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Ergonomic Analysis of Operator Consoles on Air Support Aircraft

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ABSTRACT

The Digital Human Modelling (DHM) method, in which the anthropometric characteristics of humans are represented using a computer-aided three-dimensional model, is used in many different ergonomic optimisation applications, especially in areas such as manufacturing, machine utilization, assembly simulation, cabin design, human-robot communication. This method aims to identify and reduce potential ergonomic risks in posture and work positions during the design phase by simulating human-machine interactions in digital environments. Thus, possible injuries and injuries can be prevented. Especially in critical aviation applications where operator safety is vital, functionality and ergometry analyzes are important in cockpit and console designs. In this study, ergonomic analyzes of the operator consoles in an air support aircraft were carried out according to the Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) methods, according to two different postures, using the Human Builder and Human Activity Analysis modules in the CATIA V5 sofware. In Position-1, the operator's situation of directly looking at the screen and reaching for the screen buttons is considered, while in Position-2, the operator's situation of reaching for the tablet located on the side and looking at the screen below has been evaluated from an ergonomic perspective. Additionally, angle of view analyses have been performed for these two postural positions.

Hava Destek Uçağındaki Operatör Konsollarının Ergonomik Analizi

MAKALE BİLGİSİ

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Dijital insan modelleme
Havacılık sektörü

ÖZET

İnsanlara ait antropometrik özelliklerinin bilgisayar destekli üç boyutlu model kullanılarak temsil edildiği Dijital İnsan Modelleme (DHM) yöntemi, başta üretim, makine kullanımı, montaj simülasyonu, kabin tasarımı, insan-robot iletişimi gibi alanlar olmak üzere bir çok farklı ergonomik optimizasyon uygulamalarında kullanılmaktadır. Bu yöntem, dijital ortamlarda insan-makine etkileşimlerini simüle ederek, tasarım aşamasında duruş ve çalışma pozisyonlarındaki potansiyel ergonomik riskleri belirlemeyi ve azaltmayı amaçlamaktadır. Böylece, olası yaralanma ve sakatlanmaların önüne geçilebilmektedir. Özellikle operatör güvenliğinin önemli olduğu kritik havacılık uygulamalarında, kokpit ve konsol tasarımlarında işlevsellik ve ergometri analizleri önem taşımaktadır. Bu çalışmada, CATIA V5 uygulaması içerisindeki Human Builder ve Human Activity Analysis modülleri kullanılarak bir hava destek uçağının içerisindeki operatör konsollarının iki farklı duruşa göre Rapid Entire Body Assessment (REBA) ve Rapid Upper Limb Assessment (RULA) yöntemlerine göre ergonomik analizleri gerçekleştirilmiştir. Pozisyon-1'de operatörün ekrana düz bakma ve ekran düğmelerine ulaşma durumu ele alınırken, Pozisyon-2'de operatörün yanda bulunan tablete uzanma ve aşağıda bulunan ekrana bakma durumu ergonomik açıdan değerlendirilmiştir. Ayrıca, bu iki duruş pozisyonuna yönelik görüş açısı analizleri de gerçekleştirilmiştir.

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1. INTRODUCTION (GİRİŞ)

The evolution of technology and increased industrialization have paved the way for the creation of cutting-edge machines. In recent times, there's been a noticeable shift towards autonomous machines that demand less human interaction, which aids in reducing errors caused by human factors. However, in instances where human-machine interactions persist, the ergonomic aspect of design takes on a significant role. Ergonomic analysis is utilized during the design process to ensure that machines are compatible and comfortable for human use. The focus of these ergonomic assessments is to tailor the design of workplaces, products, and systems to fit the physical dimensions and capabilities of the users. For an ergonomic workplace, it is essential to develop designs that are compatible with the physical characteristics and capacities of users [1, 2].

Ergonomics is the scientific field that investigates the anatomical, physiological, and psychological interactions between the user and the environment [3, 4]. It considers physical, cognitive, social, organizational, and environmental factors in workplace design with a human-centered approach [5, 6]. In the early years of the 20th century, there was a significant leap in technological innovations, particularly in the realm of military equipment and machinery. Concomitant with the complexity of these tools, ensuring humans could utilize these technological assets efficiently, safely, and effectively became increasingly paramount. The era marked by the world wars catalyzed the acceleration of these technological advancements. In the post-Second World War period and the subsequent years characterized by the proliferation of assembly lines, it was observed that continuous repetitive motions could lead to persistent injuries in individuals. Furthermore, it became evident that the design of military aircraft and other equipment was directly correlated with user comfort and functionality. These discoveries paved the way for the evolution of ergonomics into the comprehensive discipline we recognize today. A pivotal moment in this evolutionary trajectory was marked by the establishment of the Human Factors and Ergonomics Society in the United States in 1957.

