers' health is compromised, their productivity declines, hindering their ability to meet personal and professional obligations [11]. A driver who neglects ergonomic considerations during driving activities, such as maintaining a monotonous posture for extended periods, can inadvertently strain muscles without allowing for adequate relaxation. This lack of attention can lead to rapid fatigue. To enhance comfort, it is essential to design an ergonomic driver's seat that considers human anthropometry and includes appropriate supportive features. The design of the driver's seat must prioritize ergonomic principles and accommodate the user's body dimensions to ensure comfort and reduce the risk of accidents during long-distance travel [12]. The results of observations show that worker activities have high complaints and risks so that they can cause diseases and complaints due to work, if left continuously it can potentially cause musculoskeletal disorders (MSDs), so the focus of research needs to be done to improve redesign with an anthropometric approach to minimize musculoskeletal disorders (MSDs) in drivers.

There has been no research related to high-speed transportation, research has been conducted on large buses using the reverse engineering method [13].

2 Method

The research employs a quantitative approach, focusing on all Hiace transportation drivers. The sample consists of 44 drivers from Hiace transportation fleets. The study examines human body dimensions and percentiles as independent variables, with the redesign of the Hiace driver's seat as the dependent variable. The anthropometric method is applied to analyze the body dimensions of drivers at the Type A terminal in Langsa City, aiming to identify which body characteristics influence the design of the driver's seat. Anthropometry refers to the measurement of body dimensions and other physical characteristics relevant to design. By understanding the body dimensions of workers, work equipment, workstations, and products can be tailored to ensure comfort, health, and safety in the workplace. [14]. The activity of measuring the dimensions of the human body is an important part of anthropometry because it will be the basic information for preparing the design of various equipment, machines, processes, and workplaces [15].

The anthropometric method uses several steps, namely measurement of body dimensions using human body dimensions using an anthropometric chair or manually. The instrument in the study was the Martin anthropometer for flexible reasons [16]. Statistical Testing, in processing anthropometric data, the minimum and maximum values must be determined first, and then data testing is carried out such as data uniformity testing, data adequacy testing, and data normality testing [17]. Determination of percentiles, most anthropometric data are expressed in percentile form. Percentiles are values that state a certain percentage of the value. After obtaining anthropometric data from worker measurements, the next step is to determine the percentile value [18]. Simulation with Catia software, the results of this design will be simulated with Catia, the aim is to provide a visual description so that the company can see the value of its ergonomic analysis more clearly with the RULA work pattern.

3 Result and discussion

Seven dimensions were used in designing the driver's seat for the Hiace transportation fleet, as shown in Table 1. Of the seven dimensions above, the upright sitting height dimension is the driver's body dimension used to determine the height of the driver's seat.

Table 1. Driver Body Dimensions

Body Dimension	Utility
Sitting Height Upright	Determining the height of the driver's seat
Chin To Top Of Head	Determine the driver's headrest from the back of the head to the top of the head.
Shoulder Width	Determining the width of the driver's seat
Popliteal Height	Determining the height of the driver's seat from the floor
Popliteal Buttocks	Determining the length of the driver's seat
Thick Thighs	Determine the thickness of the driver's seat
Hip Width	Determining the width of the seat

3.1 Data reliability test

The seven dimensions tested for data diversity for the upright sitting height dimension were declared uniform, as shown in Fig. 1. Fig. 1 illustrates that the data reliability test for the height of individuals sitting upright indicates all data points are deemed reliable, as they fall between the Upper Control Limit (UCL) and the Lower Control Limit (LCL). The data reliability test for the measurement from the chin to the top of the head is presented in Fig. 2.

