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Design Improvement of a Corndog MSME Worktable to Minimize MSDs Risk Using RULA and NBM Approaches

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ABSTRACT

This study aims to analyze the ergonomic conditions of a corndog workstation and propose an improved table design based on workers' anthropometry. The research was conducted by direct observation, measurement of workstation dimensions and worker anthropometry, and posture assessment using the RULA method and Nordic Body Map (NBM) questionnaire. The results show that both workers obtained a RULA score of 5, indicating the need for further investigation and immediate improvements. The NBM results reveal discomfort in several body parts, including the neck, upper limbs, back, and wrists. Anthropometric analysis indicates a mismatch between table dimensions and workers' elbow height and reach distance, particularly in terms of height and length. Based on these findings, a redesigned worktable with dimensions of 100 × 60 × 90 cm is proposed to better accommodate optimal reach zones and worker characteristics. This improvement is expected to reduce the risk of MSDs, enhance comfort, and improve work productivity. This study contributes by providing an integrated approach combining posture analysis, worker complaints, and anthropometry as a basis for ergonomic workstation design in MSMEs.

Keyword: *Anthropometry, Ergonomics, MSMEs, Nordic Body Map, RULA*

ABSTRAK

Penelitian ini bertujuan untuk menganalisis kondisi ergonomi pada *workstation* usaha *corndog* serta merancang perbaikan desain meja kerja berdasarkan antropometri pekerja. Penelitian ini dikerjakan melalui observasi, pengukuran dimensi meja dan tubuh pekerja, serta penilaian postur menggunakan RULA dan kuesioner *Nordic Body Map* (NBM). Hasil menunjukkan kedua pekerja memiliki skor RULA sebesar 5 yang menandakan perlunya perbaikan, sementara NBM mengidentifikasi keluhan pada leher, lengan, punggung, dan pergelangan tangan. Analisis antropometri menunjukkan adanya ketidaksesuaian pada tinggi dan panjang meja terhadap tinggi siku dan jangkauan pekerja. Oleh karena itu, diusulkan desain meja kerja berukuran 100 × 60 × 90 cm yang lebih sesuai dengan karakteristik pekerja. Perbaikan ini diharapkan dapat mengurangi risiko MSDs, meningkatkan kenyamanan, dan mendukung produktivitas kerja. Penelitian ini memberikan kontribusi dengan menawarkan pendekatan terintegrasi yang menggabungkan analisis postur kerja, keluhan pekerja, dan data antropometri sebagai dasar dalam perancangan stasiun kerja yang ergonomis pada UMKM.

Keyword: Antropometri, Ergonomi, Nordic Body Map, RULA, UMKM

1. Introduction

Micro, small, and medium enterprises (MSMEs) play a crucial role in the economy, particularly for middle- to lower-income communities. In Indonesia, there are approximately 64 million MSMEs contributing around 60% to the national GDP (± IDR 8.5 trillion) and absorbing 97% of the workforce [1]. The food and beverage sector is among the fastest-growing; however, most MSMEs have not yet implemented ergonomic principles in workplace design. Limited knowledge and financial resources often lead to workstations especially worktables being constructed in a simple manner without considering compatibility with workers' characteristics.

Such conditions may result in non-ideal working postures, including bending, excessive reaching, and prolonged elevated arm positions. These postures increase the risk of musculoskeletal disorders (MSDs), reduce comfort and productivity, and may even lead to workplace accidents [2],[3]. Postural assessment can be conducted using the Rapid Upper Limb Assessment (RULA) method, while workers' discomfort can be identified through the Nordic Body Map (NBM) [4]. In addition, ISO 11228-3:2007(E) on ergonomics and manual handling, as well as guidelines from the International Labour Organization, emphasize the importance of aligning work design with workers' capabilities [5]. SNI 9011:2021 can also be used for ergonomic risk assessment because it provides a more comprehensive framework by considering factors such as posture, force, duration, and frequency of exposure [6]. However, RULA remains widely used for evaluating upper-body postures and identifying posture-related ergonomic risks. Although RULA primarily assesses posture at a specific observation period and does not fully account for exposure duration and task frequency, it is considered appropriate for work activities dominated by upper-body movements and workstation design evaluation. Identifying ergonomic risks is important because awkward postures may lead to discomfort and MSDs complaints among workers. Workers experiencing pain or discomfort tend to work more slowly and lose focus, thereby reducing production efficiency [7],[8].

