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Redesign of Work Chairs and Tables to Reduce Musculoskeletal Disorders and Motion Waste at CV Barokah Gemilang Sejahtera

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Abstract

CV Barokah Gemilang Sejahtera (BGS) is a garment industry producing ready-to-wear clothing. Observations and Nordic Body Map (NBM) questionnaires involving 14 sewing operators identified musculoskeletal complaints in the upper neck (82%), lower neck (84%), and back (91%). Operators also experienced motion waste caused by searching for sewing tools that were not systematically organized. This study aimed to redesign ergonomic work facilities to reduce Musculoskeletal Disorders (MSDs) risk and motion waste. The research employed NBM to identify MSD complaints, Rapid Upper Limb Assessment (RULA) to evaluate working posture, anthropometry to determine workstation dimensions, and the Right-Hand–Left-Hand Process Chart (PTKTK) to analyze inefficient movements. Data were collected through observations, interviews, anthropometric measurements, questionnaires, and work-activity documentation. RULA assessment produced a final score of 7, indicating a very high postural risk requiring immediate improvement. PTKTK analysis showed motion waste associated with sewing-tool searching, with work efficiency of 70.21% before improvement. The proposed redesign consisted of an adjustable chair with a height range of 68.9–80.3 cm and an adjustable table with a height range of 72.6–90.2 cm, complemented by a partitioned drawer. The proposed design projected a cycle-time reduction from 47 to 29 seconds and efficiency improvement to 82.75%, supporting improved posture, reduced MSD risk, and minimized motion waste.

Keywords: *Anthropometry, Ergonomics, Motion Waste, Musculoskeletal Disorders (MSDs), Rapid Upper Limb Assessment (RULA).*

INTRODUCTION

Ergonomics is a scientific discipline concerned with understanding the interactions between humans and other elements of a work system, as well as a profession that applies theories, principles, data, and methods to optimize human well-being and overall system performance (International Ergonomics Association, 2000). In contemporary industrial environments, ergonomic design has developed beyond the prevention of occupational injury toward the systematic integration of human capabilities, workstation characteristics, task requirements, and production objectives. Through an ergonomic approach, the design and adaptation of work facilities, workstations, and working postures can be optimized to minimize fatigue, injury, and musculoskeletal disorders while maintaining effective system performance (Chapanis, 1996). This perspective becomes increasingly important in production systems characterized by repetitive movements, prolonged static postures, and continuous interaction between workers and physical facilities. Appropriate workstation design is expected not only to reduce physical strain but also to support more consistent, efficient, and sustainable work performance. Ergonomic intervention therefore represents a human-centered engineering strategy in which worker well-being and operational effectiveness are addressed as interconnected dimensions rather than separate objectives. The quality of a workstation can determine how efficiently workers interact with tools, materials, and equipment while simultaneously influencing the physical load accumulated throughout the working cycle.

Musculoskeletal disorders (MSDs) constitute one of the major occupational problems associated with inappropriate working conditions because they affect muscles, bones, tendons, ligaments, and other supporting structures of the human body (Imran, 2023). The problem becomes particularly relevant in occupations requiring repetitive upper-limb activities and prolonged sitting because workers are repeatedly exposed to static and constrained postures with limited opportunities for postural variation. Previous ergonomic investigations have demonstrated that systematic assessment of workplace conditions can identify substantial physical risks and provide an objective basis for determining appropriate interventions (Amalia et al., 2024). When ergonomic risks are allowed to persist, discomfort may develop into recurring physical complaints that can influence concentration, work capacity, and long-term occupational well-being. The issue is not limited to the physical condition of workers because inappropriate postures may also interfere with the continuity and efficiency of production activities. Consequently, ergonomic assessment needs to consider the relationship between the worker, the workstation, and the repetitive characteristics of the task rather than evaluating posture as an isolated phenomenon. Recent research using RULA and REBA has reinforced the importance of objective postural assessment in identifying work activities that require ergonomic improvement (Prayoga et al., 2024).