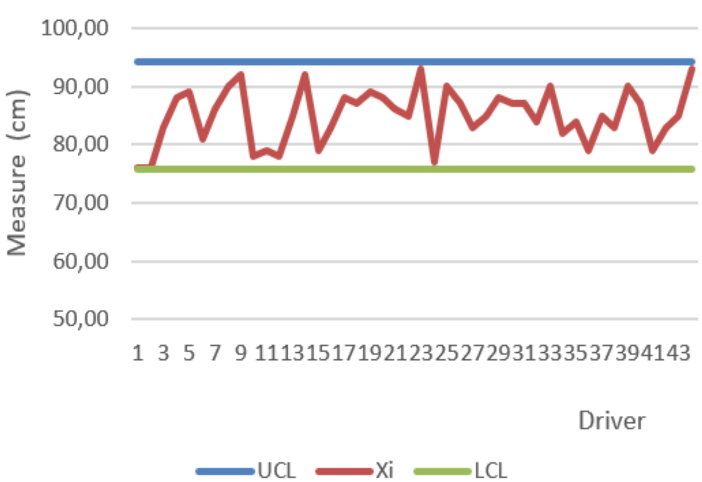

Fig. 1. Sitting height upright dimension

Fig. 2 presents the data reliability test for the measurement from the chin to the top of the head, which falls within the control limits, specifically between the Upper Control Limit (UCL) and lower control limit (LCL), indicating that the data is reliable. Additionally, the reliability test for shoulder width dimensions is illustrated in Fig. 3.

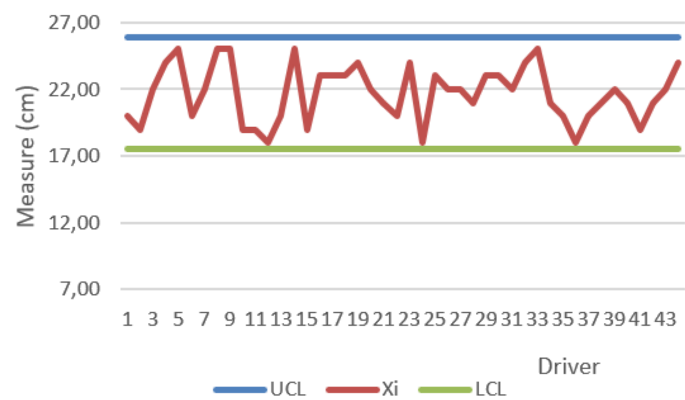

Fig. 2. Chin To Top Of Head Dimension

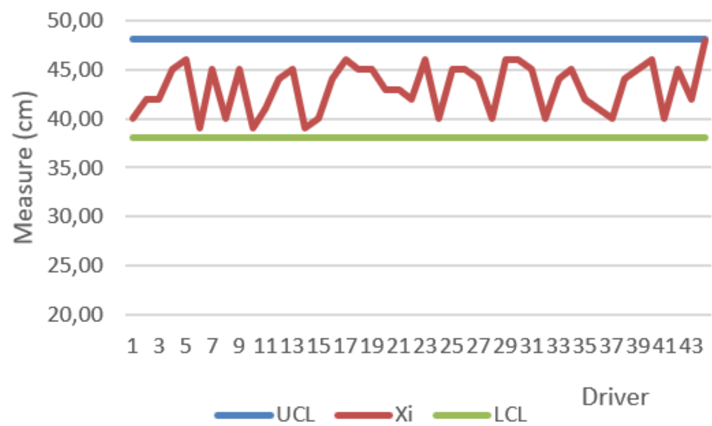

Fig. 3. Shoulder width dimension

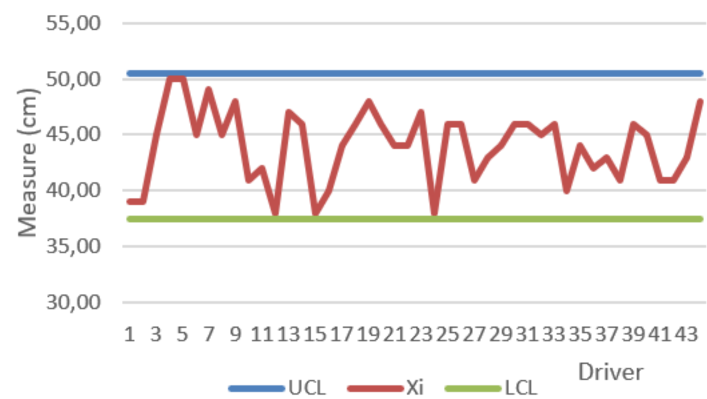

Fig. 4. Popliteal Height Dimension

Fig. 3 illustrates the reliability test for shoulder width dimension data, which is deemed reliable as all values fall between the upper control limit (UCL) and the lower control limit (LCL). The reliability test for polyplicate height dimensions is presented in Fig. 4.

