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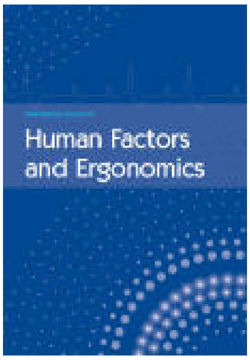

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Veeresh Elango, Staffan Hedelin, Lars Hanson, Johan Sandblad, Anna Syberfeldt, Mikael Forsman

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Evaluating ERAIVA – a software for video-based awkward posture identification

Veeresh Elango*

School of Engineering Sciences,
University of Skövde,
Högskolevägen, 541 28 Skövde, Sweden
Email: veeresh.elango@scania.com
and
Smart Factory Lab.,
Scania CV AB,
Vagnmakarvägen 1,
151 87 Södertälje, Sweden
*Corresponding author

Staffan Hedelin

Advanced Analytics,
Scania CV AB,
Vagnmakarvägen 1,
151 87 Södertälje, Sweden
Email: staffan.hedelin@scania.com

Lars Hanson

School of Engineering Sciences,
University of Skövde,
Högskolevägen, 541 28 Skövde, Sweden
Email: lars.hanson@his.se

Johan Sandblad

Global Safety, Health and Environment,
Scania CV AB,
Vagnmakarvägen 1,
151 87 Södertälje, Sweden
Email: johan.sandblad@scania.com

Anna Syberfeldt

School of Engineering Sciences,
University of Skövde,
Högskolevägen, 541 28 Skövde, Sweden
Email: anna.syberfeldt@his.se

Mikael Forsman

School of Engineering Sciences in Chemistry,
Biotechnology and Health,
KTH Royal Institute of Technology,
141 57 Stockholm, Sweden
Email: miforsm@kth.se

Abstract: The convergence of the focus of Industry 5.0 on human well-being and the prevalent problem of work-related musculoskeletal disorders necessitates advanced digital solutions due to limitations in manual risk assessment methods. This research aimed to compare usability of a newly developed video-based awkward posture identification software, the ergonomist assistant for evaluation (ERAIVA) with a conventional manual method. The risk assessment tool utilised in this study, integrated into the ERAIVA digital platform, is the risk management assessment tool for manual handling proactively (RAMP). Four assessors evaluated video-recorded tasks using both methods (manual and ERAIVA). The usability was assessed through the post-study system usability questionnaire, time consumption, number of video replays and video annotation deletions. The impact on identification of awkward posture durations was also studied. ERAIVA exhibited the highest usability score; it showed a higher number of video replays of specific sequences and annotations without significant differences in time consumption.

Keywords: awkward postures; software; work-related musculoskeletal disorder; video-based; Industry 5.0; ergonomist assistant for evaluation; ERAIVA; risk management assessment tool for manual handling proactively; RAMP.

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Biographical notes: Veeresh Elango is an industrial PhD student at Scania CV AB, focusing on applying advanced technologies to improve workplace ergonomics. He is enrolled in the research school Smart Industry and is affiliated with the University of Skövde. His research centres on using artificial intelligence to enhance workers’ well-being, aligning with Industry 5.0 principles. Specifically, his work explores video-based human posture recognition as a methodology and the optimisation of workstations to enhance ergonomics. His industrial background allows him to address real-world challenges with practical and innovative research solutions.

Staffan Hedelin is an IT architect and full-stack developer at Scania CV AB, with extensive experience in designing and implementing complex, data-intensive systems. He specialises in translating business needs into user-friendly, intuitive, and robust software solutions, demonstrating expertise across the entire development stack. His skill set spans database design, system integrations, business logic development, and front-end UI creation. Combining technical proficiency with a user-centred approach, he focuses on delivering high-performance, scalable applications that address real-world challenges. His role at Scania allows him to contribute to the development of innovative systems that drive efficiency and usability in the automotive industry.

Lars Hanson is a Professor at the School of Engineering Science at the University of Skövde. His research specialises in user-centred product and production development, focusing on digital human modelling and wearable technology to measure ergonomic exposure. His work is enhancing the integration of ergonomic principles into the design and development processes, aiming to improve both product functionality, manufacturing process and user well-being. In parallel with his academic position, he holds a position in the automotive industry, where he is dedicated to advancing automation, digitalisation, and simulation. This dual role enables him to effectively bridge the gap between research and real-world applications, driving innovation and efficiency in both sectors.