The aim of ergonomics is to minimize risk factors and the likelihood of injury in workspaces. With ergonomic studies, human access to and compatibility with machines, as well as productivity in working together, are enhanced. Ergonomics is based on research in more established scientific fields such as engineering, physiology and psychology. In the process of conducting ergonomic studies, disciplines and techniques such as anthropometry, biomechanical action analyses, environmental physics, applied psychology, and social psychology are utilized. Potential physical and psychological problems in users can be prevented at early stages with ergonomic analyses applied prior to production [7-10].

The Digital Human Modeling (DHM) approach allows for the early identification of potential problems by considering ergonomic risk factors in the design process [11]. Therefore, by previewing the interaction between the machine and the human in the digital environment with simulations, potential injuries and disabilities can be prevented. DHM not only ensures compliance with health and safety standards but also accelerates the product's time to market. As a result, work efficiency is increased and production costs are reduced [12]. Due to these advantages, the use of the DHM approach has become widespread in various sectors such as aviation and space, military, energy/power, industrial facilities, automotive, and shipbuilding industry.

Several different DHM tools such as Jack®, Ramsis®, Santos, and Delmia® have been developed. These tools allow for the simulation of digital human models in virtual environments and the analysis of ergonomic performances [11]. Ramsis® and Jack® tools are used more for aviation and automotive applications due to their success in ergonomic analyses related to force, accessibility, and comfort [13, 14]. Delmia®, on the other hand, constructs multiple human modeling systems for research related to human-centered design problems [12]. In addition to these tools, there are DHM applications that work integrated with CAD software such as CATIA.

In the aviation sector, where ergonomic analyses are frequently used, anthropometric data plays a significant role in the design of cockpits and operator consoles. These data vary according to the race of the relevant user. Designers strive to achieve an optimum design by using the anthropometric data of the country where the designs will be used. The MIL-STD-1472 Human

Engineering American military standard [15] has been published to ensure that everything involving the human factor in military designs can be designed to a certain standard. This standard includes various design criteria such as equipment design dimensions, control unit dimensions, viewing angles, etc. Standard measurements are established for devices and control units that need human interaction. This facilitates the commencement of the design process with the most appropriate dimensions prior to conducting ergonomic assessments.

In this study, ergonomic analyzes were carried out on the operator consoles of the air support aircraft by using the Human Builder and Human Activity Analysis modules in the CATIA V5 software. Analyzes were performed according to two different posture positions using Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) methods. Additionally, the results obtained from viewpoint analyses for these two posture positions were discussed.

2. MATERIAL AND METHOD (MATERYAL VE YÖNTEM)

Ergonomics is a field of science focused on analyzing ergonomic risk factors resulting from human-machine interactions, aided by anthropometric data. With the continuous advancement of technology, ergonomic considerations in workplace design and product development are now carried out using computer-aided applications, employing digital human models for simulation in a virtual environment [11]. These digital human models should be based on anthropometric data specific to different countries, allowing for evaluations based on the average body measurements of end-users to achieve the most suitable and user-friendly designs.

One of the sectors where ergonomic analyses are most prevalent is the aviation industry, particularly within air support aircraft, which often feature numerous operator consoles. Due to the spatial constraints of the aircraft's interior, these consoles are designed with minimum dimensions. However, this approach may pose ergonomic challenges, potentially impacting operator efficiency and comfort. In this study, the consoles were meticulously crafted using standard basic console dimensions as outlined in Figure 1, aiming to minimize the need for trial and error in the design process.

