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Applicability of Markerless Motion Capture Kinect for the Ovako Working-Posture Analysis System (OWAS) Ergonomic Assessment

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Abstract: Markerless motion capture systems, such as Microsoft Kinect, offer advantages over traditional marker-based systems, including reduced time costs and robust tracking capabilities for real-time ergonomic assessments. The Ovako Working Posture Analysis System (OWAS) is a recognized tool for evaluating working postures to mitigate musculoskeletal disorder (MSD) risks. This study develops a system using Kinect for ergonomic assessments with OWAS, evaluating accuracy and repeatability using Kinovea software. Findings show the system accurately captured 11 out of 14 OWAS postures (78.58% accuracy). Kinect is effective for ergonomic assessments, though further improvements are needed for complex postures. Future research should focus on enhancing accuracy and exploring broader applications.

Keywords: Markerless motion capture, Microsoft Kinect, Ergonomic assessments, Ovako Working Posture Analysis System (OWAS), Kinovea software

1. Introduction

Markerless motion capture offers several advantages over traditional marker-based systems. These advantages include reduced time costs for registration and data processing, as markerless systems involve filming from different angles and tracking the athlete's silhouette using software algorithms [1]. Markerless motion capture has shown promise in accurately quantifying joint kinematics and kinetics during various movements, simplifying experiments and enabling large-scale analyses. Additionally, markerless systems are robust to clothing variations, allowing data collection in participants' preferred attire and demonstrating comparable joint centre positions and consistent kinematic measurements with marker-based systems. Furthermore, markerless motion capture based on 2-D video analysis combined with computer vision techniques has the potential to provide accurate running technique analysis in research and clinical settings[2]. These advantages highlight the potential of markerless motion capture to revolutionize biomechanical research and enhance movement analysis in various fields.

Motion capture (MOCAP) systems like Kinect are utilized for ergonomic assessments, such as the Ovako Working Posture Analysis System (OWAS),because they provide objective data on body movements and postures. These systems, particularly Kinect, offer markerless tracking capabilities, making them cost-effective and efficient for real-time ergonomic evaluations [3]. Research comparing different motion capture systems found that Kinectcan still be suitable for ergonomic postural assessments in environments without severe occlusions despite being less stable than optical and inertial-based systems[4]. By leveraging the body tracking features of Kinect, ergonomic evaluations like the Rapid Upper Limb Assessment (RULA) methodology can be performed in real-time, allowing for the assessment of working postures and the identification of potential musculoskeletal risks in various occupational settings[5], [6].

The following are the research objectivesof this paper:

1. Develop a system and explore the utilization of Motion Capture (MOCAP) technology, specifically MOCAP by using Microsoft Xbox Kinect 1.0 version, in conducting ergonomic assessments using the OWAS (Ovako Working Posture Analysis System) method.
2. Assess the accuracy and repeatability of markerless MOCAP technologies in capturing and analyzing body movements and postures relevant to ergonomic evaluations by using the Kinovea software.

2. Literature Review

2.1 What is the Ovako Working-Posture Analysis System (OWAS)

The Ovako Working-Posture Analysis System (OWAS) is a widely recognized ergonomic assessment tool used to evaluate and categorize working postures to identify and mitigate musculoskeletal disorder (MSD) risks. It is particularly valued for its simplicity, cost-effectiveness, and ability to assess the entire body, making it a popular choice in various industries, including construction and forestry [7], [8]. OWAS involves observing and recording postures during work tasks, which are then classified based on the position of the back, arms, legs, and force exerted. These categories generate a Postural Risk Index (PRI), which helps design ergonomic interventions to improve work methods or introduce new technologies [9]. For instance, in the construction industry, OWAS has been used to identify awkward postures during tasks such as lifting and assembling formwork, leading to the development of preventive ergonomic systems to reduce MSDs [10].

Similarly, in forestry, OWAS has been employed to assess the postural load of chainsaw workers, revealing significant differences in risk levels associated with different chainsaw starting methods [11]. Despite its utility, OWAS has limitations in characterizing postural changes brought by new interventions, prompting the integration of additional metrics like the Sorensen's quotient of similarity and the Canberra metric for more detailed postural analysis [12]. The system's effectiveness in reducing musculoskeletal strain has also been demonstrated in studies involving preschool teachers, where significant reductions in knee-straining postures and trunk flexion were observed following ergonomic interventions [13]. OWAS remains a crucial tool in ergonomic risk assessment, contributing to developing safer and more efficient work environments across various sectors.