The relationship between workstation configuration and musculoskeletal risk has encouraged researchers to examine work chairs, tables, and other facilities as critical components of ergonomic intervention. Research on computer laboratory furniture indicates that chair and table dimensions need to correspond with users' anthropometric characteristics to support more appropriate working postures (Apriandi, 2023). A workstation that does not accommodate body dimensions may force workers to compensate through excessive trunk flexion, shoulder elevation, or unsupported sitting positions, even when the production task itself has relatively low physical demands. This problem suggests that ergonomic redesign should be based on measurable human dimensions rather than subjective assumptions regarding furniture size and comfort. Recent research has shown that redesigning work tables according to observed working postures can contribute to reducing work fatigue, indicating that physical workstation dimensions are directly connected to the worker's biomechanical demands (Aprianto, 2026). The effectiveness of redesign, however, depends on whether the proposed dimensions accommodate variations among workers rather than merely reproducing a single fixed configuration. An anthropometric approach is therefore essential for transforming ergonomic assessment results into specific and technically defensible design dimensions. Such an approach allows workstation design to function as an adaptive interface between human physical characteristics and the requirements of the production process.

CV Barokah Gemilang Sejahtera (BGS) is a small-scale ready-to-wear garment manufacturing enterprise established in 2021, where sewing operators perform repetitive activities in a seated position for extended working periods. Preliminary observations at CV BGS indicate that sewing operators frequently experience pain and discomfort in the neck and back, while the Nordic Body Map (NBM) questionnaire distributed to 14 sewing operators recorded complaints of 82% in the upper neck, 84% in the lower neck, and 91% in the back. These findings indicate that the existing working conditions require systematic ergonomic attention because persistent exposure to inappropriate sitting postures may increase the likelihood of long-term musculoskeletal problems. Similar concerns have been identified among industrial operators whose repetitive work activities expose them to considerable ergonomic risks requiring corrective intervention (Pratama & Suryadi, 2024). The physical problem at CV BGS is accompanied by another operational problem, namely motion waste resulting from the disorganized placement of sewing tools. Operators must perform additional searching and reaching movements to locate the tools required during sewing, causing movements that do not directly contribute to the transformation of materials into finished products. Such conditions create a connection between ergonomic risk and production inefficiency because unnecessary movements can simultaneously increase physical workload and consume productive time. The analysis of work movements is therefore required to determine which activities can be eliminated or reorganized through improved workstation and tool-storage design.

The combination of MSD risk and motion waste demonstrates that the problem at CV BGS cannot be adequately addressed through postural correction alone. Previous research has shown that ergonomic interventions can produce broader benefits when musculoskeletal complaints, work fatigue, and unnecessary movements are addressed simultaneously within the work system (Asih et al., 2026). Nevertheless, much of the existing literature has focused predominantly on identifying ergonomic risk through posture assessment or redesigning individual work facilities without explicitly integrating the spatial organization of tools into the same design decision. This creates an empirical gap because a workstation may successfully reduce postural risk while still forcing operators to perform unnecessary searching, reaching, or repositioning movements during production. Conversely, improving tool accessibility without correcting chair and table dimensions may reduce motion waste while leaving the primary source of physical discomfort unresolved. Recent work on ergonomic work-facility redesign has demonstrated the value of connecting posture and workload considerations in determining appropriate interventions, yet the integration of adjustable furniture and tool-storage features with motion analysis remains comparatively limited (Ansori et al., 2025). The gap becomes particularly important in small-scale garment production, where limited workspace and repeated sewing activities make the relationship between furniture dimensions, tool accessibility, and operator movement especially consequential. A more comprehensive redesign strategy is therefore required to address physical risk and operational inefficiency as mutually related components of the same work system.

The present study is positioned within the development of an integrated ergonomic work-system design approach that connects anthropometric requirements, postural assessment, and motion efficiency within a single workstation redesign process. The proposed intervention focuses on redesigning the sewing chair and table at CV BGS by incorporating adjustable dimensions and partitioned drawers for more systematic storage of sewing tools. RULA is used to evaluate working posture, anthropometric data are used to determine appropriate design dimensions, and the Right-Hand–Left-Hand Process Chart (PTKTK) is applied to identify unnecessary movements associated with searching for and retrieving tools. The integration of these methods provides a structured basis for translating observed ergonomic and operational problems into measurable design requirements, consistent with the broader principle that work-system design should simultaneously consider human characteristics and work methods (Ramdhani et al., 2025). The objective of this study is to redesign the work chair and table for sewing operators at CV Barokah Gemilang Sejahtera to reduce musculoskeletal disorder risks and motion waste while improving workstation suitability and work efficiency. Theoretically, the study contributes to the ergonomic workstation literature by linking postural risk, anthropometric compatibility, and motion efficiency within the context of small-scale garment production. Methodologically, the study offers an integrated redesign framework that combines RULA, anthropometric analysis, and PTKTK to formulate a workstation intervention addressing both worker well-being and production efficiency.