One growing MSME is the corndog business, which represents standing work activities where the worktable serves as the central workspace. However, it still exhibits non-ergonomic conditions, particularly in terms of table dimensions and layout. To date, there is no specific standard reference for worktable dimensions in this type of business, and previous studies remain limited to separate analyses of posture or worker complaints.

Based on these issues, the research problem is the mismatch between worktable dimensions and layout, leading to non-ideal postures and potential MSDs risk [9]. Therefore, this study aims to identify awkward working postures and propose an ergonomic worktable design based on the anthropometric characteristics and working conditions of the observed operators. Since the proposed design is developed from the characteristics of the observed workers and workplace, it is intended as a a workplace specific solution for the studied corndog outlets. Nevertheless, the ergonomic assessment and workstation redesign approach presented in this study may serve as a reference for similar ergonomic improvement efforts in other small-scale food preparation businesses.

2. Research Methodology

This study begins with a problem identification stage through direct observation at a corndog MSME outlet. A Likert scale assessment is then applied to assign specific scores, where the results serve as a basis for further analysis [10]. The flow diagram of research methodology is shown in Figure 1.

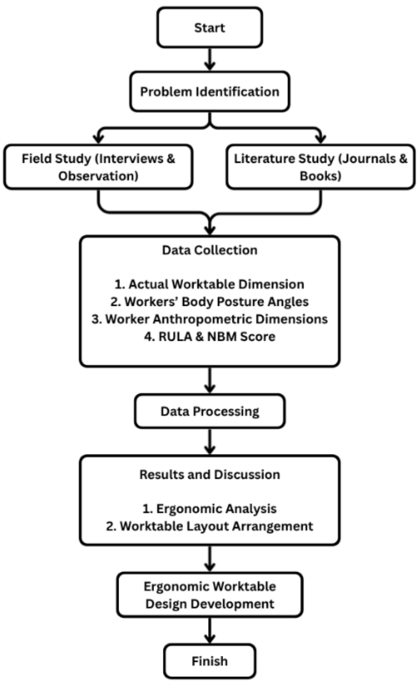


Figure 1. Research Method Flow Diagram

Subsequently, a field study is conducted using interview and observation methods to obtain information regarding work activities and working environment conditions. The next stage involves a literature review to determine appropriate methods and standards for evaluating workplace conditions and workers' ergonomic aspects.

Data collection methods include RULA, NBM, and anthropometric measurements. The NBM method is used to identify body parts experiencing discomfort [11]. The collected data consist of worktable dimension measurements, observation of workers' posture angles during work activities, measurement of workers' body dimensions, and distribution of the NBM questionnaire. Additionally, measuring workers' body angles is necessary as a basis for posture assessment [12].

2.1. Research Procedure

This study begins with the problem identification stage, followed by two initial approaches: field study (through interviews and observation) and literature study (journals and books). Next, data collection is carried out, including worktable dimension measurements, worker posture observation, body dimension measurements, as well as interviews and the NBM questionnaire. The collected data are then processed in the data processing stage to produce results and discussion, focusing on ergonomic analysis and worktable layout arrangement. Based on these results, an ergonomic worktable design is developed as a solution, and the study concludes at the final stage

2.2. Body Posture Observation

The corndog production process in this MSME generally consists of preparation, cooking, and serving stages. However, in the object of this study, the raw materials have been prepared in advance, so the workers' activities are limited to cooking and serving. The cooking stage includes taking the filling, coating it with batter, applying breadcrumbs, frying, and lifting the product. Meanwhile, the serving stage involves packaging, adding sauces, and handing the product to the customer. Among all activities, the coating and serving processes are performed most frequently and require longer durations than other processes.

Therefore, these two activities are the primary focus of posture analysis using the RULA method and are correlated with musculoskeletal complaints based on the NBM questionnaire [13]. In this research, observation was conducted to assess body posture of workers at two corndog outlets. Since the objective of this study was not to compare ergonomic conditions between outlets, each outlet was analyzed separately as an individual case study, and the existing workstation configurations were treated as part of the actual working conditions. To support the ergonomic evaluation and redesign process, workers' body dimensions are measured to obtain anthropometric data, which serve as the basis for evaluating the compatibility between worktable dimensions and workers' physical characteristics. The body postures of the workers are shown in Figure 2.