Johan Sandblad works as a European Ergonomist at Scania CV AB. He trains and supports designers, technicians, and ergonomic assessors in performing ergonomic assessments. This involves product design, equipment, and risk assessments during daily operations. He also works in the department responsible for maintaining the Scania Ergonomic Standards (SES) and collaboration with universities. He combines the maintenance of ergonomic methods with hands-on operational ergonomic work in daily operations, creating a balanced and effective approach to improving workplace ergonomics.

Anna Syberfeldt is a Professor at the School of Engineering Science at the University of Skövde. She leads the research group Production and Automation Engineering, which consists of approximately 40 researchers specialising in virtual engineering. The group's research is primarily applied and conducted in close collaboration with industrial partners, mainly in the manufacturing industry, as well as with partners in the public sector. As the Research Manager, she holds overall responsibility for the scientific quality and development of the group, including setting research strategies, ensuring academic excellence, securing relevant recruitments, planning publications, and applying for external funding.

Mikael Forsman is a Professor of Ergonomics and Head of the Division of Ergonomics at CBH, KTH – Royal Institute of Technology. He works both in field and lab projects, often in collaboration with practitioners to develop smart methods to measure physical work exposure. His interests also include psychosocial exposures since there is an association between these and physical health. He is also contributing to the area of occupational medicine by teaching and supervising PhD students.

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1 Introduction

Industry 5.0 focuses on human well-being by integrating cutting-edge technologies to automate tasks and enhance industrial efficiency, emphasising a symbiotic relationship between humans and machines in production processes (Xu et al., 2021). The concept of Operator 5.0 is central to this new paradigm, representing the human operator of the future, who is empowered with new skills and tools to interact seamlessly with advanced technologies (Mourtzis et al., 2022). As Industry 5.0 progresses, it marks a new era in which human potential and technological innovation unite to balance human well-being with productivity.

Conversely, work-related musculoskeletal disorders (WMSDs) are prevalent health issues among industrial operators (Kok et al., 2019). The operators are subjected to a variety of physical strains, such as manual handling, repetitive movements, awkward postures, considerable muscular force and vibration, leading to WMSDs in various body parts (Bonfiglioli et al., 2013; Burt et al., 2013; Kok et al., 2019; Seidler et al., 2009). This not only impacts the well-being of operators but also imposes substantial costs on enterprises and society at large (Eklund, 1995; Kok et al., 2019; Kolus et al., 2023).

During the operational phase of industries, the musculoskeletal risk assessors follow WMSD risk assessment methods to uphold operator well-being. The observational methods represent the most prevalent approach (Gonçalves et al., 2022; Takala et al., 2010) in industries for identifying risks of WMSDs, offering advantages such as ease of use, applicability to a wide range of working situations and low costs (David, 2005; Diego-Mas et al., 2015; Genaidy et al., 1994; Vedder, 1998). Observational methods are based on direct observation or a video recording of an operator during the course of work (David, 2005). For detailed postural analysis, using the conventional manual method, a video recording of an operator is scrutinised to determine the number of repetitions or the duration of awkward postures per body segment with the help of stop watches and manual counters; the findings are then fed into an assessment template on a sheet of paper or, e.g., in Excel (Maldonado-Macías et al., 2015).

Diego-Mas et al. (2015) have identified several challenges associated with the use of observational methods. One of the primary challenges is the lack of training among practitioners in the use of ergonomic analysis tools and correct interpretation of results. Another challenge is the cost of the time required for observations. The issues of significance include the difficulty practitioners face in interpreting and practically applying the results obtained from observational methods. Key demands include the ease of interpretation of results, their usefulness in identifying problems and their ability to guide the determination of causes and possible resolutions. These demands are crucial in demonstrating the need for workplace improvements to managers and encouraging changes in the work system within their organisation. Furthermore, Forsman and Lind (2019) emphasise the necessity for improving the user interface to ensure that the methods are user-friendly.