RESEARCH METHODS

This study employed an empirical quantitative case-study design to redesign the work chair and table used by sewing operators at CV Barokah Gemilang Sejahtera (BGS), with the intervention developed from direct observations of ergonomic risk and work movement. The research was conducted during October–November 2025 and involved 14 sewing operators, while one operator was selected as the representative subject for posture documentation and motion analysis because all operators performed comparable sewing activities using the same sewing machines, work facilities, and working environment. Primary data were collected through direct observation, interviews, the Nordic Body Map (NBM) questionnaire, anthropometric measurements, photographic documentation, and video recordings of sewing activities, with NBM used to identify the distribution of musculoskeletal complaints among operators (Supriyanto et al., 2025). The intervention architecture consisted of an adjustable work chair and table designed according to operator anthropometry, complemented by partitioned drawers positioned to improve accessibility and organization of frequently used sewing tools. Anthropometric data from the 14 operators were processed to obtain the mean, standard deviation, and P5, P50, and P95 percentiles, which were subsequently used to establish appropriate dimensions for the redesigned facilities. The existing and proposed work systems were then represented through the interaction between operator posture, workstation dimensions, sewing-machine position, and tool-storage arrangement so that the physical design and work movement could be evaluated as an integrated system. The design process followed the principle that ergonomic facilities should accommodate human physical characteristics while supporting efficient interaction between workers and work equipment (Elbert Kroemer & Kroemer, 2018).

The testing and evaluation procedure compared the existing workstation with the proposed redesign using three complementary assessment components, namely musculoskeletal complaints, working posture, and work movement efficiency. First, NBM responses from the 14 operators were tabulated as percentages for each body segment to establish the baseline distribution of musculoskeletal complaints before intervention. Second, the representative operator's working posture was assessed using the Rapid Upper Limb Assessment (RULA), with the resulting scores interpreted according to established ergonomic risk categories to determine the urgency of corrective action (Prayoga et al., 2024). Third, the Right-Hand–Left-Hand Process Chart (PTKTK) was used to document the sequence, duration, and coordination of right- and left-hand movements during sewing, particularly movements associated with searching for and retrieving sewing tools. The recorded movements were classified into value-added and non-value-added activities, allowing cycle time, idle time, and work efficiency to be calculated and compared between the existing and proposed workstation configurations. The redesigned workstation was considered technically improved when the RULA assessment indicated a lower postural risk level and the PTKTK analysis demonstrated reductions in unnecessary movements and associated time losses, while the anthropometric dimensions remained within the intended percentile-based design requirements. This evaluation framework was selected because ergonomic redesign is expected to address both physical workload and work-system efficiency rather than focusing exclusively on furniture dimensions or worker complaints (Asih et al., 2026).

RESULTS AND DISCUSSION

Respondent Characteristics and Musculoskeletal Disorder (MSDs) Complaints

The study involved 14 respondents who worked as sewing operators in the production department of CV Barokah Gemilang Sejahtera (BGS), with all operators performing sewing activities in a seated position for approximately 8 hours per working day. All respondents were female, with an age distribution consisting of 2 operators aged 25–34 years, 5 operators aged 35–44 years, 5 operators aged 45–54 years, and 2 operators aged 55–64 years. The relatively broad age distribution indicates that the workstation needs to accommodate differences in physical characteristics and tolerance toward prolonged static sitting rather than being designed for a single operator profile. The work characteristics observed at the company involve repetitive sewing movements performed continuously within a relatively constrained workspace, making the interaction between operator posture and workstation configuration an important factor in determining physical workload. Prolonged exposure to repetitive and static working conditions can increase the accumulation of physical discomfort, particularly when the dimensions of work facilities do not correspond adequately to operator anthropometry. Similar ergonomic assessments in industrial workplaces have emphasized the importance of identifying physical exposure conditions systematically before determining appropriate corrective measures (Amalia et al., 2024).