2.2 How does OWAS analyze working postures effectively?

The Ovako Working Posture Analysis System (OWAS) is a widely used method for evaluating working postures to identify and mitigate risks of musculoskeletal disorders (MSDs). OWAS effectively analyzes working postures by categorizing them into different action categories based on the observed positions of the back, arms, legs, and load handling. This method provides a systematic approach to assess the risk levels of various postures and suggests necessary corrective actions. For instance, OWAS has been successfully applied in the rubber industry to identify high-risk postures, such as attaching rubber hoses to cores and placing them in autoclaves, which were the most hazardous tasks [14]. The method's sensitivity and reliability have been further validated through sensitivity analysis and ordinal regression, which help identify the most impactful body variables and their weight in estimating the OWAS action category [15], [16].

Additionally, OWAS has been adapted for use in various industries, including construction and residential building sweeping, where it has identified critical postures and suggested ergonomic interventions to reduce injury risks [17]. The method's effectiveness is enhanced by integrating advanced technologies such as machine learning models and augmented reality, which streamline the analysis process and improve accuracy [18]. Moreover, OWAS provides practical guidelines for workstation design and operator training, ensuring workers maintain neutral postures to avoid awkward positions that could lead to MSDs [19]. Overall, OWAS's structured approach, technological advancements, and sensitivity analysis make it a robust tool for effectively analyzing and improving working postures across various industries.

2.3 What are the key components of OWAS analysis?

The key components of the Ovako Working Posture Analyzing System (OWAS) include the assessment of posture sensitivity, identification of insensitive and highly sensitive posture zones, utilization of ordinal regression analysis to understand the impact of body variables on posture ratings, and the classification of work postures based on observations of work tasks [20], [21]. OWAS involves recording various postures using a five-digit code representing different body parts and load forces, analyzing these data with OWAS software, and identifying the most frequent and unsuitable postures to determine areas of high risk. Additionally, OWAS aids in evaluating working postures to support ergonomic interventions by identifying awkward postures, prioritizing target postures with less postural load, and developing corrective measures to improve work postures effectively.

The OWAS analysis does not have any underlying mathematical model. Instead, it relies on a lookup table that converts three-digit posture codes into Action Categories (AC). **Table 1** converts the action category into action requirements [22].

Table 1: The OWAS action categories and requirements

Action Category	Action Requirements
AC1	No action required
AC2	Action required in the near future
AC3	Action is required as soon as possible
AC4	Action required immediately

OWAS action categories were derived based on work postures and loads managed for each jobtask[23], as shown in **Figure 1**. Action Categories (AC) classify the relative risk and urgency for intervention to prevent musculoskeletal disorders due to exposure, especially to Low Back Pain (LBP). The workers' postures were analyzed according to different work phases (corresponded with the task analysis), calculated in percentages, and assigned an action category code.

