Comparison of Quick Eksposure Check (QEC) and Nordic Body Map (NBM) in Traditional Broom Workbench Design

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Abstract
Purbalingga and Magelang are producer of traditional woven brooms. Based on preliminary observations, workers carry out their activities manually using current workstations with repetitive work postures. Workers feel MSD disturbances or pain in the back, waist, neck, and hands. A new workstation has been made with adjustments to the workstation's height, the slope of the back of the chair, the displacement of the seat (forward or backward), and adding a tool to roll the yarn, RULA work posture analysis has been measured. This study compares MSD complaints and works posture at the current workstation and the new workstation using QEC and NBM method. The NBM method's result shows improvement after using new workstations than the previous workstations. The average complaint rate for MSD decreases from 55.56% to 33.33%. This result because the bent back position is minimized, the back position is no longer bent when using the new workstation. The average QEC exposure level value also decreases from 66% to 61%. The Wilcoxon test results show significant differences in NBM complaints (0.036) and QEC exposure level significant differences (0.014). In addition to experiencing a decrease in the level of MSD complaints. The right leg experienced an increase in the level of MSD complaints. They are indicating that NBM can be used to detect design errors.

Keywords
Brooms, MSD, QEC, NBM, Workstation.

1. Introduction
Purbalingga Regency and Magelang, Central Java Province are the center of traditional broom production (Dewi 2017; Selvi 2019; Sularso, Satriani, and Hidayat 2014). Based on the 2016-2021 Purbalingga District Medium-Term Development Plan (RPJMD), the traditional broom is one of Purbalingga's superior products (Pemerintah Kabupaten Purbalingga 2016). IKM Sapu GWHC Purbalingga is an IKM that produces sorghum brooms. Based on preliminary observations, workers are still doing their activities with repetitive work postures in a non-ergonomics workstation. Musculo Skeletal Disorders (MSD) affected workers with a heavy burden, repetitive motion, awkward postures, and work sitting (Sutari et al. 2015).

Efforts have been made to transfer technology from simple equipment to facilitate the production process, improve product quality and quantity (Priswanto, Supriyanti, and Murdyantoro 2017). However, the efforts made have not considered the ergonomics aspect, adjusting the work to the craftsman's ability. Currently, traditional broom workers have experienced MSD or pain in the back, waist, neck, and hands. For improvement, a new workstation has been created with adjustments to the workstation's height, adjustment of the inclination of the soft seat back, adjustment of the seat distance displacement (forward or backward), and adding a tool for winding yarn.

There are several methods to measure work posture, namely the Ovako Working Posture Analysis System (OWAS) (Karhu, Kansi, and Kuorinka 1977), Rapid Entire Body Assessment (REBA) (Hignett and Mcatamney 2000), Rapid Upper Limb Assessment (RULA) (Mcatamney and Corlett 1993), Rapid Office Strain Assessment (ROSA) (Sonne, Villalta, and Andrews 2012), and Quick Exposure Check (QEC) (David et al. 2008). Comparison of the commonly used techniques, namely OWAS, REBA, RULA, and ROSA methods, have been carried out. REBA updates the OWAS method, RULA updates the REBA method. The RULA method is updated by the ROSA method. Meanwhile, ROSA method focus on activities in the office (Sonne et al. 2012). From the comparison, the RULA method is the best system for estimating the postural loads and work-relatedness of MSD rather than OWAS and REBA (Kee 2021).

The RULA method is suitable with the broom production workstation to assess upper work posture. There are studies about the measurement of work posture on a broom production made of fibers (Dewi 2017) and sorghum (Uletika, Krisnawati, and Musmuallim 2017) using RULA method. However, the study has not assessed the complaints of MSD in workers

The QEC brings together the practitioner and the worker to make the assessment only in 10 minutes, prompting improvements and evaluating the benefits (reducing exposure to WMSD risk factors) by providing a structured process to help prioritize the need for change (David et al. 2008). Based on the results of comparing the QEC and RULA methods, the QEC method proved to be less stringent in assessing overall risk, classifying 35% of the workstations as high risk compared to RULA with 76% (Chiasson et al. 2012).