The Nordic Body Map (NBM) questionnaire was used to identify the distribution and intensity pattern of musculoskeletal complaints experienced by the operators, providing an initial indication of body regions requiring further ergonomic assessment. The results showed that complaints were distributed across several body regions, with the highest proportions concentrated in the back, lower neck, and upper neck. These areas are directly related to the sustained sitting posture and forward-oriented visual and manual activities required during sewing, in which operators must continuously coordinate their upper limbs with the sewing machine while maintaining visual attention toward the material being processed. The dominant complaints identified through the NBM are presented in Table 1, which summarizes the three body regions with the highest complaint percentages.

Table 1. Recapitulation of Dominant Musculoskeletal Complaints Based on the NBM Questionnaire

No.	Body Part	Complaint Percentage
1	Upper neck	82%
2	Lower neck	84%
3	Back	91%

As shown in Table 1, back complaints represented the highest proportion at 91%, followed by lower-neck complaints at 84% and upper-neck complaints at 82%. The concentration of complaints in these regions indicates a consistent pattern rather than isolated discomfort, suggesting that the physical configuration of the workstation may be contributing to sustained loading of the neck and trunk. Comparable occupational studies have reported that repetitive work activities and prolonged exposure to unfavorable postures can produce substantial musculoskeletal complaints among workers, particularly when corrective ergonomic measures have not been implemented (Suarjana et al., 2024). The 91% complaint rate for the back is particularly important because repeated forward trunk inclination during precision sewing can increase static muscular demand and reduce postural variation throughout the working cycle. The neck complaint percentages also indicate that the operator's visual orientation toward the sewing area may require persistent cervical flexion, particularly when the table and machine position do not provide an appropriate working height. These findings provide a quantitative basis for proceeding from subjective complaint identification toward an objective assessment of working posture using RULA.

The NBM findings can be interpreted as an indication that the existing workstation does not adequately support the physical requirements of the sewing task, particularly for operators who remain seated for long periods while repeatedly performing fine upper-limb movements. The combination of high back and neck complaint percentages suggests that physical discomfort is likely associated with the interaction between sitting posture, workstation height, sewing-machine position, and the operator's need to continuously observe the sewing area. Ergonomic assessment should therefore distinguish between the presence of musculoskeletal complaints and the postural mechanisms that may contribute to those complaints, because subjective symptoms alone cannot determine the specific ergonomic exposure responsible for them. Previous research has demonstrated that NBM can serve as an effective initial screening instrument for identifying body regions with work-related ergonomic complaints before more detailed posture assessment is conducted (Supriyanto et al., 2025). In the present case, the concentration of complaints in the upper body and back provides a strong indication that the subsequent assessment should focus on the alignment of the neck, trunk, shoulders, arms, and wrists during sewing. The findings also indicate that workstation improvement should not be limited to cushioning or replacing individual furniture components, because the underlying postural configuration needs to be addressed. This interpretation is consistent with the broader ergonomics perspective that physical facilities should be adapted to human characteristics and task requirements rather than requiring workers to compensate continuously for unsuitable workplace dimensions (Dull & Weedmeester, 2008).

The age distribution of the respondents further reinforces the need for a workstation design that can accommodate variation in physical characteristics rather than relying on a single fixed dimension. Operators aged 25–34 years and those aged 55–64 years were both represented in the sample, while the largest groups were distributed across the 35–44 and 45–54 age ranges. Although the present analysis does not establish age as a causal predictor of MSD complaints, the variation in respondent age demonstrates that a uniform workstation configuration may not provide equivalent ergonomic suitability for every operator. Anthropometric variation can affect the relationship between the operator's body dimensions and critical workstation elements such as seat height, seat depth, table height, and working reach. This condition supports the use of anthropometric measurements as a design input in subsequent stages, allowing the proposed workstation to accommodate an appropriate range of users. Research on ergonomic furniture design similarly emphasizes the importance of matching chair and table dimensions with user anthropometry to reduce postural incompatibility during prolonged work (Apriandi, 2023). The NBM results therefore function not only as evidence of the current ergonomic problem but also as an initial design requirement for determining which physical characteristics of the workstation need to be modified.