Fig. 4 shows that the popliteal height dimension data reliability test is stated as reliable, because all data are also within the control limits of UCL and LCL. The popliteal buttocks dimension data reliability test is shown in Fig. 5.

Fig. 5 indicates that the popliteal buttock dimension falls within the upper control limit (UCL) and lower control limit (LCL), confirming the reliability of all data. Fig. 6 presents the results of the data reliability test for the thigh thickness dimension. The thickness dimension data reliability test is shown in Fig. 6.

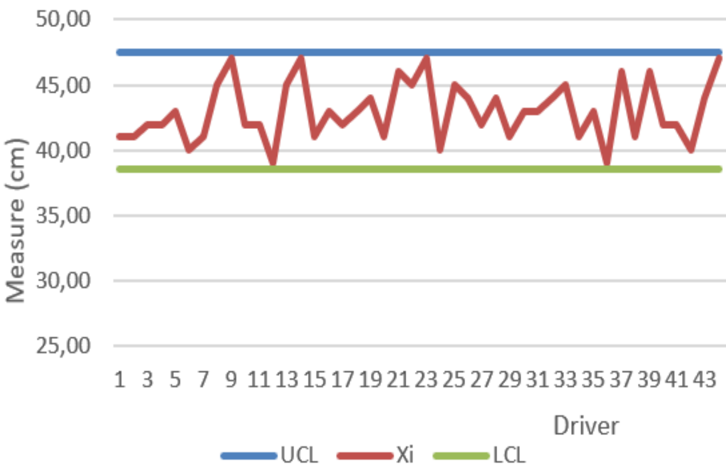

Fig. 5. Polytelal Butt Dimensions

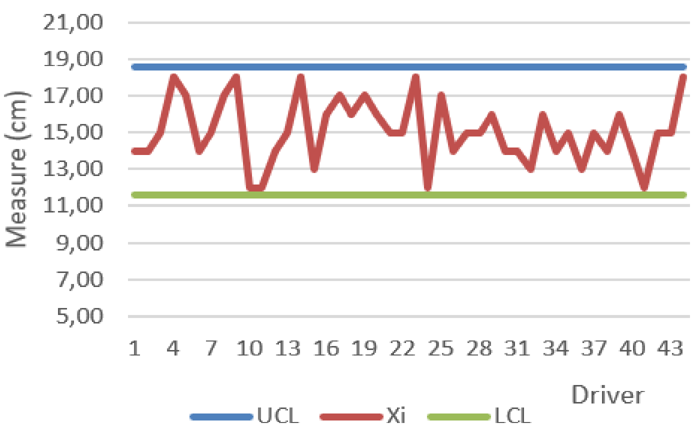

Fig. 6. Thickness Dimension

Fig. 6 shows that in the reliability test, the thigh thickness dimension data is stated to be reliable, because all data are within the UCL and LCL control limits. The data reliability test for the hip width dimension is in Fig. 7. Fig. 7 indicates that the hip width dimension data in the reliability test is deemed reliable, as all data points fall within the upper control limit (UCL) and lower control limit (LCL). The results of the data reliability test demonstrate that all data from the seven dimensions are considered reliable, as they all lie within the UCL and LCL control limits.