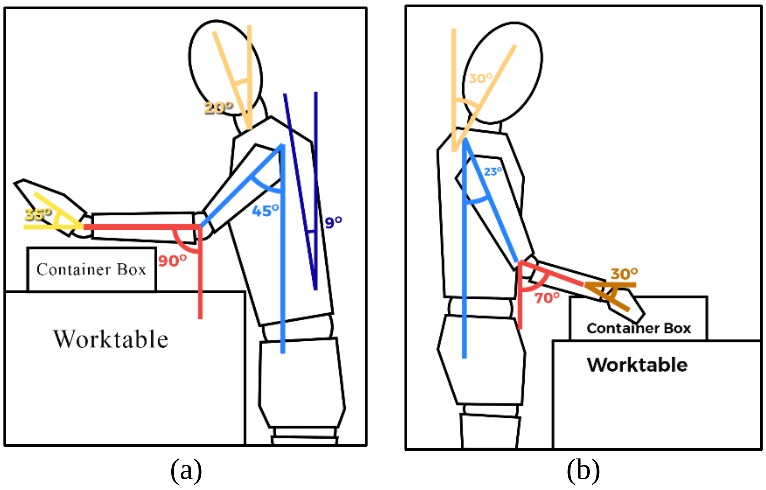


Figure 2. (a) Outlet 1 worker posture; (b) Outlet 2 worker posture.

These sketches illustrate the operators' working postures during the corndog preparation process, where awkward postures in the neck, arms, and wrists may increase the risk of MSDs. Based on the RULA assessment table, the upper arm posture is considered awkward if the angle exceeds 20°. The forearm posture is categorized as awkward when the angle is outside the range of 60°–100°. Furthermore, the wrist posture is considered awkward if the angle exceeds 0°. Neck posture is classified as awkward when the angle is greater than 10°, while the torso posture is considered awkward if there is any inclination greater than 0°. Overall, these postures indicate that the workstations are not ergonomically aligned with the workers' physical conditions, potentially contributing to MSD risks.

2.3. Data Collection

The RULA method was used to assess the risk level of MSDs in the upper limbs based on workers' postures, forces, and movements during work [14]. In addition, the NBM questionnaire was used to identify discomfort or pain reported by workers in various body regions during work activities [13]. An anthropometric approach is also applied to design a worktable that fits human body dimensions, allowing workers to maintain more optimal posture and positioning [4].

Improvements are proposed by modifying the dimensions of the worktable. The determination of worktable dimensions is based on workers' elbow height and reach area. The table height refers to the worker's elbow height, typically set within a range of 5–10 cm below it. The concept of reach zones is essential, referring to areas where objects can be accessed easily without excessive effort, within the natural reach of the user's hands [15]. Furthermore, the workspace is divided into zones: the primary zone ranges from 30–40 cm, the secondary zone extends up to 60 cm from the body for effective task performance, and the tertiary zone is designated for infrequently used areas [16].

Anthropometric observations and measurements are conducted directly on the workers. However, body height data are obtained based on respondents' statements, which may differ from actual conditions. Additionally, elbow height measurements may be subject to inaccuracies due to variations in body posture during the measurement process.

3. Result and Discussion

3.1. Worktable Dimension and Layout

In this study, observations were conducted at two corndog outlet locations, each using a different worktable design with distinct dimensions and layouts. Each worktable is operated by one worker. The shapes and layouts of the worktables in Outlet 1 and Outlet 2 are presented in Figures 3 and 4, respectively. Data of both worktable dimensions is shown in Table 1.

Table 1. Both Outlet Table Dimension

Location	Table Shape	Length (cm)	Width of Side 1 (cm)	Width of Side 2 (cm)	Height (cm)
Outlet 1	L	110	80	60	100
Outlet 2	Rectangle	200	60	-	80

Based on the data presented in the table above, the layout and dimensions of the Outlet 1 worktable are illustrated in Figure 3.