The findings from the respondent characteristics and NBM assessment establish that the ergonomic problem at CV BGS involves a substantial concentration of musculoskeletal complaints in body regions directly exposed to the demands of seated sewing work. The back complaint rate of 91% represents the most prominent finding, while the upper- and lower-neck complaint rates of 82% and 84% indicate that cervical discomfort is also a major component of the operators' physical burden. These results suggest that the existing workstation configuration may not provide adequate support for maintaining a neutral posture throughout the 8-hour working period. The pattern is particularly relevant because ergonomic risk can emerge from the cumulative interaction between task repetition, static posture, workstation dimensions, and limited postural variation rather than from a single movement or isolated task. Studies of ergonomic intervention have shown that redesigning work facilities based on identified postural and physical workload risks can provide a more direct pathway for reducing MSD exposure than relying only on behavioral adjustments (Ansori et al., 2025). The NBM findings consequently provide the empirical justification for conducting a more detailed RULA assessment in the next stage of the analysis, where the specific postural configurations associated with the observed complaints can be quantified and linked to the required workstation modifications.

Working Posture Assessment Using Rapid Upper Limb Assessment (RULA)

The high prevalence of musculoskeletal complaints identified through the Nordic Body Map (NBM) assessment required a more objective evaluation of the operator's working posture. The Rapid Upper Limb Assessment (RULA) method was applied to the representative sewing operator to quantify postural exposure involving the upper limbs, neck, trunk, and legs during normal sewing activities. The selection of RULA is appropriate for repetitive sewing work because the method evaluates body-segment positions associated with static and repetitive activities and translates them into an ergonomic risk score (McAtamney & Corlett, 1993). The assessment was conducted from photographic documentation of the operator while performing the sewing process using the existing chair, table, sewing machine, and pedal arrangement. The observed posture was divided into Group A, comprising the upper arm, lower arm, wrist, and wrist twist, and Group B, comprising the neck, trunk, and legs. This assessment provides a quantitative basis for identifying which postural characteristics of the existing workstation require correction before the anthropometric-based redesign is implemented.

The Group A assessment generated a score of 5, reflecting considerable loading of the upper extremities during the sewing operation. The upper arm was positioned in approximately 57° of forward flexion, while the lower arm formed an elbow angle of approximately 134° and remained relatively static during continuous fabric handling. The wrist also moved laterally when the operator reached for sewing tools, creating an additional deviation from a neutral wrist position. These conditions indicate that the operator's upper limbs were required to maintain a working configuration that was strongly influenced by the position of the sewing machine and the available workspace. RULA is designed to identify such deviations from neutral upper-limb positions because repetitive muscle use combined with awkward joint angles can increase the physical demands imposed on workers (McAtamney & Corlett, 1993). Similar ergonomic assessments have reported that inappropriate working postures and repetitive activities can increase exposure to musculoskeletal risk among industrial workers (Prayoga et al., 2024). The Group A result consequently indicates that improvement cannot be limited to the chair alone because the relationship between table height, sewing-machine position, and upper-limb reach must also be considered.

The specific postural observations used to establish the RULA assessment are presented in Table 2, with the numerical characteristics indicating the dominant deviations occurring during sewing. The 57° upper-arm flexion reflects sustained forward positioning of the shoulder and upper arm, while the approximately 134° elbow angle indicates a relatively extended forearm configuration. Wrist deviation occurred particularly during movements associated with reaching for sewing tools, linking the upper-limb exposure to the arrangement of tools around the workstation. The neck and trunk were also positioned forward because the operator needed to maintain visual concentration on the needle and material being processed. The combination of these conditions indicates that the postural risk was generated by the interaction between the operator, sewing machine, work surface, and tool arrangement rather than by a single body movement. Ergonomic design principles emphasize that work facilities should be adapted to human physical characteristics and task requirements so that workers are not required to compensate continuously through unfavorable postures (Elbert Kroemer & Kroemer, 2018).

