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Ergonomic risk analysis with OWAS method on some machines used by students taking training on furniture in vocational high schools

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ABSTRACT: It is a fact that today, occupational accidents resulting from the use, structure and working principle of the planer, circular saw, vertical drilling, lathe and edge banding machines used in furniture production enterprises and vocational high school application workshops where furniture education is given lead to serious injuries. The main cause of work accidents and risks is machines which are incompatible with human ergonomics. In this thesis study, general information about ergonomics is given in the second chapter after the literature review. The third section mentions musculoskeletal system disorders that ergonomic incompatibilities may cause. In the fourth chapter, OWAS (Ovako Working Posture Analyzing System), which is an ergonomic risk assessment method based on simple observation, is mentioned. In the fifth chapter, general information is given about the Furniture and Interior Design Field in Vocational and Technical Anatolian High Schools affiliated with the Ministry of National Education and some of the machines used by students studying in this field in their application workshops. In the last part, an ergonomic risk analysis was carried out using the OWAS method to adapt the students to some machines they use while practising. This research aims to reveal, reduce, and, if possible, eliminate ergonomic risks in practice workshops. As a result, it was concluded that ergonomic arrangements should be made urgently in the machines used in the vocational high school furniture workshop.

Keywords: Ergonomic Risk Analysis, Ergonomics, OWAS, Vocational High Schools.

Meslek liselerinde mobilya eğitimi alan öğrencilerin kullandıkları bazı makinelerde OWAS yöntemi ile ergonomik risk analizi

ÖZ: Günümüzde mobilya üretimi yapan işletmelerde ve mobilya eğitimi verilen meslek lisesi uygulama atölyelerinde kullanılan makinelerin kullanımı, yapısı ve çalışma prensibinden kaynaklanan iş kazalarının ciddi yaralanmalara yol açtığı bir gerçektir. İş kazalarının ve risklerinin başlıca nedeni insan ergonomisine uygun olmayan makinelerdir. Bu tez çalışmada literatür taramasının ardından ikinci bölümde ergonomi hakkında genel bilgiler verilmiştir. Üçüncü bölümde ergonomik uyumsuzlukların neden olabileceği kas-iskelet sistemi bozukluklarından bahsedilmektedir. Dördüncü bölümde basit gözleme dayalı ergonomik risk değerlendirme yöntemi olan OWAS'tan (Ovako Çalışma Duruşu Analiz Sistemi) bahsedilmiştir. Beşinci bölümde Milli Eğitim Bakanlığına bağlı Mesleki ve Teknik Anadolu Liselerinde Mobilya ve İç Mekân Tasarımı Alanı ve bu alanda eğitim gören öğrencilerin uygulama atölyelerinde kullandıkları bazı makineler hakkında genel bilgiler verilmiştir. Son bölümde ise öğrencilerin uygulama yaparken kullandıkları bazı makinelere uyum sağlayabilmeleri için OWAS yöntemi kullanılarak ergonomik risk analizi yapılmıştır. Bu araştırma, uygulama atölyelerindeki ergonomik risklerin ortaya çıkarılmasını, azaltılmasını ve mümkünse ortadan kaldırılmasını amaçlamaktadır.

Anahtar Kelimeler: Ergonomik Risk Analizi, Ergonomi, OWAS, Meslek Liseler.

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1 Introduction

Ergonomic risk factors are associated with employee risks caused by repetitive, continuous work and poor postures leading to Musculoskeletal Disorders (MSD) (Mulyati et al., 2019). Ergonomics is one of the important factors in industry. Ergonomic factors need to be taken seriously because they play an important role in the efficient operation of companies. (Balasundaram et al., 2017). Complaints about workers' body postures are very common and this is due to workers' lack of knowledge about the dangers of working in a non-ergonomic work environment. Musculoskeletal disorders (MSDs) cause pain symptoms in various body locations such as neck, shoulders, wrists, hips, knees, and heels (Cho et al., 2016). Good interaction between people and workplaces should be ensured through ergonomics which plays an important role in many fields such as manufacturing, agriculture, furniture, mining, services, and other industries to address this deficiency. (Jusoh and Zahid, 2018).