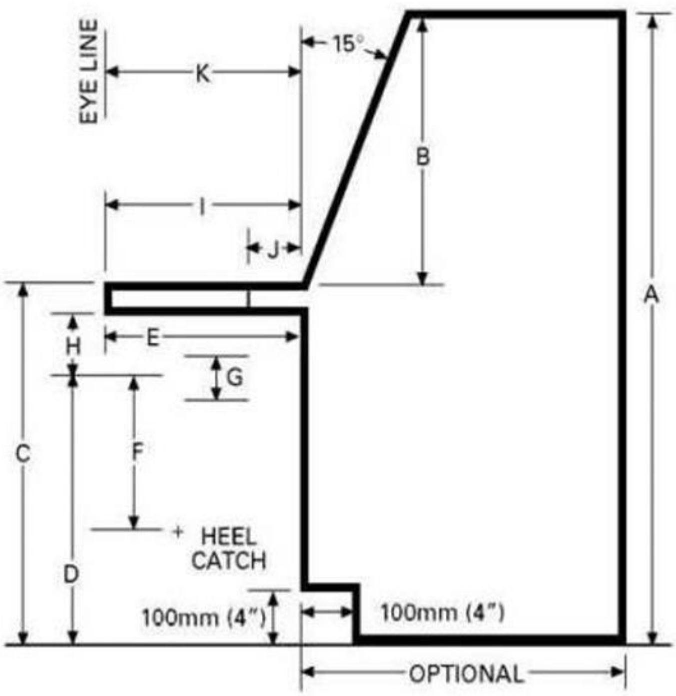


Figure 1. Basic console dimensions in MIL-STD-1472 standards (MIL-STD-1472 standartlarındaki temel konsol boyutları) [15]

Various analysis methods such as Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), Ovako Working Analysis System (OWAS), National Institute for Occupational Safety and Health (NIOSH) Lifting Equation, and Lumbar Motion Monitor (LMM) are utilized for ergonomic risk assessments [16-18]. These analyses involve examining the interaction between a digital human model, based on anthropometric data, and the machinery. In the scope of this study, REBA and RULA analyses were employed to identify ergonomic risks associated with two different posture positions of operator consoles within an air support aircraft.

The REBA (Rapid Entire Body Assessment) ergonomic analysis method is a tool that allows the identification of potential risks that may arise from postural behaviors during work. The REBA method focuses on discomforts that may occur in the human musculoskeletal system, developing a scoring system for muscle activity caused by various postures - static, dynamic, rapidly changing, or unbalanced, based on the aircrafts of movement [19]. The REBA ergonomic analysis method can be conducted easily without the need for expensive equipment or advanced ergonomic knowledge. Using standard charts (Figure 2) utilized in the REBA analysis, posture measurements are identified and scored accordingly. To determine the REBA score, the body is considered in two groups: Group A (neck, trunk, and legs) and Group B (upper arm, lower arm, and wrists) (Figure 2).