Method to find out about of 28 part of the body symptoms MSD complaints (Widyanti 2018) were the Nordic Body Map (NBM) questionnaire (Kuorinka et al. 1987) with the level of complaints ranging from Not Sick (TS), slightly sick (AS), Sick (S) and Very Sick (SS). The NBM questionnaire is often used because it is easy, standardized, and neatly structured. A significant relationship between work posture measured with REBA and Musculoskeletal Disorders (MSD) complaints in Indonesian weavers measured with NBM, common complaints are the elbows, the neck, the hands, and the buttocks (Mallapiang et al. 2021).

Based on the explanation above, this study will measure the MSD complaints using the NBM questionnaire and work posture measurements using the QEC method at the old workstation and the new workstation at IKM Sapu GWHC Purbalingga. The formulation of the problem in this research includes: how are the results of NBM and QEC at IKM Sapu GWHC Purbalingga at old workstations and new workstations? How is the difference between MSD complaints and work posture at the old workstation and the new workstation? Based on the formulation of the problem, it can determine that the objectives of this study are to determine the complaints of workers' musculoskeletal disorders (MSD) and to measure work posture at IKM Sapu GWHC Purbalingga at the old workstation and new workstation.

2. Literature Review

In industries, workers performing manual operations are subjected to musculoskeletal disorders (MSD) (Sylla et al. 2014). Musculoskeletal Disorders (MSD) are a series of pain in the tendons, muscles, and nerves. Activities with a high repetition rate can cause tissue damage, leading to pain and discomfort in the muscles, either in the skeletal muscle. Felt by a person ranging from very mild to very painful complaints, if the muscles receive static loads repeatedly for a long time, it can cause complaints in the form of damage to joints, ligaments, and tendons. MSD causes workers to become ill, lowers job quality, and cannot continue the work (Sutari et al. 2015).

The Nordic Body Map (NBM) is a tool that can identify the parts of the muscles that are experiencing complaints with the level of complaints ranging from No Pain (TS), slightly sick (AS), Pain (S), and Very Painful (SS). NBM is an instrument to assess the body segments that the operator feels (according to the operator's perception), whether they with the standards of no complaints (score: 28), delicate complaints (score: 29–56), moderate complaints (score: 57–84), and high complaints (score: 85–112) (Mallapiang et al. 2021). With the NBM questionnaire, it can be seen which muscle parts are experiencing complaints, with the level of complaints ranging from painless to very painful (Nigel Corlett 2005).

The Quick Exposure Check (QEC) is a tool for assessing work-related musculoskeletal disorders (WMSD) in the workplace. QEC assesses risk disorders in the back, shoulder/arm, wrist (hand/ wrist), and neck (Stanton et al. 2005). Assessment of work posture using the QEC method is carried out from two sides. The first assessment is based on an observer's assessment (Observer's Assessment) by filling out an Observer's Assessment Checklist. The second is based on a Worker's Assessment by completing a Worker's Assessment Checklist (Stanton et al. 2005).

The Quick Exposure Check (QEC) already used in different work task (David et al. 2008; Oliv et al. 2019), occupational groups at a hospital (Ericsson, Björklund, and Wahlström 2012), taxi drivers (Bulduk et al. 2014), and tower crane operators (Ibrahim et al, 2020).

Table 1 show ergonomic comparation analysis method. Study comparing the Nordic Body Map (NBM) and Rapid Upper Limb Assessment (RULA) were the most common method used. In the food products industry of amplang

(Cahyadi, Muis, and Etwin 2018), engine tune up practice (Noor et al. 2020), office working environment (Widodo and Saptadi 2020), manual harvesting peasan (Sa'diyah, Maksum, and Mulyati 2021), and cracker industry (Ayu and Ratriwardhani 2021). Only two studies either used NBM and QEC respectively, production process of plastic spoons (Sukania et al. 2020) and breeding hens (Milania et al. 2021).