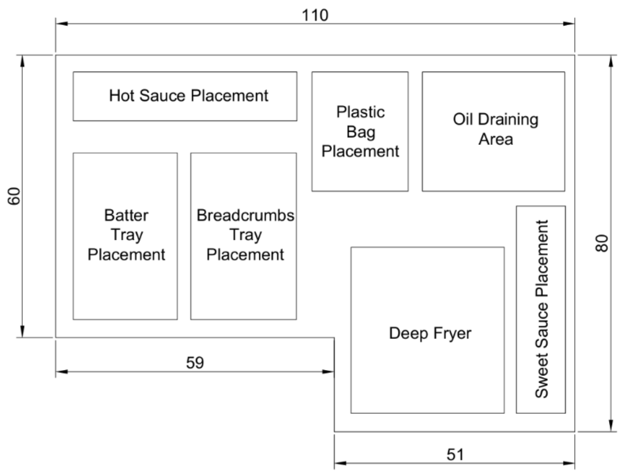


Figure 3. Outlet 1 Worktable Design

The worktable layout in Outlet 1 is L-shaped, with the worker positioned on the inner side of the table to allow easy access to all food preparation areas. The front area is used for batter coating. On the side, there is a deep fryer. The serving and savory-spicy sauce area is located at the far end of the table, while the sweet sauce station is positioned on the right side of the deep fryer. Furthermore, based on the data presented in Table 1, the layout and dimensions of the Outlet 2 worktable are illustrated in Figure 4.

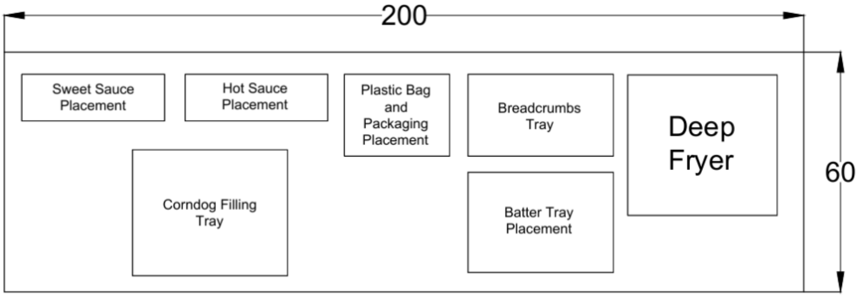


Figure 4. Outlet 2 Worktable Design

The worktable layout in Outlet 2 is rectangular. In this setup, the worker is predominantly positioned on the left side of the deep fryer, with the batter coating area located in front of the worker. The sauce station is placed at the far-left end of the table. In this outlet, the worker needs to change position more frequently because the sauce area is located beyond the dominant reach zone of the worker.

3.2. Work Posture Analysis Using the RULA (Rapid Upper Limb Assessment) Method

In this study, RULA observations are only conducted on the most dominant activities in the corndog production process, namely the coating and serving stages (including sauce application and product packaging). The frying activity is not analyzed because it has a short duration and does not involve prolonged static working postures.

The first step in this method is to observe the working posture, followed by determining the posture angles. These are then assigned scores based on the RULA assessment tables. Observation of worker posture presented in Figure 5.

(a) (b)

Figure 5. (a) Outlet 1 worker posture; (b) Outlet 2 worker posture.

Based on observations of the worker at Outlet 1, the upper arm angle is 45°, the lower arm is 90°, and the wrist is extended upward at 35°, with additional wrist twisting movements. The neck position shows a 20° forward flexion. In this outlet, the worktable is relatively high, and the placement of tools allows them to be reached easily without the need for repositioning.

Meanwhile, observations at Outlet 2 show an upper arm angle of 23°, a lower arm angle of 70°, and the wrist bent downward at 30°, also involving twisting movements. The neck position indicates a 30° forward flexion. In this outlet, the worktable is lower, and some tools are placed beyond the worker's immediate reach, requiring more frequent changes in position. Based on these observations, the measured posture angles are then classified according to the RULA assessment categories. The evaluation results for both outlet workers are presented in Table 2.