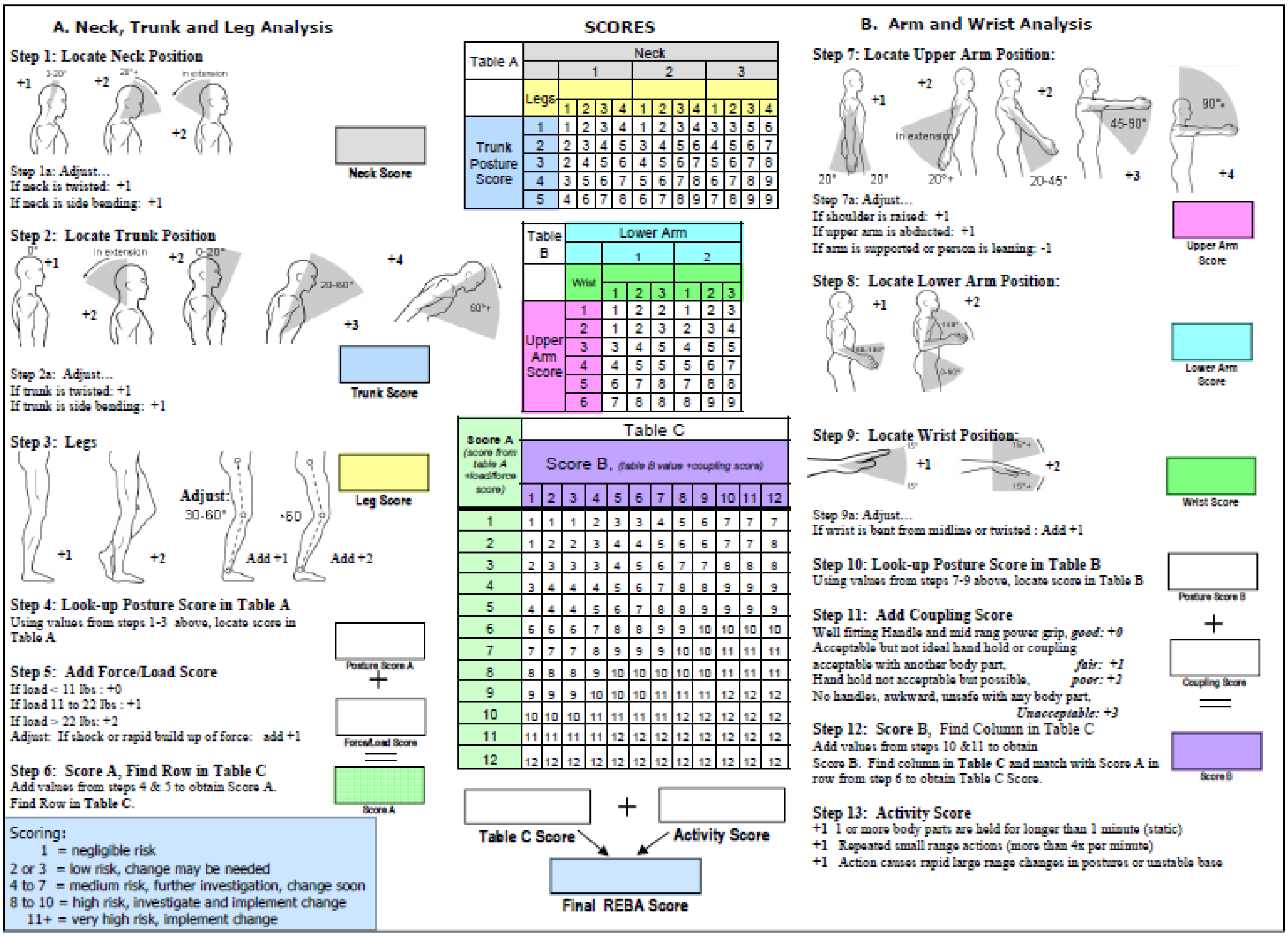


Figure 2. REBA scoreboard (REBA puan tablosu) [19]

The Rapid Upper Limb Assessment (RULA) method is utilized to detect potential problems that may arise in the region of the upper extremities during static and repetitive tasks. Similar to the REBA method, in RULA, the body is also divided into two groups: Group A (arms and wrists) and Group B (trunk, neck, and legs) [20]. The final RULA score is determined using data from the RULA standard chart (Figure 3) for the ergonomic analysis. The RULA analysis method examines the impact of a machine or platform on the user's musculoskeletal system. Health problems resulting from the usage of the designed environment or machine are evaluated through the RULA scoring system.