Table 2. RULA Risk Score Category (McAtamney & Corlett, 1993)

Final RULA Score	Risk Level	Risk Category	Required Action
1–2	1	Low	No problem with body posture
3–4	2	Moderate	Further investigation is required; changes in working posture may be necessary
5–6	3	High	Investigation and immediate improvement are required
7+	4	Very high	Investigation and improvement are required as soon as possible

The Group B assessment produced a score of 6 and was strongly influenced by the position of the neck and trunk during sewing. The operator maintained the neck in forward flexion exceeding 20°, while the trunk was inclined forward by approximately 20–30° to maintain visual access to the sewing area. The leg position also affected the assessment because one foot was continuously used to operate the sewing-machine pedal, limiting symmetrical foot support on the floor. These conditions are consistent with the NBM findings in which the back, lower neck, and upper neck recorded complaint percentages of 91%, 84%, and 82%, respectively. Sustained forward flexion of the neck and trunk can increase static muscular loading and contribute to discomfort when the posture is maintained repeatedly over an extended working period (Suarjana et al., 2024). The relationship between posture and musculoskeletal symptoms is particularly relevant in sewing operations because the visual and precision requirements of the task restrict opportunities for substantial postural variation. The Group B score therefore demonstrates that the existing workstation configuration contributes not only to upper-limb loading but also to sustained loading of the cervical and trunk regions.

The combination of Group A and Group B produced a final RULA score of **7**, placing the operator in the very-high-risk category and indicating that investigation and corrective improvement are required as soon as possible. The RULA classification in Table 2 shows that scores of 5–6 already require investigation and improvement, whereas a score of 7 or above represents the most critical action level. A score of 7 indicates that the observed posture contains sufficient cumulative ergonomic exposure to justify immediate intervention rather than continued reliance on behavioral adjustment alone. The finding is particularly important because the RULA score corresponds with the high prevalence of MSD complaints identified through the NBM, creating consistency between subjective complaint data and objective postural assessment. Previous ergonomic studies have demonstrated the value of combining complaint identification with systematic posture assessment to establish a stronger basis for workplace intervention (Pratama & Suryadi, 2024). The result also supports the application of ergonomic redesign strategies in which work facilities are modified according to identified postural risks and physical workload characteristics (Ansori et al., 2025). The RULA score of 7 consequently becomes a primary technical requirement for the subsequent design of the adjustable chair and table, particularly because the existing fixed dimensions appear unable to accommodate the operator's anthropometric characteristics adequately.

The RULA findings demonstrate that the ergonomic problem at the sewing workstation is associated with an integrated postural configuration involving the upper limbs, neck, trunk, and lower-body support. The forward arm position, wrist deviation, neck flexion above 20°, trunk inclination of approximately 20–30°, and asymmetric foot position collectively create conditions that increase the physical demand of repetitive sewing work. The result reinforces the ergonomics principle that workstation dimensions should support an appropriate relationship between the worker and the equipment rather than forcing the worker to adapt continuously to fixed facility dimensions (International Ergonomics Association, 2000). Research on work-facility redesign has similarly indicated that modifying workstation characteristics based on working-posture assessment can reduce exposure to musculoskeletal risk and improve the suitability of the work system (Ansori et al., 2025). The present RULA result provides a quantitative justification for introducing adjustable dimensions in both the chair and table, allowing the working height and seating configuration to accommodate anthropometric variation among the 14 operators. The intervention also needs to preserve sufficient working reach and stable foot support while reducing excessive neck and trunk flexion during sewing. The anthropometric analysis in the following stage therefore serves as the technical basis for translating the RULA findings into measurable dimensions for the redesigned workstation.

Motion Waste Analysis Using the Right-Hand–Left-Hand Process Chart (PTKTK) and Anthropometric Design

The Right-Hand–Left-Hand Process Chart (PTKTK) was applied to identify unnecessary movements and differences in hand utilization during the sewing process. The analysis focused on the bottom-hemming operation, which involves repetitive coordination between the operator's hands, sewing machine, fabric, and supporting tools. Under the existing workstation configuration, the cycle time for one product was 47 seconds, with the left hand recording 21 seconds of idle time (44.6%) and the right hand recording 1 second (2.1%). The resulting hand-work efficiency was 70.21%, indicating that the two hands were not utilized proportionally throughout the work cycle. The dominant non-value-added activities involved searching for, reaching toward, and retrieving sewing tools that did not have a fixed storage location. Motion-study principles emphasize that unnecessary searching and reaching should be minimized because these activities consume working time without directly contributing to product transformation (Wignjosoebroto, 2003).