Table 1. Ergonomic comparation analysis method

	Different work task	Packaging fertilizer producer	Food industry, engine tune up office working environment, manual harvesting peasan, and cracker industry	Construction workers	Bag production	Plastic spoons production	Breeding hens
Quick Exposure Check (QEC)	√			√		√	√
Nordic Body Map (NBM)		√	√		√	√	√
Rapid Entire Body Assessment (REBA)	√				√	√	
Rapid Upper Limb Assessment (RULA)	√		√	√			
Workplace Ergonomic Risk Assessment (WERA)					√	√	
Occupational Repetitive Actions (OCRA) Index	√	√					
Ergonomic Workplace Analysis by the Finnish Institute of Occupational Health (FIOH)	√						
ACGIH's Hand Activity Level threshold limit values method (HAL)	√						
The Job Strain Index (JSI)	√						
The EN 1005-3 standard	√						

3. Methods

The data collected in this study are primary data generated by filling out the NBM questionnaire, measuring work posture using the QEC method, interviews, and documentation.

3.1 Determining the Population and Sample Research

The population in this study were six male professional weavers workers at Brooms SME GWHC Purbalingga who produced traditional brooms manually participated in this phase of the study with a productive age (15-54 years) with more than 5 years broom production experience.

3.2 Retrieval and Processing of NBM Questionnaire at the Old Workstation

At this stage, the NBM questionnaire data collection and processing will be carried out to find out worker MSD complaints using the old workstation. Data retrieval is carried out in the afternoon after the worker has finished working.

3.3 Measurement of Work Posture using the QEC method on the Old Workstation

At this stage, work posture measurements will be carried out using the Quick Exposure Check (QEC) method to find out how the work posture is when using the old workstation. The steps in measuring work posture using the QEC method are:

1. Collecting questionnaire data filled out by observers and operators at one workstation.
2. Process the questionnaire data that has been taken to calculate the exposure score of each observed limb, the back, shoulders/arms, wrists, and neck. The level of risk of injury to the limb is based on the obtained exposure score.
3. Calculate the exposure level to determine what actions to take based on calculating the total exposure score.

3.4 Training using the New Workstation

In the previous studies, the weavers performed their normal weaving task each session of 45 min followed by breaks of 15 minutes (Choobineh et al. 2007). In this study, workers carry out training in work hours for three days to know the impact or difference of using old workstations and new workstations. Old and new workbench shows in Figure 1.

Figure 1. Old (left) and new (right) workbench

3.5 Retrieval and Processing of NBM Questionnaire on the New Workstations

At this stage, the NBM questionnaire data collection and processing will be carried out to determine workers' MSD complaints using the new workstation. Data retrieval is carried out in the afternoon after the worker has finished working.

3.6 Measurement of Work Posture using the QEC method on the New Workstation

At this stage, work posture measurements will be carried out using the Quick Exposure Check (QEC) method to find out how the work posture is when using a new workstation. The steps in measuring work posture this time are the same as measuring work posture at the old workstation.

3.7 Recapitulation of NBM and QEC Data on Old Workstations and New Workstations

At this stage, data on the results of NBM and QEC on the old workstation and the new workstation will be recapitulated in order to facilitate the next stage.

3.8 Normality Test and Difference Test

Data normality test is used to test data whether the data is normally distributed or not. Normality needs to be checked for many statistical procedures, namely parametric tests, because their validity depends on it, especially for small samples (< 30 or 40) (Ghasemi and Zahediasl 2012). There are different methods used to test the normality of data, including numerical and visual methods. The Kolmogorov–Smirnov test and the Shapiro–Wilk test is the most widely used methods to test the normality of the data (Mishra et al. 2017). If the number of research samples is large (>40), the normality test used is the Kolmogorov-Smirnov test, whereas if the research sample is small (<40) (Biercewicz

and Borawski 2020), the normality test used is the Shapiro-Wilk test. This study used Shapiro-Wilk statistical test to check whether the examined features have a similar distribution to normal.

Paired sample t-test is used to test the differences between two paired samples. A Paired sample is defined as a sample with the same subject but has experienced two different treatments, namely before and after the process. Paired sample t-test is used when the data is normally distributed. Paired sample t-test is one of the test methods are used to assess the effectiveness of treatment, marked by differences in the average before and after treatment. Statistical tests used to compare two groups (e.g., t-test, Mann–Whitney U-test) and to compare two or more groups (e.g., ANOVA, Friedman test) (Salvendy 2012).