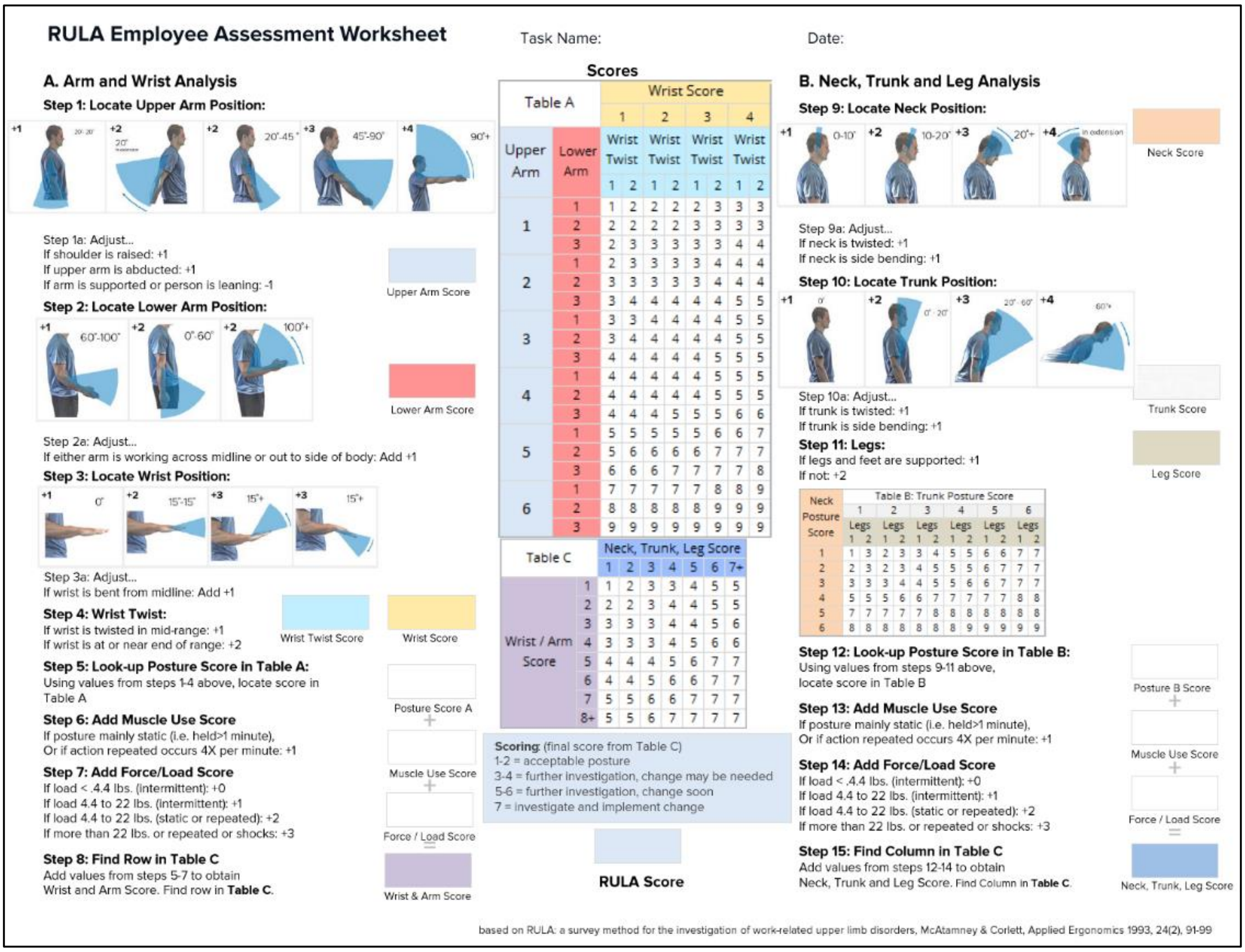


Figure 3. RULA scoreboard (RULA puan tablosu) [21]

3. FINDINGS (BULGULAR)

This research assessed the operator's posture while working on a console, considering two distinctive positions through the application of both REBA and RULA methodologies. The operator was evaluated under two separate scenarios, with observed differences noted between them. The work postures were labeled as Position-1 and Position-2. REBA and RULA analyses were conducted on both situations using CATIA. In Position-1, the situation of the operator looking straight at the screen and reaching the screen buttons was considered, while in Position-2, the situation of the operator reaching for a tablet on the side and looking at a screen below was evaluated from an ergonomic perspective.

3.1. Ergonomic Analysis with REBA (REBA ile Ergonomik Analiz)

The REBA scoring for Position-1 was calculated in accordance with the tables present in Figure 2, yielding an A score of 2 and a B score of 1. Consequently, the overall REBA score was determined to be 2 (Figure 4).

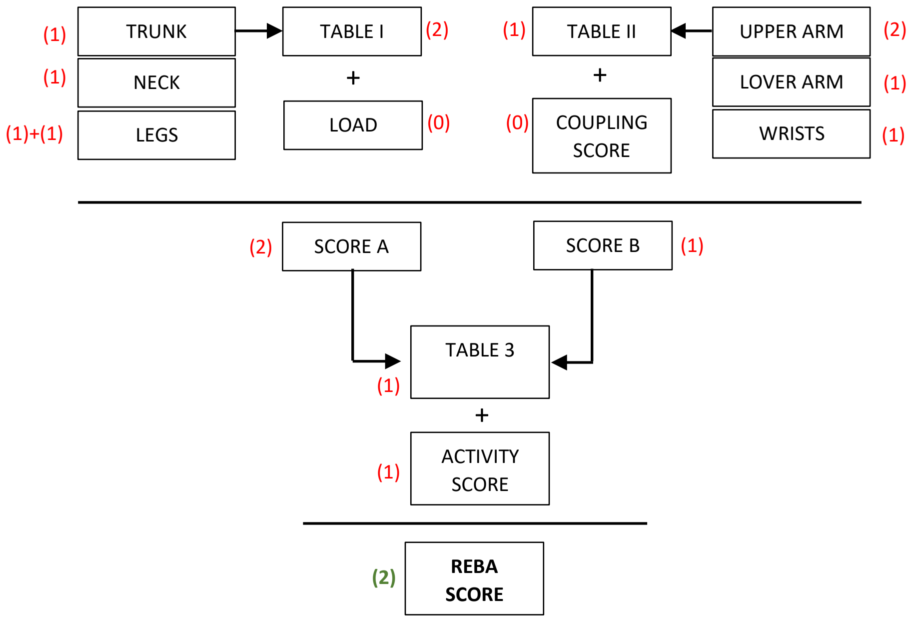


Figure 4. Determination of REBA score for Position-1 (Pozisyon-1 için REBA puanının belirlenmesi)

The risk assessment based on the REBA score for Position-1 is given in Table 1. According to the analysis results, even though the risk level was identified as low, it was determined that potential design changes might be required over an extended period.

Table 1. Classification of risks according to REBA and RULA tools scores (REBA ve RULA araçları puanlarına göre risklerin sınıflandırılması) [22]

RULA		REBA		
RULA Score	**Action Required**	**Action level (Risk level)**	**REBA Score**	**Corrective Measure**
1-2	Acceptable	0 (Negligible)	**1**	None necessary
3-4	Change may be necessary	1 (Low)	**2-3**	May be necessary
5-6	Change necessary soon	2 (Medium)	**4-7**	Necessary
7	Change immediately	3 (High)	**8-10**	Necessary soon
		4 (Very High)	**11-15**	Necessary NOW

The REBA scoring for Position-2 was derived in accordance with the tables in Figure 2, generating an A score of 2 and a B score of 4. As a result, the final REBA score was determined to be 4 (Figure 5).