The high proportion of left-hand idle time indicates that motion waste was concentrated primarily in activities surrounding tool retrieval rather than in the core sewing operation. Frequently used tools, particularly scissors and tweezers, were placed without an organized storage location, requiring the operator to interrupt the sewing sequence to locate the required tool. The imbalance is reflected in the difference between the 21 seconds of left-hand idle time and only 1 second of right-hand idle time within the 47-second cycle. This condition also creates additional reaching and searching movements that can interact with the postural risks identified through the RULA assessment. From a work-system perspective, the arrangement of tools should support short and direct movement paths because repeated unnecessary movements can accumulate into significant time losses over multiple production cycles (Prawirosentono, 2009). The relationship between motion waste and ergonomic exposure is also consistent with the lean-ergonomics approach, which considers unnecessary movement as an operational inefficiency that may simultaneously increase physical workload and fatigue (Asih et al., 2026). The PTKTK findings consequently establish tool accessibility as an important design requirement for the proposed workstation.

The proposed intervention addresses this motion waste through a partitioned drawer positioned beneath the work table and within the operator's accessible working area. The drawer is divided into two sections, with the first section intended for large and small scissors and the second section for tweezers, bobbins, and measuring tape. The storage height was determined at 15 cm, based on the approximately 10 cm height of the largest scissors, providing sufficient clearance for placing and retrieving the tools. The drawer location was selected to allow the operator to access frequently used equipment without leaving the primary sewing position or performing excessive trunk flexion. This arrangement follows human-factors principles in which frequently handled objects should be located within an appropriate reach area to reduce unnecessary displacement and physical effort (Sanders & McCormick, 1993). The storage configuration also supports motion economy because each tool has a predetermined location, reducing the need for visual searching and repeated exploratory movements. The proposed drawer therefore represents a relatively simple workstation modification with direct implications for both movement efficiency and ergonomic exposure.

After the proposed storage arrangement was introduced into the work-system analysis, the cycle time was projected to decrease from 47 seconds to 29 seconds, representing an 18-second reduction or approximately 38.30%. Left-hand idle time decreased from 21 seconds to 9 seconds, reducing the idle proportion from 44.6% to 31.0%, while right-hand idle time remained at 1 second, corresponding to 3.4% of the shorter cycle. Hand-work efficiency increased from 70.21% to 82.75%, or an improvement of 12.54 percentage points. The reduction in cycle time is primarily associated with the elimination of repeated tool-searching activities rather than with changes to the fundamental sewing process. This pattern demonstrates that workstation organization can improve productivity by reducing non-value-added movement while maintaining the existing production method. Lean ergonomic intervention similarly emphasizes that improvements in workplace arrangement can simultaneously reduce motion waste and support better physical working conditions (Asih et al., 2026). The projected improvement therefore provides quantitative evidence that tool organization should be incorporated into the workstation redesign rather than treated as a separate housekeeping issue.

Anthropometric data were subsequently processed to establish physical dimensions for the redesigned chair and table. Measurements from the 14 sewing operators were analyzed using the mean, standard deviation, and P5, P50, and P95 percentiles, with the selected percentile depending on the functional purpose of each workstation component. The application of different percentiles is important because dimensions intended to provide clearance, accommodation, or reach should not necessarily be based on the same point of the anthropometric distribution (Bridger, 2008). Seated shoulder height was used to determine backrest height, popliteal height was used for adjustable seat height, popliteal length was used for seat depth, and hip breadth was used for seat width. Seated elbow height and knee height were considered in determining the appropriate working-table configuration, while lateral arm reach was used to establish the width of the accessible working area. The anthropometric values and their applications are presented in Table 3, providing the quantitative basis for translating operator body dimensions into specific workstation dimensions. Anthropometric-based furniture design is important because inappropriate relationships between body dimensions and furniture dimensions can force workers to compensate through non-neutral postures during prolonged activities (Apriandi, 2023).