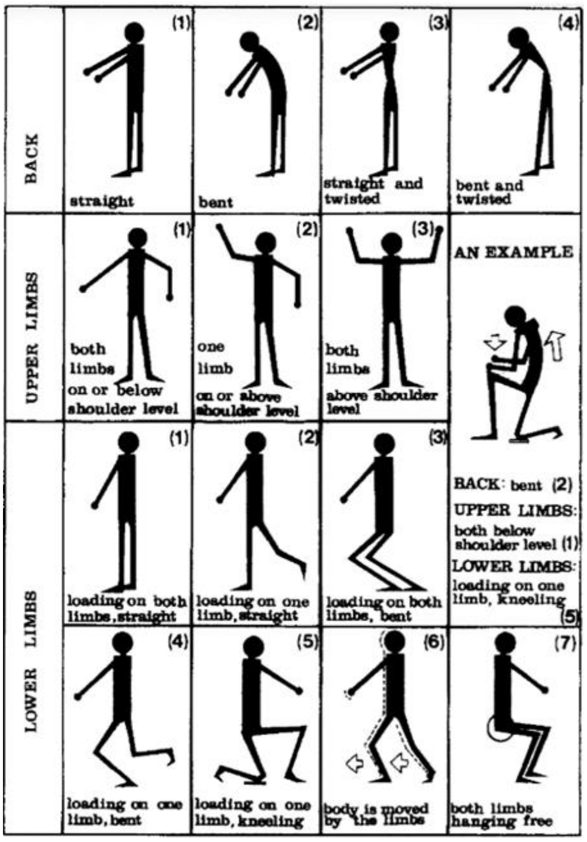


Figure 1: List of items classified by OWAS

2.4 How do the main components of OWAS analysis interact?

The main components of OWAS analysis interact by conducting a comprehensive analysis of working postures using observational methods, such as OWAS, to identify awkward postures that may lead to musculoskeletal disorders. This analysis involves observing work movements, identifying poor working postures, and determining the frequency of these postures during specific tasks[24]. Subsequently, based on the identified awkward postures, a systematic procedure for ergonomic intervention is implemented, including setting gradual target postures with less postural load, proposing corrective measures, selecting the most effective measures, and ensuring their implementation to improve working conditions and reducing injuries. The OWAS method allows for calculating a risk index based on the frequency and severity of poor postures assumed during tasks, providing a quantitative measure to prioritize interventions and enhance ergonomic conditions in various work settings.

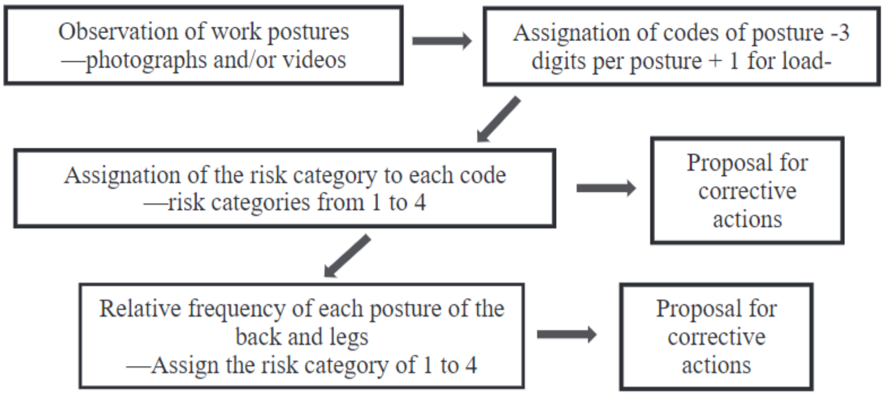


Figure 2: Flow diagram of the OWASapplication process

2.5 What are the limitations of OWAS analysis solved by markerless 3D motion capture (MOCAP)?

Markerless 3D motion capture (MOCAP) addresses the limitations of traditional marker-based systems in OWAS analysis by offering improved accuracy and practicality. Marker-based MOCAP requires precise marker placement, leading to challenges with occlusions, ghost markers, and misplacements [25]. Markerless MOCAP overcomes these issues by eliminating the need for markers, simplifying experiments, and facilitating large-scale analyses with high accuracy in joint kinematics and kinetics, especially in ankle and knee angles and moments. Markerless systems can reconstruct missing joint data, making downstream analysis of full-body movements more feasible. By providing a more efficient and accurate solution, markerless 3D MOCAP enhances the applicability of OWAS analysis in various fields, including healthcare and biomechanics.

3. Motion and Posture CapturingSystem and Result

3.1 Motion and posture capturing process and accuracy assessment using Kinovea

Motion animation and 3D postures are captured in data collection, as shown in Figure 3. After the author modelled the positions and gestures, they were recorded using the Iclone program. The Blender program cannot directly record gestures with Kinect since the device is still operating on the outdated version 1.0. It would help if you had Kinect 2.0 to record straight from Blender. Because it can be used with the original Kinect, the Iclone program is utilized. A camera is used to record the initial postures, which yield an MP4 format. Kinect V1 and the OBS application are used to capture 3D postures, which yield an MP4 format.The final project's data are in the form of motion animation and 3D poses. For this final assignment, posture and motions are recorded as data collection. After the author modeled the positions and gestures, they were recorded using the Iclone program. The Blender program cannot directly record gestures with Kinect since the device is still operating on the outdated version 1.0. It would be best to have Kinect 2.0 to record straight from Blender. Because it can be used with the original Kinect, the Iclone program is utilized. A camera is used to record the initial postures, which yield an MP4 format. Kinect V1 and the OBS application are used to capture 3D postures, which yield an MP4 format.