The risk assessment based on the REBA score for Position-2 is given in Table 9. Based on the outcomes of the analysis, the ergonomic risk level was assessed as medium with a score of 4, indicating a necessity for alterations in the operator's posture.

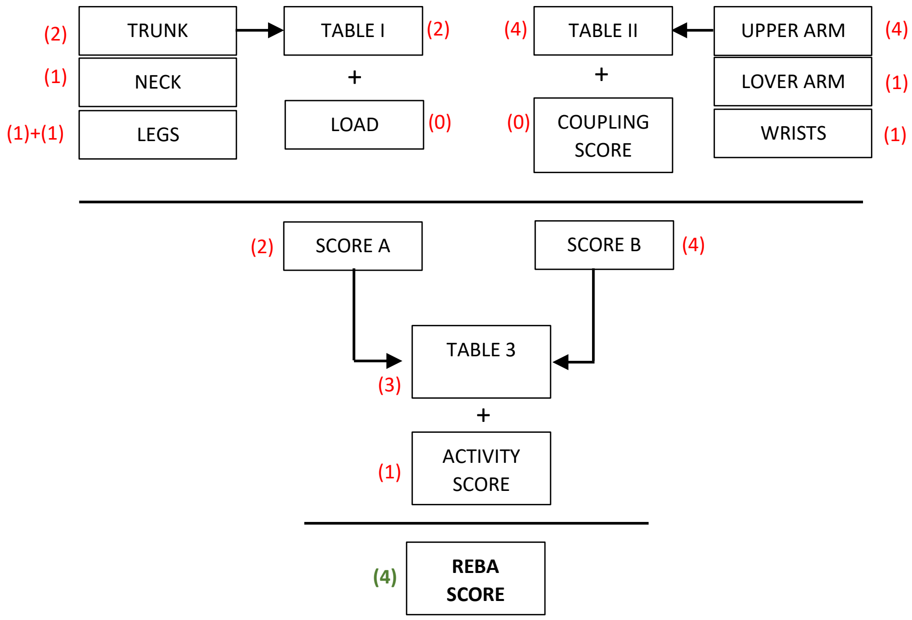
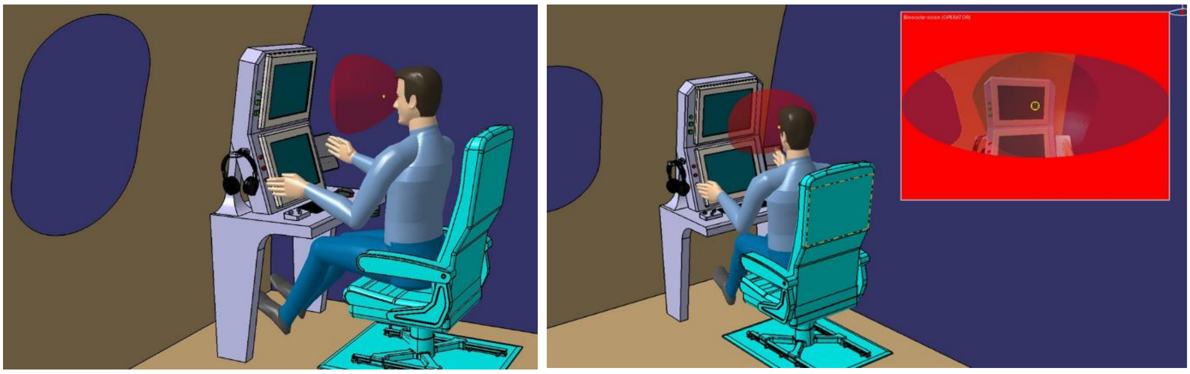


Figure 5. Determination of REBA score for Position-2 (Pozisyon-2 için REBA puanının belirlenmesi)

3.2. Ergonomic Analysis with RULA (RULA ile Ergonomik Analiz)

The human model, created using CATIA V5 Human Builder, was positioned on the three-dimensional console model in accordance with Position-1, and then RULA analysis was applied (Figures 6 and 7). As a result of the RULA analysis conducted using the CATIA V5 software, the final score was established as 3, thereby classifying it within the low-risk group (Table 9).