There have also been specific studies, such as Rhén and Forsman (2020), Nyman et al. (2023) and Forsman and Lind (2019), that have indicated moderate intra-rater and inter-rater reliability concerning observational methods. Furthermore, Eliasson et al. (2019) assert that musculoskeletal risk assessors need support to effectively employ research-based, observation-oriented risk assessment tools in industrial settings. Although ProAnalyst (Xcitex Inc.) has been applied in fields such as gait analysis and athletic performance to study human and animal motion, it does not cater to the unique challenges of video-based physical risk assessment in industrial settings or to the needs of musculoskeletal risk assessors. Notably, past endeavours, such as those by Kadefors and Forsman (2000), Paquet et al. (2006), Pinzke (1994), Yen and Radwin (1995, 2007) and Radwin et al. (2023) aimed to devise digital tools for video-based risk assessment. However, these attempts encountered challenges, including complexity in usage, steep learning curves and resistance to incorporate automation and, at the time of these studies, validity of automation. Recognising these imperfections underscores the critical need for innovative digital solutions to address the deficiencies in video-based musculoskeletal risk assessment processes.

The aim of this study was to compare the usability of a newly developed video-based awkward posture identification software, the ergonomist assistant for evaluation (ERAIVA) with that of a conventional manual method.

2 Method

2.1 The included ergonomic risk assessment method

The risk management assessment tool for manual handling proactively (RAMP), an observation-based assessment tool for screening and assessing major musculoskeletal exposures in industrial manual work, was chosen for this study (Lind et al., 2020). The RAMP tool for assessing the musculoskeletal disorder risk has garnered global recognition and adoption by occupational safety and health (OSH) service providers in Sweden and multinational manufacturing industries, as highlighted by Rose et al. (2020). RAMP comprises 35 assessment items grouped in seven categories:

1. postures
2. work movements and repetitive work
3. lifting
4. pushing and pulling
5. influencing factors
6. reports on physically strenuous work
7. perceived physical discomfort.

In this study, the first category of RAMP, postures, was chosen due to its predominant role in terms of time consumption and its iterative nature. This selection was informed by discussions with industrial experts specialising in musculoskeletal risk assessments. In addition, for this study, the musculoskeletal risk assessors used RAMP for risk assessment of the work task in the video recording.

2.2 The newly developed ERAIVA

ERAIVA is a web application developed in collaboration with industrial musculoskeletal risk assessors using. Net technology stack. Figure 1 illustrates the workflow of the ERAIVA web application, detailing the interaction between the user (musculoskeletal risk assessor), computer and various backend components.

The process begins with the assessor (1) uploading a video intended for an assessment, which is stored on a file server. Next, the assessor (2) accesses the ERAIVA application through a browser on their computer to initiate the risk assessment process. The application code in the application server (3) retrieves the uploaded videos from the file server (4), which are (5) processed by the assessor to perform the necessary risk analysis. During the risk assessment, (6) the results are simultaneously sent to the application logic to (7) be stored in application code. This architecture streamlines the video-based musculoskeletal risk assessment process by integrating user interaction with automated backend processing and data storage functionalities.