Table 2. RULA Scores of Both Outlet Workers

		Outlet 1 Workers	Outlet 2 Workers
A	Arm and Wrist Analysis		
	Upper Arm Position	2	2
	Lower Arm Position	1	1
	Wrist Twist Score	2	2
	Wrist Score	3	3
	Posture Score A (Score section A, RULA table)	4	4
	Muscle Use Score	1	1
	Load Score	0	0
	Wrist & Arm Score	5	5
B	Neck, Trunk and Leg Analysis		
	Neck Position	2	3
	Trunk Position	2	1
	Legs	2	2
	Posture Score B (Score section B, RULA table)	3	3
	Muscle Use Score	1	1
	Load Score	0	0
	Neck, Trunk, Leg Score	4	4
C	Final Score		
	RULA Score (Score section C, RULA table)	5	5

Based on the RULA assessment results, both outlet workers obtained the same score of 5. This score falls under Action Level 3, indicating that further investigation is required and improvements to the working conditions should be implemented in the near future [8].

Based on the evaluation of each body segment, the working postures of both workers are generally similar. The main difference lies in the neck position of the worker at Outlet 2, who exhibits a greater flexion angle. This is caused by the relatively lower table height compared to the worker's body height, leading to a more pronounced forward bending posture during work activities.

3.3. NBM (Nordic Body Map) Method Analysis

Next, data were collected using the NBM questionnaire, which was administered directly to both outlet workers to identify the musculoskeletal complaints they experienced. This method is used to determine which body parts are affected by pain or discomfort during work. The results of the NBM questionnaire are then analyzed to examine the relationship between workers' complaints and their working conditions and postures. The results of the NBM questionnaire for workers from both outlets are presented in Table 3.

Table 3. NBM Questionnaire Results of Both Outlet Workers

Musculoskeletal System	Outlet 1 Worker	Outlet 2 Worker
Upper Neck		1
Left Upper Arm		1
Right Upper Arm	1	1
Back	1	1
Right Wrist	1	1
Left Calf	1	1
Right Calf	1	1
Total Score	5	7

The results obtained from the NBM questionnaire show that the Outlet 1 worker has a total score of 5, while the Outlet 2 worker has a score of 7. Based on the NBM risk level, both scores are categorized as low, as they are below 20, indicating that immediate corrective actions are not yet required [17].

However, there are reported discomforts in specific body areas such as the upper neck, upper arms, back, wrist, and calves. These complaints indicate the presence of non-ideal working postures, which is also supported by the RULA analysis results.

Furthermore, the Outlet 2 worker reports discomfort in the upper neck, whereas this complaint is not reported by the Outlet 1 worker. This suggests that differences in working conditions affect body posture. This is likely related to the relatively lower table height in Outlet 2, as well as the placement of tools and materials outside the optimal reach zone, causing the worker to bend forward more frequently and reach further during activities.

3.4. Workers' Anthropometric Analysis

Anthropometric analysis is conducted by comparing workers' body dimensions with the workstation dimensions, particularly the worktable height. The anthropometric dimensions used in this study include body height, standing elbow height, and forward reach distance. The anthropometric data of both outlet workers are presented in Table 4.

Table 4. Anthropometric Data of Outlet Workers

Anthropometric Dimensions	Outlet 1 Worker (cm)	Outlet 2 Worker (cm)
Body Height	165	160
Standing Elbow Height	90	104
Forward Reach Distance	81	65

The anthropometric data in the table indicate that the Outlet 1 worker has a lower elbow height compared to the Outlet 2 worker. Additionally, the forward reach distance of the Outlet 1 worker is greater than that of the Outlet 2 worker. Comparison of workers' standing elbow height and worktable height at both outlets is presented in Table 5.

Table 5. Comparison of Workers' Elbow Height and Worktable Height

Outlet	Standing Elbow Height (cm)	Worktable Height (cm)	Difference (cm)	Description
1	90	100	+10	Relatively higher than elbow height
2	104	80	-24	Lower than elbow height

After obtaining the standing elbow height of each worker, the data were compared with the worktable height at each outlet. The results show that in Outlet 1, the worktable height is relatively higher than the worker's elbow height by 10 cm. In contrast, in Outlet 2, the worktable height is 24 cm lower than the worker's elbow height. These differences in height can be a primary cause of non-ideal ergonomic conditions, which may lead to MSDs if not addressed promptly.