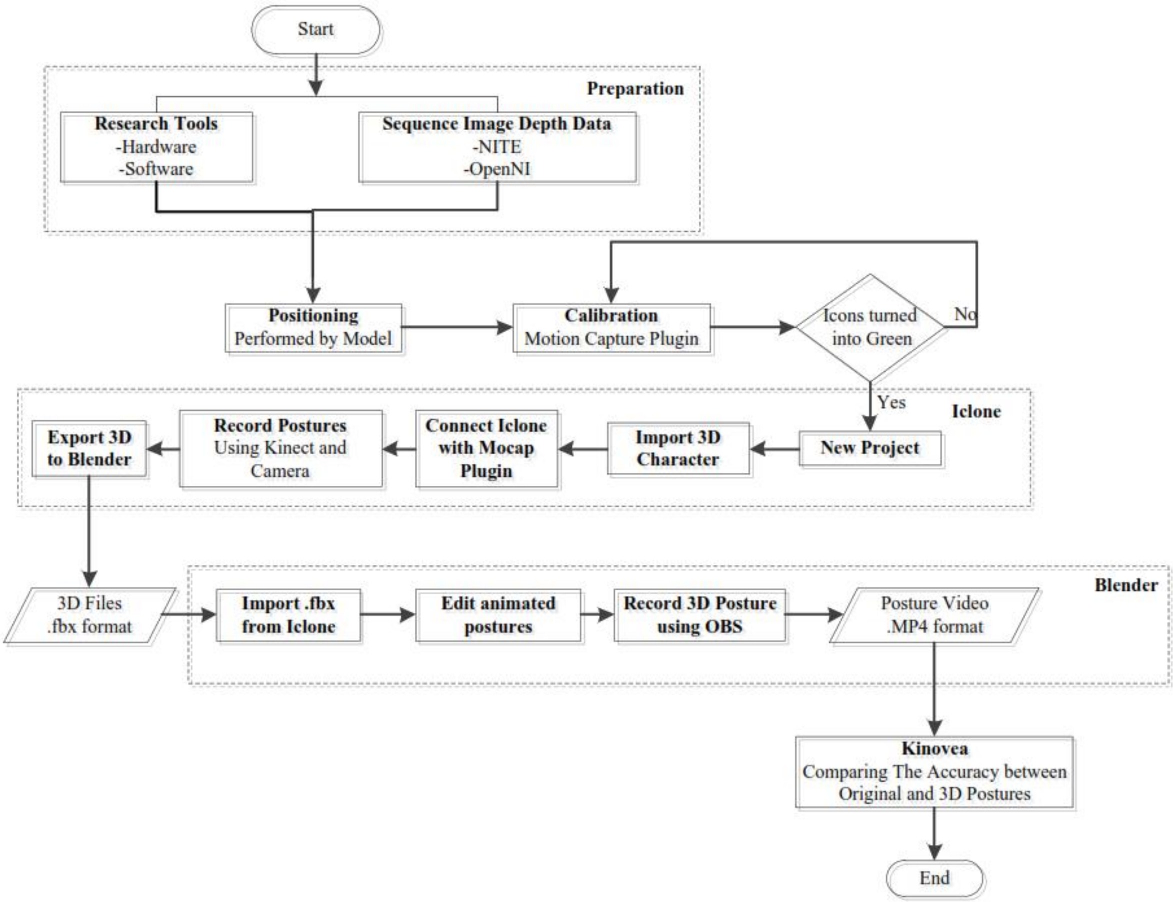


Figure 3. Data Collection Flowchart

The data in this project is in the form of postures and motion data in FBX format, which is then transferred into the Blender. The last step is comparing the accuracy of the original posture and the animated 3D using Kinovea for each posture.