The Wilcoxon test is a test to determine whether there is a difference between two paired or related samples and is used as an alternative to the paired sample t-test if the data is not normally distributed (Salvendy 2012). Two samples are said to be pairs if several subjects are taken from a population, and the same subject is given different treatment.

At this stage, the normality test will be carried out using SPSS software on each of the NBM and QEC results data on the old workstation and the new workstation. Furthermore, a different test is carried out to determine whether there is a difference in the NBM and QEC results data at the old workstation and the new workstation. If the normality test for each data results in a normal distribution, a different test will be carried out using the paired sample t-test. Meanwhile, if the results are not normally distributed, a different test will be carried out using the Wilcoxon test.

4. Data Collection

4.1 Analysis of MSD Complaints Measurement Results using the NBM Questionnaire

Based on the results of the NBM questionnaire, there are differences in the level of MSD complaints as shown in Table 2. The average complaint rate for MSD has decreased where the highest decrease in the level of MSD complaints occurred on the back from 55.56% to 33.33%. This happens because when using the new workstation, the bent back position can be minimized, the back position is no longer bent so that it can reduce the level of MSD complaints in that section.

In addition to experiencing a decrease in the level of MSD complaints. The right leg experienced an increase in the level of MSD complaints. The highest increase in MSD complaints occurred in the right ankle from the previous 5.56% to 33.33%. When using a new workstation, the right ankle often holds back to not step on the pedal—this result indicates a design error in the manufacturing workstation. The pedal should be stepped on occasionally when it is necessary to stretch the thread, but in reality, the pedal should always be stepped on and only released when stretching the thread.

Table 2. Recapitulation of NBM questionnaire

Worker Complaint	Old Workstation	New Workstation	Change	(%)
Neck	38.89%	33.33%	Decrease	5.56%
Nape	38.89%	33.33%	Decrease	5.56%
Left shoulder	33.33%	33.33%	Decrease	0.00%
Right shoulder	50.00%	38.89%	Decrease	11.11%
Left upper arm	38.89%	33.33%	Decrease	5.56%
Back	55.56%	33.33%	Decrease	22.22%
Right upper arm	50.00%	38.89%	Decrease	11.11%
Waist	55.56%	44.44%	Decrease	11.11%
Hip	38.89%	33.33%	Decrease	5.56%
But	38.89%	33.33%	Decrease	5.56%
Left elbow	33.33%	33.33%	Decrease	0.00%
Right elbow	33.33%	33.33%	Decrease	0.00%
Left forearm	38.89%	33.33%	Decrease	5.56%
Right forearm	50.00%	38.89%	Decrease	11.11%
Left wrist	33.33%	33.33%	Decrease	0.00%
Hand wrist	38.89%	33.33%	Decrease	5.56%
Left palm	33.33%	33.33%	Decrease	0.00%
Right palm	33.33%	33.33%	Decrease	0.00%
Left thigh	11.11%	11.11%	Decrease	0.00%

Worker Complaint	Old Workstation	New Workstation	Change	(%)
Right thigh	11.11%	27.78%	Increased	16.67%
Left knee	5.56%	0.00%	Decrease	5.56%
Right knee	5.56%	0.00%	Decrease	5.56%
Left calf	5.56%	5.56%	Decreased	0.00%
Right calf	5.56%	11.11%	Increased	5.56%
Left ankle	5.56%	5.56%	Equal	0.00%
Right ankle	5.56%	33.33%	Increased	27.78%
Left foot	0.00%	0.00%	Equal	0.00%
Right foot	0.00%	0.00%	Equal	0.00%

4.2 Analysis of Work Posture Measurement Results using the QEC Method

Based on the QEC exposure level data processing in the previous chapter, there are differences in the QEC exposure level values, as shown in Table 3. The average QEC exposure level has decreased from 66% to 61%, this is because when using a new workstation, the bending work posture can be minimized so that the exposure score is reduced. Therefor the average QEC exposure level value is automatic decrease. The average value of the QEC exposure level is in the value range of 50% - 69%, so that the action level or action that can be taken is that it needs further research and changes.