Figure 1 High-level architecture of the ERAIVA application

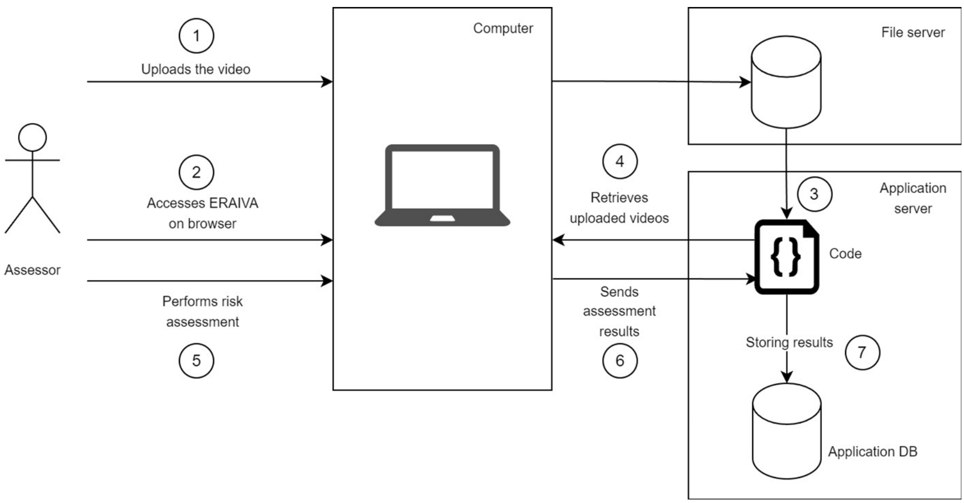
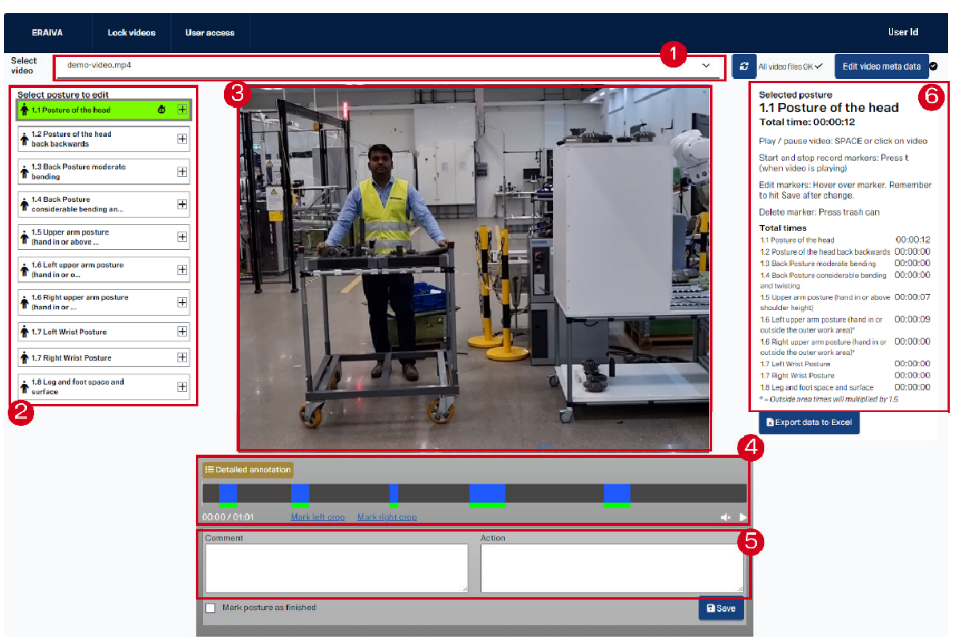


Figure 2 ERAIVA user interface with five components: (1) dropdown menu (2) ramp sections (3) video (4) video timeline (5) notes (6) results (see online version for colours)



The assessor (5) performing risk assessment with ERAIVA in Figure 1 is explained in detail using Figure 2. The user interface of ERAIVA comprises six distinct components, as shown in Figure 2. At the top (1), a dropdown menu lets the assessor select the video intended for assessment. The left panel (2) provides information pertaining to the posture category of RAMP, with the ability to access specific details by clicking on the relevant section. The central area (3) displays the video, enabling the assessor to observe and analyse the worker's movements. Below the central area, the video timeline (4) presents the annotations of awkward postures identified by the assessor in blue colour bars. At the bottom, (5) two textboxes provide options to the assessor to add comments and required actions regarding the identified awkward postures. The right panel (6) presents the identified durations of awkward postures for each RAMP section.

The assessor interacts with the user interface of ERAIVA in the following way. The assessor selects the video for assessment from the dropdown menu, followed by selection of a RAMP section from the left panel. The selected RAMP section is highlighted on a green background. To annotate awkward postures on the video timeline, the letter 'T' on the keyboard has to be pressed to signify the commencement and conclusion of the annotation process. The duration of the awkward postures detected for the selected RAMP section is automatically stored and displayed on the right pane.

2.3 Participants included in the evaluation

Four assessors who were responsible for conducting RAMP assessments in a manufacturing industry volunteered to participate. These same assessors served dual roles: offering feedback during the developmental phase and participating in the subsequent evaluation process. These participants were industrial musculoskeletal risk assessors with varying experience in musculoskeletal risk assessment; they were invited to ensure that the software meets the practical needs and standards of the industry. Detailed information regarding the participants is presented in Table 1.