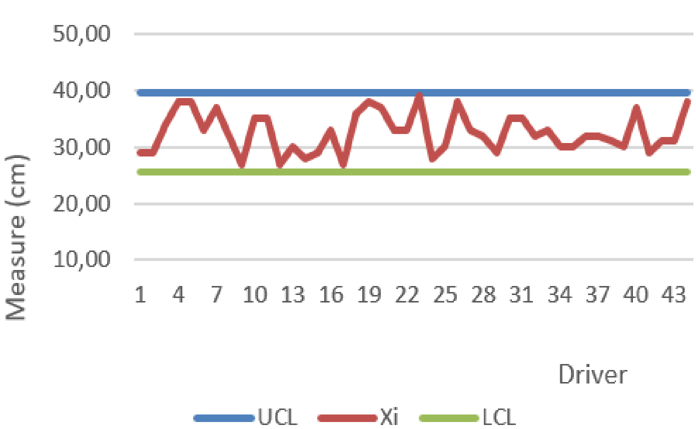

Fig. 7. Popliteal Height Dimension

The dimensions used are in accordance with the dimensions of the research [19]. The dimensions used are following the dimensions of the research [19], that all data in the data reliability test must be stated as reliable, if not reliable, the non-reliable data must be removed.

3.2 Validity Test

After conducting the data reliability test, a data validity test is performed to determine whether the amount of data used in the measurement is representative of the observed population. In the data validity test, a confidence level of 95% and an accuracy level of 5% are applied, as illustrated in Table 3.

Table 3. Data Validity Test Recapitulation

Body Dimensions	N	Z	A	N′	Information
Sitting Height Upright	44	2	0,05	6,41	Valid
Chin To Top Of Head	44	2	0,05	15,2	Valid
Shoulder Width	44	2	0,05	5,33	Valid
Popliteal Height	44	2	0,05	9,32	Valid
Popliteal Buttocks	44	2	0,05	12,9	Valid
Thick Thighs	44	2	0,05	33,0	Valid
Hip Width	44	2	0,05	18,0	Valid

Table 3 shows that the recapitulation of the results of the data validity test has a value of N'<N, so the data is declared valid, meaning that the theoretical amount of data is smaller than the actual amount of observation data [20].

3.3 Normality Test

After conducting the normality test to determine whether the obtained data is normally distributed, the following criteria were applied: H_0 = Data is normally distributed if the significance level exceeds $\alpha = 0.05$; H_1 = Data is not normally distributed if the significance value is less than $\alpha = 0.05$. Following the hypothesis formulation in this study, the researcher calculated the significance value using SPSS 26 software, encompassing all residualized body dimensions, as presented in Table 4.

Table 4. Normality Test Recapitulation

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		44
Normal Parameters	Mean	,0000000
	Std. Deviation	1,40467366
Most Extreme Differences	Absolute	,101
	Positive	,079
	Negative	-,101
Test Statistic		,101
Asymp. Sig. (2-tailed)		,200[c]

Table 4 shows that the results of the normality test show that the significance value of all dimensions is > 0.05, so it can be concluded that it is normally distributed. According to [21]Every data obtained is smaller than 0.05, which states that the data is normally distributed

3.4 Percentile

The purpose of calculating percentiles is to find out the user population of a product, as presented in Table 5. Table 5 shows that the 5th, 50th, and 95th percentile values are used for the driver's seat redesign. Based on the percentile calculation results, the driver's seat is adjusted to the dimensions of the seat to be redesigned. The colored columns are the dimensions to be used in the driver's seat redesign.

Table 5. Percentile Recapitulation

Body Dimensions	P_5(cm)	P_{50}(cm)	P_{95}(cm)
Sitting Height Upright	77,32	84,98	92,63
Chin To Top Of Head	18,18	21,7	25,2
Shoulder Width	38,99	48,18	47,28
Popliteal Height	38,68	44,00	49,32
Popliteal Buttocks	12,22	15,07	17,92
Thick Thighs	39,10	43,00	46,90
Hip Width	26,81	32,57	38,33

1. Driver's Seat Design Before Redesign

Fig. 8 shows the design of the driver's seat that causes MSDs complaints, so if it is still used, it can cause traffic accidents. The initial seat size is a seat height of 80 cm, a headrest height of 15 cm, a driver's seat width of 43 cm, a driver's seat length of 41 cm, and a driver's seat height from the floor of 37 cm