The furniture industry is one of the labour-intensive and generally the hand–made working industries. Production to be done by hand increases the physical work demands, it also brings musculoskeletal system diseases and risks. Therefore, furniture manufacture is one of the sectors where musculoskeletal disorders are intense, and it is one of the most experiencing sectors for lumbar, back, and shoulder problems (Özkaya et al., 2017). If the necessary improvements are not made and the issues are ignored, the increase in Musculoskeletal Disorders (MSDs) cannot be prevented. Additionally, there will be inefficiencies and even losses in the workforce due to KISR. This also means a waste of cost and time. For these reasons, ergonomic adjustments have gained significant importance recently to minimise MSD (Çiçek et al., 2018). The methods used to assess KISR risk can be classified as personal survey methods, methods based on systematic observations, and direct measurement methods (Özel and Çetik, 2010). The methods used to quantitatively assess the KISR risk can also be divided into simple observation-based methods and advanced observation-based methods. Simple observation-based methods are NIOSH, RULA, SI, OCRA, QEC, REBA, OWAS. Advanced observation-based methods include Ergo-Man, 3DSSPP, Jack, RAMSIS Model, and AnyBody Modeling System (Koç and Testik, 2016). The OWAS (Ovako Working Posture Analysis System) method is an observation-based work posture analysis method used to identify the load on the employee's musculoskeletal system and the poor postures caused by the system. The OWAS method is designed as an analytical tool to serve work study practitioners and a work sampling tool based on the times occurring at each posture. The OWAS method allows the identification of poor postures and activities by comparing different systems based on the power expended by the workforce and predicting the most suitable work methods. Additionally, it ensures the evaluation of the workplace in terms of productivity, comfort, and occupational health as well as the systematic examination of the human-machine interface. OWAS is a method used to evaluate all body parts related to the musculoskeletal system, determine the load, identify improper postures, system-related repetitions, and the most suitable working methods. If the OWAS action class code is 3 or 4, corrective actions for improvement are urgently required. (Brandl et al., 2017)

In literature, there are studies in which OWAS has been used for the purpose of conducting work posture and ergonomic analyses. It is observed that these studies generally focus on sectors such as construction, manufacturing, furniture, repair-maintenance, health, agriculture and livestock, and transportation. (Esen, 2013). The OWAS method examined and addressed the posture problems of healthcare workers on ambulances. (Doormaal et al., 1995). Akay et al. (2003) analyzed the working postures of employees in a car maintenance service using a computer program with OWAS and determined that the frequency rates of certain working postures could be reduced at high risk levels. Kurt and Erdem (2003) analysed working postures and strains on a lathe using OWAS. As a result of the study, the reasons for the inappropriate posters and the measures that should be taken according to ergonomic criteria have been determined. In addition, the proposed system's efficiency has been demonstrated. Ülker et al. (2004) analysed the working postures of students working on ships and at ports in Iran using OWAS. It was stated in the study that lost workdays occurred in the system and that work stoppages needed to be corrected to fix the errors in the system. Risk analysis of back and lower back pain in carpenters was conducted and recommendations were made to address strains caused by loading using the OWAS method. (Gilkey et al., 2007). Özel and Çetik (2010) analysed the movements and postures during loading operations at a tile factory in Kütahya using OWAS. Two different loading rounds used for analysis have been classified in terms of ergonomic risk. Sönmez (2011) analysed the working postures of students during manual apple harvesting in the orchards of Niğde, Isparta, and Afyon using OWAS. The study has shown that the work postures are mostly in the 1st and 2nd categories. Ülker and Burdurlu conducted another study (2012)in which the postures of body parts of workers operating some machines used in panel furniture production were categorised according to load and strain conditions and analysed using the OWAS method and it was determined that the adjustments made particularly regarding postures in the high load and strain categories resulted in a total reduction of 37% in the hazard category values. Koç and Testik (2016) have addressed musculoskeletal disorders in a multifaceted manner in a factory operating in the furniture sector. They conducted an ergonomic risk assessment analysis using the OWAS, REBA, QEC, and ManTRA methods. Alıcı et al., (2017) observed the tasks performed during the production phase in a furniture manufacturing workshop and the ergonomic risk assessment of pneumatic screwing and pneumatic stapling tasks, which are thought to have harmful effects on the musculoskeletal system of employees, was analysed using OWAS. Koç (2021) investigated some ergonomic risk assessment methods in a factory that produced wooden pallets and crates and conducted studies to determine the measures that could be taken in the mentioned workplace. Bachmid and Andesta (2023) applied the OWAS method to analyse worker postures in their study titled “Analysis of Improvement of Employee Work Posture Using the OWAS Method (Case study at PT. XYZ)”. Their findings revealed that cutting, marking, fitting up, and packing tasks were associated with a risk level 2.