3.2 Motion and posture capturing system

Figure 4:Components of markerless motion and posture capturing system

The need for motion and posture-capturing systems in conducting research consists of hardware and software, including:

a. Hardwareand the specifications used in this research are as follows:
- Laptop with Processor Intel Core i5, 4 GB RAM, and 500 GB hard disk.
- Mirrorless Camera
- Microsoft Xbox 360 Kinect. Kinect is a Microsoft product that introduced motion gaming technology as its main feature. It allows players to interact with the Xbox 360 console without a game assistance controller and enough only by using limb movements.

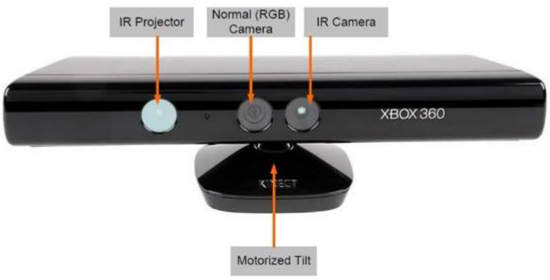


Figure 5: Microsoft Xbox 360 Kinect

b. Softwareused in thisresearch are as follows:
- Blender 3D
- ONIRecorder (OpenNI & NITE)
- Iclone 7 from https://www.reallusion.com (trial version)
- Mocap Device Plug-in (Kinect for Windows) v1.21
- Kinovea: Kinovea is a free and open-source software organized around four core missions studying human motion: capture, observation, annotation, and measurement (https://kinovea.org).

3.3 OWAS back posture results

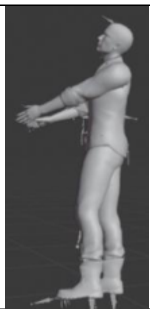
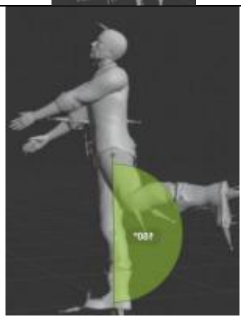
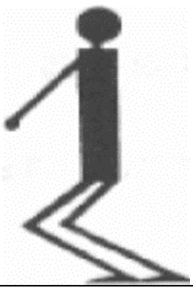
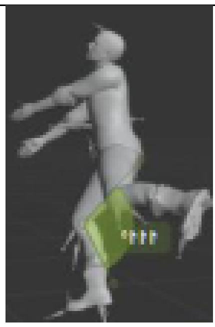
Work Postures	MOCAP	Kinovea
1. Straight (<20°) 		
2. Bend (>20°) 		
3. Straight and twisted(>20°) 		
4. Bend forward and twisted (>20°) 		

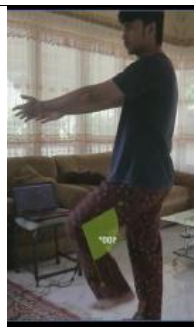
3.4 OWAS Upper Limbs (Arms) Posture Results

1. Both arms on or below the Shoulder Level 		
2. One arms on or above Shoulder Level 		

3. Both arms above Shoulder Level 		

3.5 OWAS Lower Limbs (Legs) Posture Results

1. Stand on both legs straight 		
2. Stand on one straight leg (> 150 °) 		
3. Stand/crouch on both feet with knees bent (≤150°) 		
4. Stand/crouch on one leg with knees bent (≤150°) 		

5. Kneel on one or both knees 		
6. Body is moved by Thelimbs (walk) 		
7. Both Legs Hanging Free (Sit) 		

A summary of the results can be seen in Table 2.Three postures cannot be detected due to lost tracking. Rotate or tilt sideways, bent and twisted, and kneel on one or both knees cannot be tracked accurately by markerless motion capture version one. In other words, 3 of 14 postures or 21,42% of postures, can not be detected by the markerless mocap system, or to say, the accuracy of the markerless mocap system is around 78,58%.