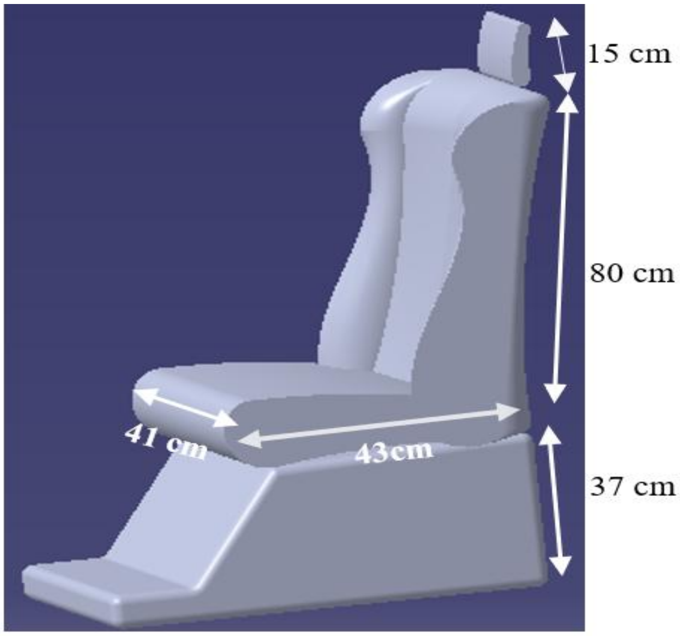

Fig. 8. Driver's Seat Design Before Redesign

2. Driver seat redesign

Fig. 9 shows the proposed design of a driver's seat to reduce MSDs complaints such as pain, muscle fatigue, back and knee injuries.

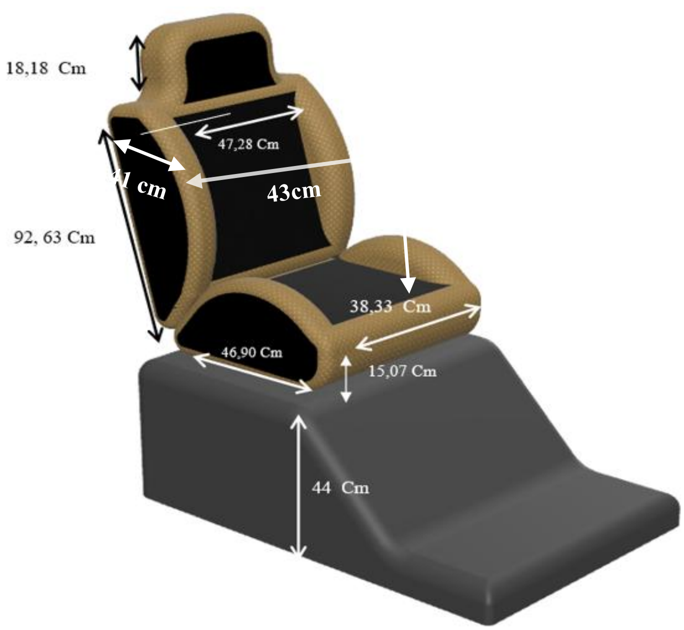

Fig. 9. Driver's Seat Redesign

3.5 Simulation Results Using Catia V5 Software

The design and redesign of the driver's seat was simulated using Catia V5 software to analyze MSDs complaints. The results of the driver's seat design simulation are shown in Fig. 10.

Fig. 10. shows the simulation results using Catia V5 software stating that the design of the driver's seat on the hiace transportation that has been proven by the RULA assessment obtained a score of 4, meaning that the operator's working posture is in the unsafe category or in other words cannot reduce the risk of musculoskeletal disorders (MSDs), meaning that the old driver's seat design does not match the size of the driver, so it is necessary to improve the design of the driver's seat. Improvements to the driver's seat design to reduce MSDs complaints are re-simulated, Fig. 11.