Table 1 Participants' characteristics

Assessor ID	*Role*	*RAMP experience (years)*	*Educational background*	*Industrial experience (years)*
1	Ergonomist	13	Bachelor of Science in Physiotherapy, Master of Physiotherapy, Master in Occupational Health and Work Environment	13
2	Ergonomist	2	Bachelor of Science in Physiotherapy, Master of Medical Science: Ergonomics (ongoing)	10
3	Production technician	6	Higher vocational education, internal courses on RAMP	7
4	Production technician	1.5	Higher vocational education, courses on RAMP	1.5

2.4 Assessed video-recorded work tasks

Table 2 shows the description of the tasks that the operator performed in each video.

The video recordings were captured during the routine activities of operators engaged in manufacturing work tasks. It is noteworthy that diverse operators were involved in the execution of each video.

Table 2 Information about videos

Video id	*Video length*	*Description of the work task*
1	2 mins 16 secs	Pickup a seat holder plate and place it on a fixture. Pick up the driver seat from the logistics rack with the help of the lifting device and move it to the fixture. Connect the cables. Remove the plastic cover. Tighten two screws in the front and two at the back of the driver seat to the seat holder with the help of a tightener. Move the car seat to another fixture to take it to the next station
2	4 mins 21 secs	Pull the cart to load parts from the storage racks. Pick a part and load it in the corresponding location of the cart. Repeat this for 29 other parts. Station the cart back to its initial position
3	3 mins 5 secs	Walk to the logistics rack and pick up the parts. Walk to the fixture and fix the parts. Walk to the next station. Pick up the parts and load them on the fixture
4	1 min 30 secs	Detach a rack full of parts from the tugger train. Detach the empty rack from the line and attach it to the tugger train. Attach the rack full of parts to the line. Replace a box of parts to feed the line with the empty box. Repeat the last step one more time

2.5 Experimental setup

In order to evaluate the usability of ERAIVA, four experienced musculoskeletal risk assessors were tasked with evaluating four videos using both conventional manual methods and the ERAIVA approach. Before their first evaluation, all assessors received an introduction on how to use ERAIVA. Each assessor carried out eight assessments, making it a total of 32 assessments. To minimise potential bias due to sequence effects, the videos and their corresponding assessment techniques were maintained in a randomly-balanced order throughout this study.

2.6 Evaluation metrics

In order to evaluate the user friendliness, a standardised user-experience measuring questionnaire, the post-study system usability questionnaire (PSSUQ) was chosen (Sauro and Lewis, 2016). The PSSUQ consists of 16 statements which the user rates on a Likert scale from 1 to 7, with lower scores indicating a higher degree of satisfaction. These 16 statements yield four distinct sub-scores, encompassing overall quality, system usefulness, information quality, and interface quality. The PSSUQ questionnaire was chosen since the statements are easy to comprehend. A useful way to interpret the PSSUQ scores is to compare them with the ones from similar products or processes (Sauro and Lewis, 2016). Consequently, after the conclusion of their assessments, the assessors were assigned the responsibility of filling out the PSSUQ for both the conventional manual method and the ERAIVA method. This preliminary qualitative study included a focused sample of four industry experts. According to Nielsen and Landauer (1993), a sample of three to five users is typically sufficient to identify usability issues in an early-stage investigation.

To understand the effect of a digital tool on the process of detecting awkward postures, it is essential to examine several metrics. These metrics include the time taken for assessment, the number of video replays, the number of deletions of video annotations and the duration of observed awkward postures according to the RAMP framework. The assessors replay certain video sequences in which awkward postures are identified. Analysing the count of video replays helps ascertain whether the assessor finds it intuitively beneficial to review specific portions of the video more than once due to the difficulty in observing multiple body angles simultaneously. Additionally, the ERAIVA system allows assessors to self-review and delete the annotations. The number of deletions made by the assessors serves as an indicator of an intention to be accurate in their assessments. These metrics were analysed with descriptive statistics. For statistical hypothesis testing with paired samples, the Wilcoxon signed-rank test (Rey and Neuhäuser, 2011) was chosen. A significance level of 0.05 was used. The null hypothesis is considered as no significant difference between paired observations.

3 Results

3.1 Qualitative assessment

Table 3 presents PSSUQ scores for the current manual method and the ERAIVA system. ERAIVA scored higher in every category of PSSUQ, such as system usefulness (questions 1 to 6), information quality (questions 7 to 12), interface quality (questions 13 to 15) and overall (questions 1 to 16).