Table 2: Results of the OWAS working posture using markerless motioncapture

OWAS Working Posture Level	No	Working Posture	Posture Accuracy	
			Original	3D Animated
Back Posture	1	Straight	Straight Posture	
	2	Bend	36°	35°
	3	Rotateor TiltSideways	Lost Tracking	
	4	BendForwardandSideways	Lost Tracking	
Upper Limbs (Arms) Posture	1	BothArmsonor belowShoulderLevel	Straight Posture	
	2	OneArmonor aboveShoulderLevel	71°	72°
	3	BothArmsaboveShoulderLevel	70°	69°
Lower Limbs (Legs) Posture	1	BothLegsHangingFree(Sit)	91°	94°
	2	StandonBothLegsStraight	Straight Posture	
	3	Stand on one Straight Leg	180°	180°
	4	Stand/Crouch on Both feet with knees bent	69°	69°
	5	Stand/Crouch on one leg with knees bent	111°	111°
	6	Kneel on one or both knees	Lost Tracking	
	7	Body is moved by the legs (Walk)	100°	99°

4. Implementation Case Study

An example of a case study is the position in daily activities, one of which is lifting water gallons. During activities, workers lift a gallon with a heavy load of 19 kg. This activity can be potentially dangerous, and an ergonomic study is needed. The analysis compares the two positions performed by the model when lifting gallons. The aim is to get an optimal position, and injury can be avoided when working specifically when lifting gallons. The first position to be analyzed is lifting the gallon by bending down. In OWAS assessment, this posture consists of a back with an angle bigger than 20 degrees, that is, 88 degrees, so it can be said to bend position (position 2). Next, both arms are on or over the shoulder (position 3), and the stand/crouch is on both feet with knees bent at a 136-degree angle (position 4). The load weights are 19 kg (load 2). Therefore, this position is considered as the fourth category. It means that this position is dangerous for the musculoskeletal system (this work results ina post in obvious risks) andneeds to be repaired directly/right now [26] [27].

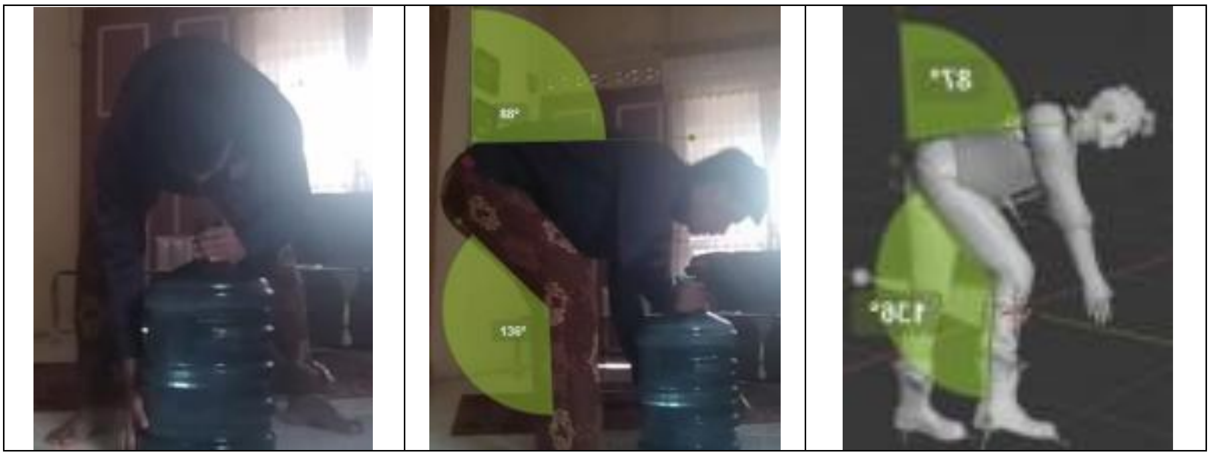


Figure 6: First alternative posture of loading water gallon

Table 3: OWAS Assessment for the first alternative posture of loading water gallon

Back	Arms	1			2			3			4			5			6			7			Legs
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Load
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	2	2	2	2	1	1	1	1	1	1	
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	2	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	4	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	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	4	3	3	4	4	4	4	4	4	4	4	4	4	4	2	3	4	

In contrast to the first position, the second position to be analyzed is the position of lifting gallons with a straight back position. In OWAS assessment, this posture consists of a back which angle is smaller than 20 degrees which are 17 degrees. So that it can be said to be straight position (position 1), next, both arms are under the shoulders (position 1), stand/crouch on both feet with knees bent with an angle of 40 degrees (position 4), and the same load is 19 kg (load 2). So, this position is considered the second category. It means that this position is a little dangerous to the musculoskeletal system (work posture results from the influence of tension that is not too significant). Need improvement in the future. This position is better than the first position.