The furniture industry is one of the sectors with the highest physical strain during operations. Nevertheless, the number of studies conducted in this sector in Turkey is low. In this study, the OWAS (Ovako Working Posture Analysis System) method, one of the most used risk assessment methods, was applied by observing the tasks performed on the sofa production line in a furniture manufacturing business. When the literature is examined, observational studies have been conducted in many sectors to measure the strain on employees' skeletal and musculoskeletal systems. However, it has been determined that there is no relevant study on students studying furniture and interior design in vocational high schools. Based on this, the aim of this study is to evaluate the ergonomic risk analysis of the machines used by vocational high school students for practical work by observing the working postures that occur while working with some of these machines.

2 Method

Every conceivable back, arm, and leg posture adopted by workers during their tasks was investigated and standardised as 'OWAS Working Postures' depicted in Figure 1. Four codes are used in back postures, 3 codes are used in arm postures and 7 codes are used in leg postures. Also, three codes are used for loading. The final scores obtained from the table of action categories for different posture combinations assist in determining the action states in Table 1.

BACK POSTURES	Code 1  The condition where the angle between the shoulders and hips, as well as the line angle between the hip-leg and head, is less than 20 degrees.	Code 2  The forward and backward bending of the upper extremities at an angle of 20 degrees or more.	Code 3  The twisting or lateral bending of the back at an angle of 20 degrees or more.	Code 4  The bending and simultaneous rotation of the back.
ARM POSTURES	Code 1  Arms are completely below the level of the shoulders.	Code 2  Any arm being above or at the same level as the shoulders.	Code 3  Both arms are above shoulder level or at the same level.	
LEG POSTURES	Code 1  Supporting the body's weight above the hips.	Code 2  The knee angle is less than 150 degrees and the body's weight is supported on two straight legs.	Code 3  The knee angle is less than 150 degrees with weight supported on any straight leg	Code 4  The bending of both knees is less than 150 degrees with the body weight distributed on both legs due to the bending of the kness.
	Code 5	Code 6	Code 7	

Figure 1. Typical occupational stances are utilised in the OWAS approach (Whitford, 2005).

Table 1. Action Categories for Determined Different Posture Combinations (Whitford, 2005).

Back	Arm	Leg																				
		1			2			3			4			5			6			7		
		Load																				
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

International results:

1- No action required

2-Corrective actions required shortly

3-Corrective actions should be done as soon as possible

4-Corrective actions for improvement are required immediately

Corrective actions concerning the task and workplace to the action code are shown in Table 2.

Table 2. Action States in the OWAS Methodology (Whitford, 2005).

Action Code	Action State	Explanation
AC1	Harmless normal posture for the musculoskeletal system.	No action is required.
AC2	Postures with some harmful effects on the musculoskeletal system.	Corrective actions should be taken in the near term.
AC3	Posture with harmful effects on the musculoskeletal system	Corrective actions should be implemented promptly.
AC4	Postures with severe effects on the musculoskeletal system	Corrective actions must be applied urgently.

3 Results and Discussion

The ergonomic risk analysis evaluation of the applications on machine working postures was conducted using the OWAS method. The terms and definitions used in the OWAS task and posture combination analysis table are provided in Table 3.

Table 3. Analysis of OWAS task and posture combinations used in the study

Term	Description
Measurement No	The sequence number of the application performed.
Used Machine	The name of the machine on which the application is performed.
Operation Time	Refers to the observation period during which OWAS analyses are conducted.
OWAS Code	Refers to the values scored according to the OWAS coding table for the criteria of back, arm, leg, and load/force, respectively.
OWAS Action Code	Refers to the classification code found according to the action classes table.
OWAS Action Class	Specifies the sequence number of the 4 action classification criteria
Evaluation	Refers to the analysis result that emerges from the action classification.