Table 3 PSSUQ results for manual method and ERAIVA

PSSUQ items	*Manual method*	*ERAIVA*
System usefulness (statements 1 to 6)	3.0	1.4
Information quality (statements 7 to 12)	4.0	1.9
Interface quality (statements 13 to 15)	4.0	1.5
Overall (statements 1 to 16)	4.0	1.5

3.2 Quantitative assessment

3.2.1 Time used for assessment

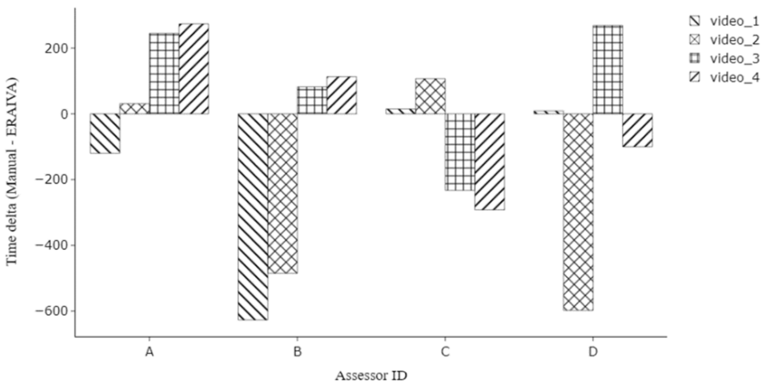
The time used to complete the assessment was measured for all 32 assessments. Subsequently, the delta value, representing the disparity in completion time between assessments conducted via the manual method and ERAIVA, was computed for each video. A positive delta indicates that the duration of assessment completion is reduced when using ERAIVA compared with the manual method, while a negative delta signifies the opposite scenario. According to the findings presented in Table 4, it can be observed that when utilising ERAIVA, assessors B, C and D on average tended to spend more time completing assessments. The maximum delta value recorded was 274 seconds, while the minimum value was –627 seconds. Additionally, Figure 3 depicts that out of the 16 delta values, 9 showed a positive trend.

In the context of the Wilcoxon signed-rank test, the calculated p-value was 0.56, not falling below the predetermined significance threshold of 0.05. Consequently, the null hypothesis, asserting no disparity in the distribution of time taken for assessment between the manual method and the ERAIVA software, could not be rejected.

Table 4 Delta values (the manual method minus the ERAIVA software) in seconds between assessments conducted via the manual method and ERAIVA

Assessor ID	*Mean*	*Maximum*	*Minimum*
A	107.50	274	–120
B	–229.25	113	–627
C	–100.75	107	–292
D	–105.00	269	–598

Figure 3 Time delta between manual method and ERAIVA (in seconds)



3.2.2 Number of replays

Table 5 shows that, on average, assessors employed the ERAIVA method to replay video content approximately three times more often than the conventional manual approach. Notably, Table 5 reveals that specifically Assessor C did not utilise the manual method for replaying videos.

Table 5 Descriptive statistics of number of replays

Assessor ID	*Manual method*		*ERAIVA*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
A	3.3	3.9	15.5	13.5
B	3.3	3.3	9.3	3.0
C	0.0	0.0	6.0	4.2
D	0.5	1.0	4.8	1.9

Utilising the Wilcoxon signed-rank test, a p-value was computed to assess the null hypothesis positing no disparity in the distribution of replay frequencies between the manual method and the ERAIVA software. The resultant p-value was 0.01, falling below the predetermined threshold of 0.05. Consequently, the null hypothesis is rejected in this instance.