Figure 7: Second alternative posture of loading water gallon

Table 4: OWAS Assessment for the secondalternative posture of loading water gallon

Back	Arms	1			2			3			4			5			6			7			Legs
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Load
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	2	2	2	2	1	1	1	1	1	1	
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	2	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	4	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	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	4	3	3	4	4	4	4	4	4	4	4	4	4	4	2	3	4	

After lifting the gallon from below, the next posture is holding it by hand before placing it into the dispenser. Experiments are using two examples of different postures. First, if the location of the dispenser is at the hand level, the posture is as shown in Figures 4.48 and 4.49. Second, if the location of the dispenser is higher than the hand, then it needs a little help from the legs, as shown in Figures 4.50 and 4.51.

Figure 8: First posture alternative of walking and unloading water gallon

Table 5: OWAS Assessment for walking and unloading water gallon

Back	Arms	1			2			3			4			5			6			7			Legs
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Load
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	2	2	2	2	1	1	1	1	1	1	
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	2	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	4	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	
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	3	4	4	4	2	4	3	3	4	4	4	4	4	4	4	4	4	4	4	2	3	4	

Figure 9: Second posture alternative of unloading water gallon

Table 6: OWAS assessment for the second posture of unloadinggallon

Back	Arms	1			2			3			4			5			6			7			Legs
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Load
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	2	2	2	2	1	1	1	1	1	1	
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	2	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	2	3	4	
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	3	2	2	3	1	1	1		2	3	3	4	4	4	4	4	4	4	4	1	1	1	
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	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	4	3	3	4	4	4	4	4	4	4	4	4	4	4	2	3	4	

In OWAS assessment, this posture consists of a back whose angle is smaller than 20 degrees, which is 17 degrees. So it can be said to be a straight position (position 1); next, both arms are under the shoulders (position 1), and both stand on both straight legs (position 2), and the load is 19 kg (load 2). So, this position is considered the first category. In this position, there is no problem in the musculoskeletal system (harmless). There is no need for improvement.

5. Discussion

Markerless motion capture for OWAS posture evaluation works properly with an accuracy of around 78,58%. There are 11 outof 14 full bodies of OWAS postures that can be captured accurately for assessments.

These cause optical occlusions with the limbs due to the Kinect sensor missing the line of sight. Overall, the system can workas markerless motion or posture capturing to support OWAS analysis. This conclusion has been approved by a case study of a common activity among people in Indonesia: loading, bringing, and unloading water gallons. Based on the OWAS analysis, the first alternative posture for loading water gallonsneeds to be repaired directly/right now. The second alternative posture of loading water gallonsis better than the first alternative posture.Furthermore, the OWAS assessment for the first alternative of unloading water gallons shows no problem in the musculoskeletal system (harmless) or no need for improvement.Additionally, there is no difference between the first and the second posture when unloading the gallon.

6. Conclusion

The study demonstrated that markerless motion capture using Microsoft Kinect is effective for ergonomic assessments with the Ovako Working-Posture Analysis System (OWAS). The system accurately captured 11 out of 14 OWAS postures, achieving an accuracy rate of approximately 78.58%. However, three postures (rotate or tilt sideways, bend and twist, and kneel on one or both knees) could not be accurately tracked due to optical occlusions and the limitations of the Kinect sensor. Despite these limitations, the study confirms the potential of markerless motion capture systems to support OWAS analyses. It suggests that further improvements in the technology could enhance its accuracy and applicability. The case study of lifting and unloading water gallons illustrated the practical applications of the system and highlighted the importance of proper posture to prevent musculoskeletal disorders. Future research should focus on improving the accuracy of complex posture detection and exploring broader applications of markerless motion capture in ergonomic assessments.

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