Table 3. QEC exposure level data

Respondent	Old Workstation	New Workstation	QEC	(%)
1	65%	60%	Decrease	5
2	65%	60%	Decrease	5
3	65%	60%	Decrease	5
4	65%	60%	Decrease	5
5	68%	63%	Decrease	5
6	65%	60%	Decrease	5
Average	66%	61%	Decrease	5

4.3 Analysis of Normality Test Results of NBM Data

Based on Table 3 regarding the MSD complaint data normality test results, the Sig value for the old workstation is 0.002, and the Sig value at the new workstation is 0,000, so that both the Sig value on the old workstation and the new workstation is smaller than 0.05. This shows that the MSD complaint data are not normally distributed.

Table 3. SPSS Output shapiro-wilk normality test on MSD complaints data

Workstation	Kolmogorov-smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Old	0.253	28	0.000	0.868	28	0.002
New	0.378	28	0.000	0.747	28	0.000

[a.] Lilliefors significance correction

4.4 Analysis of Normality Test Results of QEC Data

Based on Table 4 regarding the QEC level exposure data normality test results, the Sig value for the old workstation is 0,000, and the Sig value at the new workstation is 0,000 so that both the Sig value on the old workstation and the new workstation were smaller than 0.05. This shows that the QEC level exposure data are not normally distributed.

Table 4. SPSS Output shapiro-wilk normality test on QEC exposure level data

Workstation	Kolmogorov-smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Old	0.492	6	0.000	0.496	6	0.000
New	0.492	6	0.000	0.496	6	0.000

[a.] Lilliefors significance correction

4.5 Analysis of Different Test Results on NBM Data

Based on the results of the normality test, the MSD complaint data were not normally distributed so that the difference test was carried out using the Wilcoxon test with the following results. Based on Table 5, the Asymp value is obtained. Sig is 0.036, so the value is ≤ 0.05, which means that there is a significant difference in the level of MSD complaints after using the old workstation and the new workstation.

Table 5. Wilcoxon test SPSS output on MSD complaints data

	New Workstation- Old Workstation
Z	-2.096[b]
Asymp.Sig. (2-tailed)	0.036

[a.] Wilcoxon Sign Ranks Test
[b.] Based on positive ranks

4.6 Analysis of Different Test Results on QEC Exposure Level Data

Based on the results of the normality test, the QEC exposure level data were not normally distributed so that the difference test was carried out using the Wilcoxon test with the following results. Based on Table 6, the Asymp value is obtained. Sig is 0.014 so that the value is ≤ 0.05, which means that there is a significant difference in QEC exposure levels at the old workstation and the new workstation.

Table 6. Wilcoxon test SPSS output at QEC exposure level data

	New Workstation-Old Workstation
Z	-2.449[b]
Asymp.Sig. (2-tailed)	0.014

[a.] Wilcoxon Sign Ranks Test
[b.] Based on positive ranks

5. Results and Discussion

Based on the results of research and data processing that has been carried out, the following conclusions can be drawn:

1. Based on the data from the NBM questionnaire after using the old workstation and the new workstation, most MSD complaint rates have decreased and some have increased. The highest decrease occurred in the back from the previous 55.56% to 33.33%, while the highest increase occurred in the right ankle from 5.56% to 33.33%.
2. Based on the data from the QEC exposure level results at the old workstation and the new workstation, the average exposure level value has decreased from the previous 66% to 61%, the average exposure level value is in the value range of 50% -69%. This shows action that can be taken, namely that further research is needed and changes are made.
3. Based on the results of different tests using the Wilcoxon test on the MSD complaint data of workers and the QEC exposure level data on the old workstation and the new workstation, the following conclusions can be drawn. There is a significant difference in the complaint rate for MSD after using the old workstation and the new workstation because of the Asymp value. Sig is 0.036. There is a significant difference in QEC exposure level at the old workstation and the new workstation due to the Asymp value. Sig is 0.014.

6. Conclusion

Based on the research results, NBM can be used to detect design errors. The improvement actually increased the complaints of MSD in the right leg. Hence, it is necessary to improve the manufacture of pedal workstations so that the mechanism does not burden the feet of the craftsmen. For further research on the redesign of work station improvements based on the operator's work posture, with several alternatives that can be done with full factorial and partial factorial considerations.

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