3.2.3 Number of annotation deletions

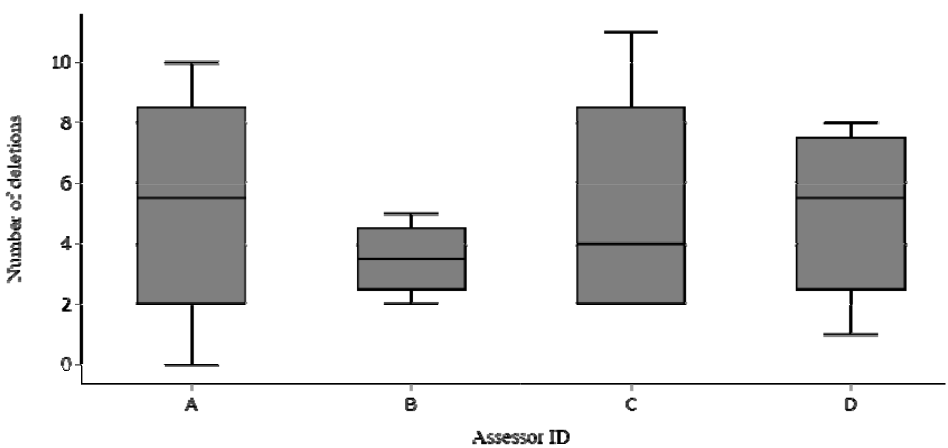
ERAIVA offers the ability for assessors to conduct self-reviews of their annotations and provides the option to delete them. On average, assessors A, C, and D utilised this feature at least five times per video during the assessment, whereas assessor B utilised it three times per video as shown in Table 6. In contrast, the manual method lacks this functionality; therefore, a comparative analysis between the two methods was not carried out in this regard.

Table 6 Number of annotation deletions

Assessor ID	*ERAIVA*	
	Mean	*Standard deviation*
A	5.3	4.3
B	3.5	1.3
C	5.3	4.3
D	5.0	3.7

Figure 4 shows that the distribution of annotations deleted varies from one assessor to another.

Figure 4 Distribution of annotation deletions among assessors

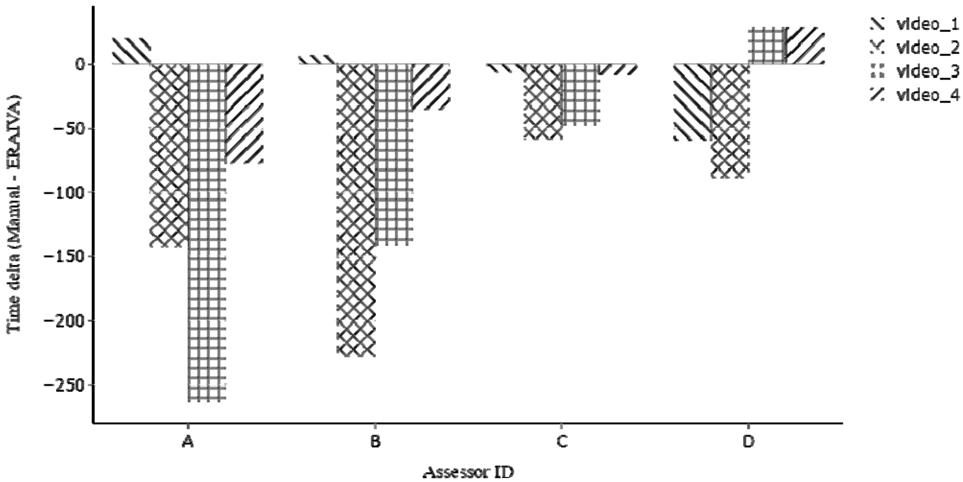


3.2.4 Duration of awkward posture detection

The delta value, denoting the difference in the duration of awkward postures between assessments performed using the manual method and ERAIVA, was calculated for each video, as shown in Figure 5. A positive delta indicates a decreased duration of awkward postures when employing ERAIVA as opposed to the manual method, whereas a negative delta signifies the opposite scenario.

Figure 5 illustrates that, in 12 out of 16 assessments, the duration of identified awkward postures was longer when utilising ERAIVA as opposed to utilising the manual method. Additionally, the average delta value for all 16 assessments was –66.6 seconds with a standard deviation of 87.9 seconds. Hence, the ERAIVA times were significantly longer than the manually obtained times.

Figure 5 Awkward posture duration (manual – ERAIVA)



4 Discussion

ERAIVA's user interface comprises merely six essential elements tailored specifically to the RAMP evaluation procedure, thereby adhering to principles of minimalism. Careful consideration was given to the arrangement of these components to ensure their intuitiveness for users. Notably, ERAIVA mirrors conventional manual methods while eliminating the need for physical tools, thus making it more accessible to assessors seeking to adopt this technology. Due to the potential size of video recordings surpassing one gigabyte, direct copy-paste to an internal file server proves significantly more expeditious than online uploads via the internet.