(a) (b)

Figure 6. RULA analysis for Position-1 (a) CATIA V5 model, (b) viewpoint analysis (Pozisyon-1 için RULA analizi (a) CATIA V5 modeli, (b) bakış açısı analizi)

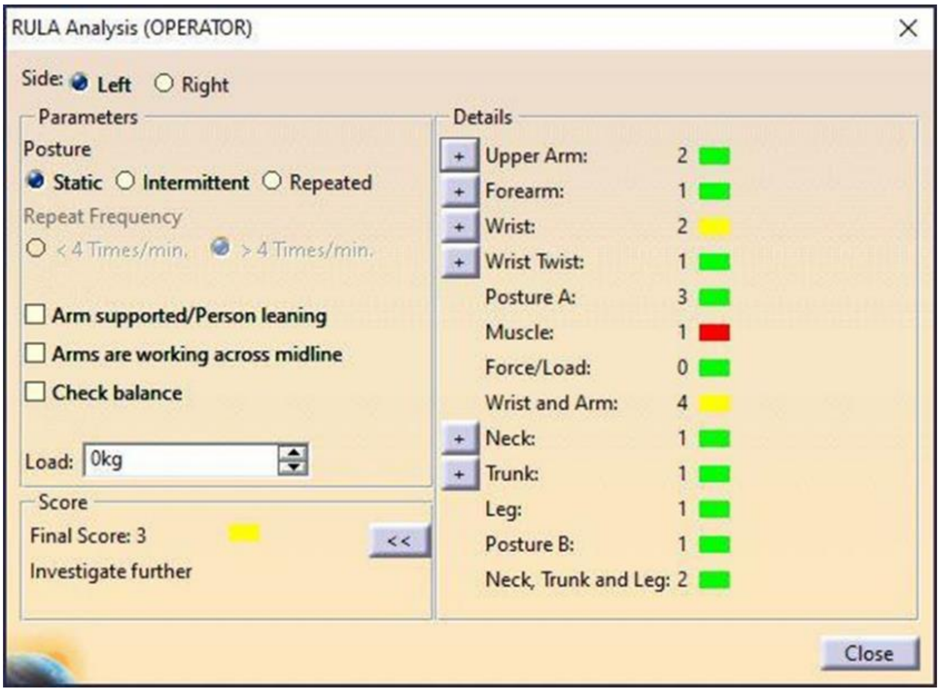


Figure 7. Results for RULA Analysis for Position-1 (Pozisyon-1 için RULA Analizi Sonuçları)

The human model, created using CATIA V5 Human Builder, was positioned on the three-dimensional console model in accordance with Position-2, which was then followed by a RULA analysis (Figures 8 and 9). The results from the RULA analysis carried out in the CATIA V5 program led to a final score of 3, which, as per Table 8, is classified within the low-risk group.

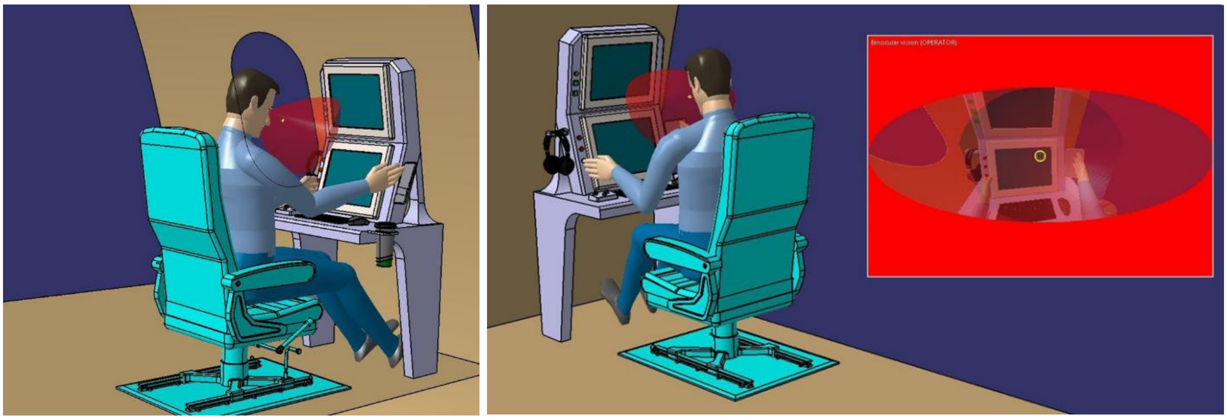


Figure 8. RULA analysis for Position-2 (a) CATIA V5 model, (b) viewpoint analysis (Pozisyon-2 için RULA analizi (a) CATIA V5 modeli, (b) bakış açısı analizi)