The study made observations for three different applications: chip amount adjustment on the planer machine, first-stage planning operation, and second-stage planning operation. The analyses and evaluations of the 3 applications performed on the planer machine are presented in Table 4, and the planer machine is shown in Figure 2.

Figure 2. The planer machine.

Table 4. OWAS task table and findings related to the applications performed on the planer machine.

Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
Analysis of stop combinations for chip quantity adjustment on a planer machine									
1	5-10 second	Planer Machine	4	3	4	1	4	4	Ergonomic adjustment must be done urgently
Planer machine planing process first stage downtime combination analysis									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
2	5-10 second	Planer Machine	2	1	2	1	2	2	Requires ergonomic adjustment
Planer machine planing process second stage downtime combination analysis									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
3	5-10 second	Planer Machine	4	2	3	1	3	3	Ergonomic adjustments should be prioritised

For the first measurement, “Adjustment of Chip Amount on the Planer Machine”, the posture combination analysis indicates that ergonomic adjustments need to be made urgently.

For the second measurement, “First Stage Planing Operation on the Planer Machine”, the posture combination analysis indicates that ergonomic adjustments are necessary.

For the third measurement, “Second Stage Planing Operation on the Planer Machine”, the posture combination analysis indicates that ergonomic adjustments should be prioritised.

For the fourth measurement, “Pre-Operation Saw Height Adjustment on the Circular Saw Machine,” the posture combination analysis indicates that ergonomic adjustments are necessary.

3 applications were made with the circular saw machine for the pre-processing saw height adjustment, squaring operation, and width and length dimensioning operation in the study.

The analyses and evaluations of the 3 applications performed on the circular saw machine are presented in Table 5, and the circular saw machine is shown in Figure 3.

Figure 3. The circular saw machine.

Table 5. OWAS task table and findings related to the applications performed on the circular saw machine.

Analysis of stop combinations for pre-operation saw height adjustment in a circular saw machine									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
4	5-10 second	Circular Saw Machine	2	1	3	1	2	2	Requires ergonomic adjustment
Analysis of stop combinations for squaring operation on a circular saw machine									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
5	5-10 second	Circular Saw Machine	2	1	3	1	2	2	Requires ergonomic adjustment
Analysis of stance combinations for width and length measurement operations on a circular saw machine									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
6	5-10 second	Circular Saw Machine	2	2	2	1	2	2	Requires ergonomic adjustment

For the fifth measurement, “Squaring Operation on the Circular Saw Machine”, the posture combination analysis indicates that ergonomic adjustments are necessary.

For the sixth measurement, “Width and Length Measurement Operation on the Circular Saw Machine”, the posture combination analysis indicates that ergonomic adjustments are necessary.

2 applications were made for the drilling process to adjust the table height with a vertical drilling machine in the study. The analyses and evaluations of the 2 applications conducted on the vertical drilling machine are presented in Table 6, and the vertical drilling machine is shown in Figure 4.

Figure 4. The vertical drilling machine.

Table 6. OWAS task table and findings related to the applications performed on the vertical drilling machine.

Analysis of stop combinations for adjusting table height on a vertical drilling machine									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
7	30-60 second	Vertical Drilling Machine	2	1	2	1	2	2	Requires ergonomic adjustment
Analysis of stop combinations for drilling operations on a vertical hole machine									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
8	30-60 second	Vertical Drilling Machine	1	2	2	1	1	1	It does not require ergonomic adjustments.

One application was performed for the turning process using a lathe machine in the study. The analysis and evaluations related to the application on the wood lathe are presented in Table 7, and the lathe machine is shown in Figure 5.

Figure 5. The lathe machine.

For the seventh measurement, "Table Height Adjustment on the Vertical Drilling Machine", the posture combination analysis indicates that ergonomic adjustments are necessary.

Table 7. OWAS task table and findings related to the applications performed on the lathe machine.