3.5. Worktable Design Improvement

Based on the observation and assessment using the RULA method, a score of 5 was obtained, indicating the need for improvements in working conditions. This result is supported by the NBM questionnaire, which shows complaints in several parts of the workers' bodies. In addition, the comparison between anthropometric data and worktable dimensions reveals a mismatch, thus requiring a proposed improvement in the form of a more ergonomic worktable redesign to reduce the risk of MSDs. To accommodate more ergonomic worktable work surface positioned approximately 5–10 cm below the standing elbow height is recommended to reduce static loading on the back muscles during standing work activities [16]. To determine the appropriate table height, the average elbow height of the workers is first calculated:

$$\frac{104 + 90}{2} = 97 \text{ cm}$$

The range of table height is then determined as follows:

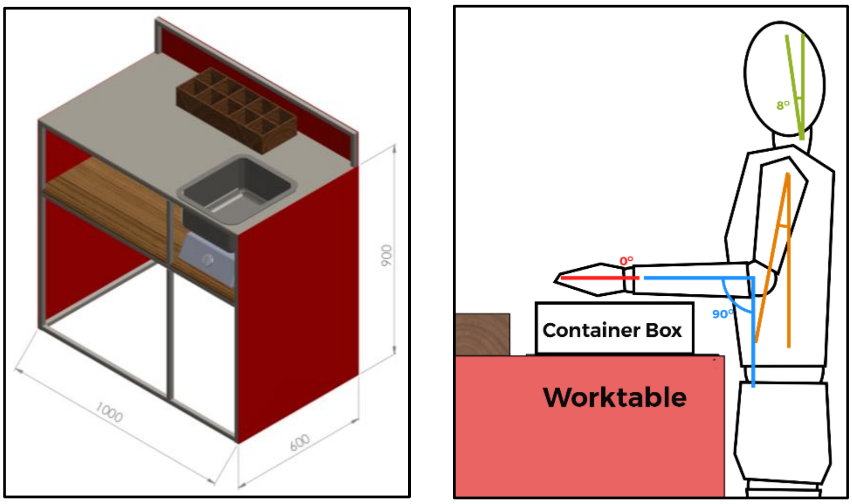
$$X_{min} = H_{elbow} - H_{max\ allowance} = 97 - 10 = 87 \text{ cm}$$

$$X_{max} = H_{elbow} - H_{min\ allowance} = 97 - 5 = 92 \text{ cm}$$

Thus, the recommended table height range is 87–92 cm, and a compromise value of 90 cm was selected. The table length was determined based on the workers' forward reach zone (65–81 cm), with the main activities performed within approximately 60 cm, while also considering the space required for tools and equipment. Therefore, a table length of 100 cm was selected, reduced from the previous 110 cm. The table width was maintained at 60 cm, as it remained within the optimal reach zone for both workers [16].

The proposed worktable dimensions were determined using the average anthropometric measurements of the observed workers. Therefore, the resulting design is intended to accommodate the characteristics of the workers involved in this study and should be regarded as a workplace-specific ergonomic solution. Further adjustments may be required when applying the design to workers with different anthropometric characteristics or workplace conditions.

Accordingly, the proposed worktable dimensions (100 × 60 × 90 cm) and the resulting improvements in worker posture are illustrated in Figure 6.



(a) (b)

Figure 6. (a) proposed worktable layout and dimension; (b) proposed worker posture

In the proposed design, the worktable dimensions were adjusted to reduce the potential risk of musculoskeletal complaints and disorders among workers. These dimensional changes are expected to improve the posture of the upper arms, neck, and wrists, bringing them closer to ideal positions.

With the proposed workstation dimensions, particularly by adjusting the table height to 90 cm with estimation of container box height that used is 10 cm, the proposed dimensions are expected to promote a more ergonomically appropriate and comfortable posture. Based on the proposed dimensions, the expected posture includes an upright torso, an upper-arm angle of approximately 10°, a forearm angle of 90°, a wrist angle close to 0°, and a neck angle of approximately 8°. In addition, the adjusted table length and width were designed according to the workers' reach dimensions, allowing workers to easily access the components without needing to twist their bodies or frequently change positions.