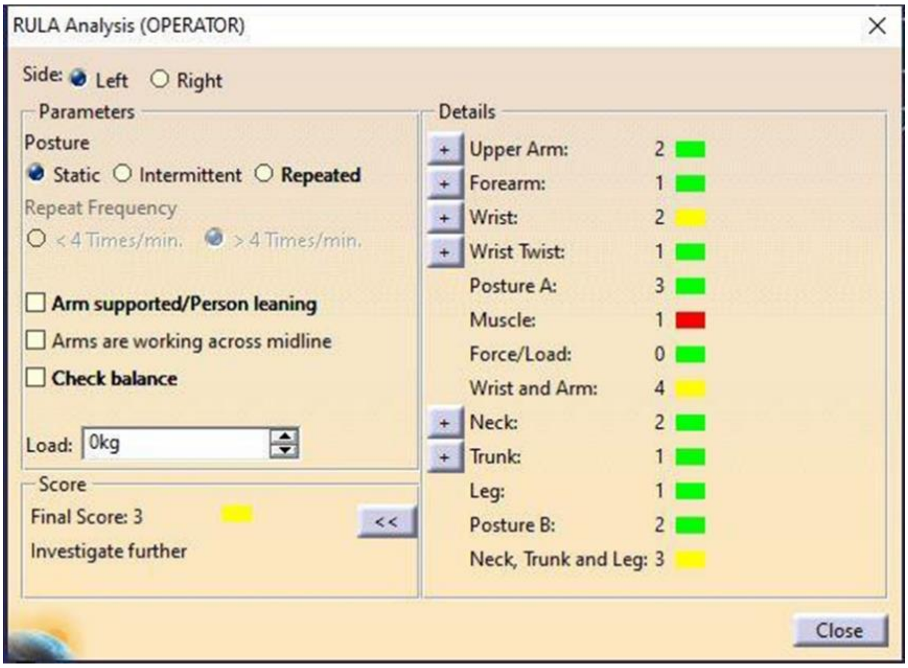


Figure 9. Results for RULA Analysis for Position-2 (Pozisyon-2 için RULA Analizi Sonuçları)

4. CONCLUSIONS (SONUÇLAR)

In this study, the ergonomic analyses of operator consoles within the aircraft fuselage were evaluated from the perspective of two different postural positions using the REBA and RULA methods. Position-1 considered the operator's situation of looking directly at the screen and reaching the screen buttons, whereas Position-2 assessed the operator's situation of reaching for the tablet on the side and looking at the screen below from an ergonomic point of view. Additionally, viewing angle analyses were conducted for these two postural positions.

Similarly, there are studies in the literature that evaluate different working and posture positions from an ergonomic point of view. In the study where the ergonomic evaluation of the driver in different postures was made, REBA and RULA tools of the CATIA V5 program and digital human models were used [4]. According to the results, when calculating the REBA score for both positions, the RULA scores were determined as 3. According to these values, it was stated that in the long term, it may be necessary to make changes by maintaining the existing standing positions. In another study, ergonomic evaluation of different working positions was made using the RULA method [1]. In this study, in which 5 different working and posture positions were evaluated, the RULA final scores ranged from 2 to 7. The designs for the respective working position have been updated for higher values. In a similar study, an ergonomic risk assessment of a functional product was performed using the REBA and RULA tools [18]. According to the analysis results, an ergonomic risk value that would require a change in the design was not determined. As a result, in this study, the ergonomic analyses of operator consoles within the aircraft fuselage were evaluated from the perspective of two different postural positions using the REBA and RULA methods. For Position-1, the final REBA score was determined as 2, indicating a low level of ergonomic risk. Upon examining the results of the RULA analysis for Position-1, the final score was determined as 3, also indicating a low level of ergonomic risk. Conversely, the final REBA score for Position-2 was determined as 4. This was due to the neck angles being different from the normal postural position, and the level of ergonomic risk was identified as medium. Lastly, upon analyzing the RULA results for Position-2, the final score was found to be 3, suggesting a low level of ergonomic risk.

This study has evaluated the importance of the harmony and connection between humans and machines. Optimal working environments can be provided through fundamental ergonomic analyses like REBA and RULA. Presently, numerous products necessitate ergonomic evaluation. Each product involving human interaction, from the most intricate to the most straightforward, should be subjected to this analysis to diminish potential risks to the minimum. Future research could propose alternate working postures aimed at minimizing the ergonomic risk factor associated with the two different posture positions studied. For Position-2, making the tablet located on the right adjustable could help in reducing the neck angle. By implementing revisions in both seating positions, it would be possible to bring risk scores down to the lowest feasible level.

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