The PSSUQ results from Table 3 indicate that ERAIVA consistently outperformed the manual approach across all four PSSUQ scores, achieving scores twice as good. Notably, within ERAIVA's scores, information quality received the highest rating, suggesting room for further improvement. In the initial evaluations, assessors overlooked clicking on a RAMP section in the left panel before commencing their annotations. Consequently, they encountered a pop-up error message. However, this oversight was recognised in subsequent evaluations by the assessors, highlighting the adaptability and learning curve of the ERAIVA system. The results revealed that a digital software application such as ERAIVA has potential benefits in enhancing the effectiveness of musculoskeletal risk assessment and ultimately helping to create a better work environment for musculoskeletal risk assessors.

In examining the time taken to complete assessments, the descriptive statistics and p-value showed no significant difference between the manual and the ERAIVA methods. The inherently higher usability of ERAIVA motivated assessors to engage in frequent self-reviews of their work. Two self-review actions measured in this study are replaying the video and deleting annotated segments. As shown in Table 5, assessors demonstrated a preference for replaying annotated segments in the video when using ERAIVA compared with the manual method. This preference stems from the limitation in the manual method, where the assessors, after having rated the total time in an awkward posture, only have input time regarding the total duration of awkward postures identified for a RAMP section without the exact location of the annotation on the video timeline. ERAIVA, on the other hand, provides assessors with a new feature allowing them to delete annotations if deemed incorrect. Table 6 illustrates that all assessors utilised this functionality. The improved usability and the capability for self-review in ERAIVA have led to an increased duration in the detection of awkward postures, as shown in Figure 5.

The qualitative and quantitative results have shown the improved ease of use with ERAIVA when compared with conventional manual methods, as asked for by Forsman and Lind (2019). A minimalistic user interface and transparency in assessment has potential to enable not only musculoskeletal risk assessors but also engineers and operators in industries to perform awkward posture detection. ERAIVA's advantage extends to improved communication, as it may enable assessors to visually articulate and discuss their findings more effectively with peers and operators. Furthermore, ERAIVA simplifies the process of receiving reviews or feedback on assessments from peers. Notably, experienced ergonomists involved in the study identified the potential for ERAIVA to be utilised in training new assessors, showcasing its versatility beyond assessment facilitation. Therefore, ERAIVA could overcome the challenges mentioned by Diego-Mas et al. (2015). Also, software such as ERAIVA effectively employs research-based, observation-oriented risk assessment tools in industrial settings as suggested by Eliasson et al. (2019).

The distinctiveness of this study lies in its experimental setup, which was conceived and executed in an industrial context and from an end-user perspective. The study's videos feature real industrial operators engaged in their official tasks, showcasing natural body movements without any pre-informed instructions for the research. Additionally, the assessors involved in this study are professional musculoskeletal risk assessors employed in the industry. However, the industrial context and the use of assessors employed in the industry impose a limitation on the attainable sample size, which was limited to four assessors. Although there are other studies concerning methods for risk assessment that also have used a low number of assessors (1–4) (Dahlgren et al., 2022; Palm et al., 2016; Radwin et al., 2023), this does, of course, limit the confidence and generalisability of the results.

A future study with a larger sample size is recommended to enhance the robustness and rigour of the results. Furthermore, ERAIVA should be evaluated across multiple observational risk assessment methods and industries. Additionally, its potential to integrate contact-based and contactless methods for automatic identification of awkward postures should be tested.

5 Conclusions

The usability of ERAIVA outperformed that of conventional manual methods, and its impact demonstrated significant advantages for musculoskeletal risk assessors. This study indicates that the ERAIVA software application improves the working process for musculoskeletal risk assessors by eliminating measurement errors associated with manual observations of joint angles and the use of stopwatches. Furthermore, ERAIVA enables self-review of work and the ability to explain assessments to peers, thereby improving the overall effectiveness in identification of postural risks of WMSD. In summary, the incorporation of digital software in musculoskeletal risk assessment aligns with Industry 5.0 by promoting a collaborative human–machine partnership, reducing errors and increasing efficiency. This research underscores the essential role of digital software applications in assessing musculoskeletal risks in the context of industrial work.

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