Since the proposed workstation has not yet been physically implemented, the resulting posture shown in Figure 6 represents an expected posture based on anthropometric design. Therefore, further studies are required to validate the effectiveness of the proposed design through implementation and post-intervention ergonomic assessment.

Furthermore, the layout of components should also be adjusted according to the workers' reach distance, as illustrated in Figure 7.

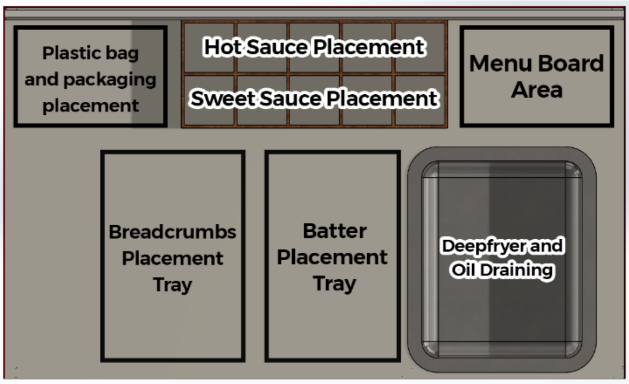


Figure 7. Component Placement Layout

In this layout, frequently used components are placed within a 60 cm radius to ensure easy reach. Materials such as corndog fillings are stored in lower drawers so they do not interfere with main activities and do not need to be repeatedly placed on the table surface. Furthermore, the workers' reach distance is illustrated in Figure 8.

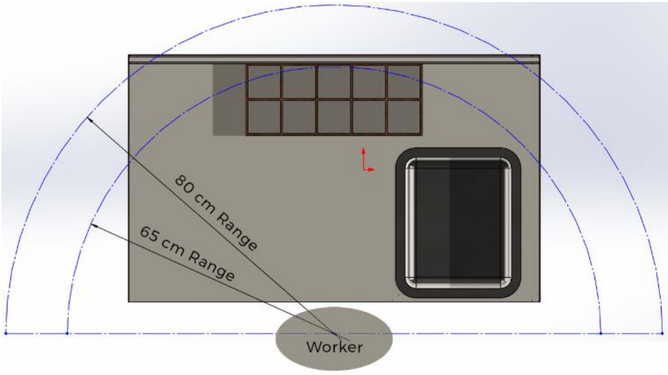


Figure 8. Estimated Workers' Reach Distance

The figure shows the estimated reach distance of both workers on the redesigned worktable with dimensions of 100 cm × 60 cm. Previously, the table length was 110 cm in Outlet 1 and 200 cm in Outlet 2. With the new dimensions, the main activity area can be easily reached by both workers.

4. Conclusion

The current working posture of the outlet workers is not yet optimal, as indicated by a RULA score of 5, which suggests the need for further investigation and improvements to working conditions in the near future. This finding is consistent with the NBM questionnaire results, where the workers scored 5 and 7. Although these scores are still within a low-risk category, complaints were reported in several body areas, including the upper neck, upper arms, back, wrists, and calves, which may lead to MSDs if sustained over a long period. The main contributing factor is the worktable dimension, which is relatively high in Outlet 1 and too low and excessively long in Outlet 2.

Improvements to working conditions are proposed through redesigning the worktable and rearranging the layout to ensure all components are easily reachable. The original table dimensions of 110 × 60 × 100 cm in Outlet 1 and 200 × 60 × 80 cm in Outlet 2 are redesigned into a proposed dimension of 100 × 60 × 90 cm based on the anthropometric characteristics of the observed workers.

The proposed dimensions were developed using the average anthropometric measurements of the observed workers and are therefore intended as a workplace-specific ergonomic solution for the studied corndog outlets.

This study has several limitations, including a limited sample size and the fact that the proposed workstation design has not yet been implemented and evaluated under actual working conditions. In addition, a long-term evaluation of the proposed design is still required to assess its sustainability and effectiveness over time. Therefore, future research is recommended to involve a larger number of respondents and to conduct postimplementation evaluations to assess the effectiveness of the improvements in reducing the risk of MSDs. Nevertheless, the ergonomic assessment and redesign approach presented in this study may serve as a reference for similar ergonomic improvement efforts in small-scale food preparation businesses.

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