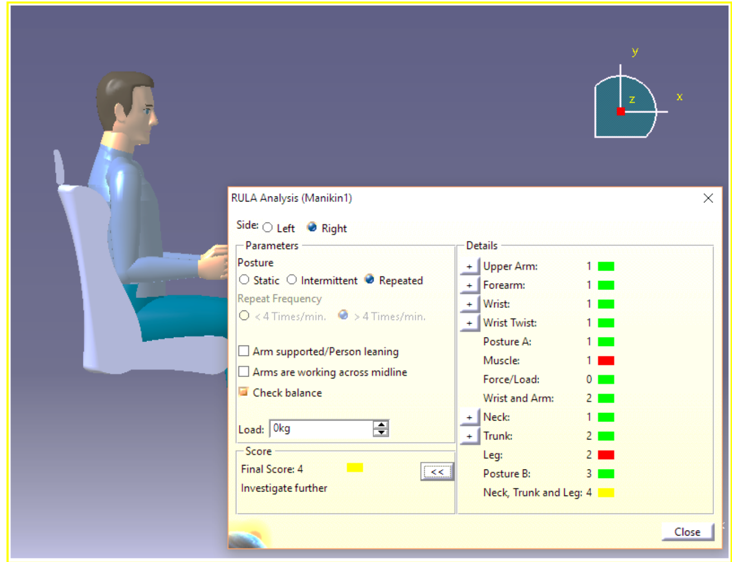

Fig. 10. Driver Seat Design Simulation Results

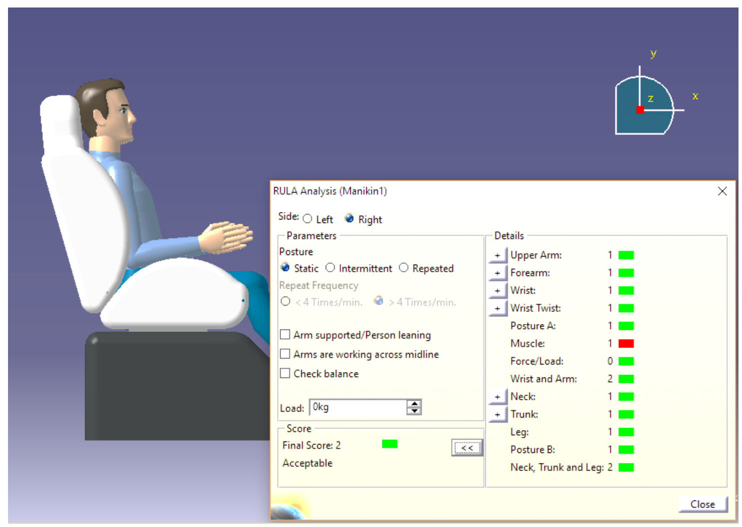

Fig. 11. Redesign simulation results

Fig. 11. shows the simulation results using Catia V5 software, stating that the proposed improvements that have been proven by RULA assessment obtained a score of 2, meaning that the operator's work posture can be accepted in the safe category and can reduce the risk of musculoskeletal disorders (MSDs). Musculoskeletal disorders (MSDs) occur when the driver's work posture is not normal [22].

4 Conclusion

This study concludes that the ergonomic redesign of driver seats in transportation fleets, based on detailed anthropometric analysis, is vital for minimizing the risk of musculoskeletal disorders among drivers. The optimized design recommends a seat base height of 92.63 cm, a headrest height of 21.7 cm, a seat width of 47.28 cm, a seat base length of 46.90 cm, a seat height from the floor of 44.00 cm, a seat base thickness of 15.07 cm, and a seat base width of 38.33 cm. The use of both the 50th and 95th percentile anthropometric measurements ensures that the seat accommodates a wide range of driver body types, enhancing comfort and reducing fatigue over extended periods of operation. Moreover, by employing CATIA software for ergonomic simulation and design validation, the study ensures that the resulting seat configuration aligns with biomechanical and ergonomic principles critical to reducing physical strain.

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