Analysis of stopping combinations for turning operations on a lathe machine									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
9	30-60 second	Lathe Machine	1	1	2	1	1	1	It does not require ergonomic adjustments.

One application was performed for the linear edge banding process on the linear edge banding machine in the study. The analyses and evaluations of the application performed on the linear edge banding machine are presented in Table 8, and the edge banding machine.

Figure 6. The edge banding machine.

Table 8. OWAS task table and findings related to the applications performed on the lathe machine.

Analysis of stop combinations for edge banding process in a linear edge banding machine									
Measurement No	Operation Time	Used Machine	OWAS Posture Code (Back, Arms, Legs, Load)				OWAS Action Code	OWAS Action Class	Evaluation
10	30-60 second	Edge Banding Machine	1	1	2	1	1	1	It does not require ergonomic adjustments.

Healthcare professionals working in the ambulance were examined and postural problems were resolved using the OWAS method (Doormaal et al., 1995). The daily activities of the nursery workers were recorded on video, their action postures were examined, and precautions were taken against traumas that may occur in the musculoskeletal system (Grant et. al., 1995). A risk analysis of back and waist pain in carpenters was made and suggestions were made against strains arising from loading using the OWAS method (Gilkey et al., 2007). The postures of supermarket employees were examined and suggestions for ergonomic arrangements were made using the OWAS method (Carrasco et al.,1995).

4 Conclusion

In this study, applications were conducted on some machines used for educational purposes in the Furniture and Interior Design Field workshops of vocational education institutions, and ergonomic risk analyses were carried out by the OWAS technique with the stages being observed.

Based on the observations and analyses conducted, we can list the issues we identified as follows:

- Since the study was conducted with students, poor working postures have affected their physical development.
- The machines used in the application are old models and the lack of the necessary ergonomic equipment has also been an important factor.

- The machines used for practice are not different from those used in normal industry which means the developmental levels of the students are not taken into account during their design.
- The ergonomic compatibility in the design of the machines is not sufficiently considered.
- Students do not have enough knowledge about proper working postures.
- Due to the high number of students in the branches, they do not have enough chance and time to practice on the machines.
- They do not know that improper and inefficient working postures will become habitual over time and may cause temporary and/or permanent disorders and damages in the musculoskeletal system in the future.

It is a necessity to reduce or eliminate ergonomic risk factors arising from the mentioned reasons. If this is not done, students who practice improper and inefficient working postures will gradually develop habits that may lead to temporary and/or permanent disorders and damage to their musculoskeletal systems over time.

Regarding the necessary ergonomic adjustments and improvement efforts for this purpose,

- The machines to be used in the practical workshops of vocational training schools should be selected following the physical development of the students.
- The old-type machines in the application workshops should be replaced with new ones as much as possible.
- Machines designed for students should differ in size from those used by adults in the industry.
- Ergonomic compatibility should be considered in the design of machines, especially with the fact that students will be using them.
- More modern computer-controlled machines (CNC) should be preferred.
- Students should be given training on appropriate working postures. Appropriate and correct working postures should also be included in textbooks.
- In schools that provide practical education, the number of students in each class should not be too high, and each student should be able to practice sufficiently.
- While providing training on occupational health and safety, training on ergonomics and musculoskeletal disorders should be also given to the students.

Students who are still in the early stages of their vocational training will transfer the correct working postures they learn and make a habit of to their lives after their student years. In conclusion, it is important for students studying in the practical workshops of vocational high schools to be ergonomically compatible with the machines they work with as this is crucial for occupational health and safety in their future working lives. Non-ergonomic working postures negatively affect occupational health and safety. Inappropriate working postures will also increase the risk of workplace accidents and lead to musculoskeletal disorders. Preventing potential issues like this is only possible during the student years referred to as the initial learning phase of the profession.

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Author Contributions

Ahmet Çakıcı: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing- original draft, Writing-review & editing, **Abdurrahman karaman:** Conceptualization, Investigation, Methodology, Resources, Validation, Visualization, Writing-original draft. **Sait Dundar Sofuoglu:** Formal Analysis, Investigation, Methodology, Visualization, Writing-original draft

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Conflict of interest statement

The authors declare no conflict of interest.

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