Table 3. Anthropometric Percentiles Used for Work Chair and Table Design

No.	Anthropometric Dimension	Percentile	Application	Dimension
1	Seated shoulder height	P50	Chair backrest height	45.79 cm
2	Popliteal height	P5 & P95	Adjustable chair height	68.9–80.3 cm
3	Popliteal length	P5	Seat depth	41.7 cm
4	Hip breadth	P95	Seat width	45.6 cm
5	Seated elbow height	P5 & P95	Adjustable table height	72.6–90.2 cm
6	Knee height	P5 & P95	Table height	46.7–52.2 cm
7	Lateral arm reach	P95	Working-area width	73.4 cm

The percentile selection demonstrates that the proposed workstation was not based on a single average body dimension but on functional compatibility between specific body measurements and workstation components. The P50 seated shoulder height of 45.79 cm was used for the chair backrest, while the P5–P95 popliteal height range of 68.9–80.3 cm was selected for the adjustable chair-height mechanism. The P5 popliteal length of 41.7 cm was used for seat depth to reduce excessive contact behind the knees, whereas P95 hip breadth of 45.6 cm was selected for seat width to provide adequate lateral clearance. The P5–P95 seated elbow-height range of 72.6–90.2 cm forms the basis for the adjustable table height, while the P95 lateral arm reach of 73.4 cm defines the intended working-area width. The knee-height measurement was also incorporated into the table-design consideration, with a reported range of 46.7–52.2 cm for the relevant clearance requirement. These dimensions provide a quantitative bridge between the ergonomic risks identified through RULA and the physical characteristics of the proposed workstation, allowing the redesign to address both postural compatibility and movement efficiency. The approach is consistent with ergonomic design principles that require work facilities to be adapted to human capabilities and task requirements rather than expecting workers to accommodate unsuitable fixed dimensions (Elbert Kroemer & Kroemer, 2018).

Redesign of Work Chairs and Tables and Comparison of Improvement

The redesign of the work chair and table was developed by integrating the findings from the NBM, RULA, PTKTK, and anthropometric analysis into a single workstation intervention. The existing workstation was identified as a contributing factor to non-neutral sitting and upper-body postures, while the PTKTK analysis demonstrated that the absence of organized tool storage generated unnecessary searching and reaching movements. The proposed chair incorporates an adjustable height range of 68.9–80.3 cm, a backrest height of 45.79 cm, a seat depth of 41.7 cm, and a seat width of 45.6 cm. The table incorporates an adjustable height range of 72.6–90.2 cm, allowing the working surface to be adapted to differences in seated elbow height among operators. The use of adjustable dimensions is important because fixed workstation dimensions may not provide equivalent ergonomic suitability for operators with different anthropometric characteristics (Elbert Kroemer & Kroemer, 2018). The redesign was consequently developed as an integrated physical intervention intended to improve postural compatibility while supporting more efficient interaction between the operator, sewing machine, work surface, and tools.

The chair adjustment mechanism uses a knob-bolt system positioned on the front legs, allowing the operator to modify the seating height according to individual requirements. The backrest is 45.79 cm high and is covered with foam and synthetic leather to provide continuous support for the back toward the shoulder region during prolonged sitting. The seat has a depth of 41.7 cm and a width of 45.6 cm, corresponding to the selected anthropometric requirements based on popliteal length and hip breadth. The table uses a multiplek surface covered with HPL, has a thickness of 3 cm, and incorporates rounded corners to reduce sharp contact points within the operator's working area. Both the chair and table frames use hollow steel with an estimated load-bearing capacity of 100–200 kg, providing structural support for routine production activities. These characteristics reflect the human-factors principle that furniture dimensions, adjustability, and structural features should be considered together to establish compatibility between users and work equipment (Sanders & McCormick, 1993). The resulting configuration provides greater dimensional flexibility than the previous fixed workstation and directly addresses the anthropometric variation identified among the 14 sewing operators.

The three-dimensional model of the redesigned workstation was developed using SketchUp 2017 to visualize the spatial relationship among the chair, table, sewing machine, and tool-storage component. Figure 1 presents the proposed workstation from the front and rear views, showing the adjustable structure and the integration of the storage facility into the work table. The chair and table are positioned as a connected system so that changes in seating height can be coordinated with the working-surface height rather than adjusted independently without regard to operator posture. The design also provides a dedicated area for sewing tools, reducing the distance between the operator's primary working position and frequently accessed equipment. Visualizing the workstation in three dimensions is useful for evaluating spatial relationships before fabrication because ergonomic design requires consideration of both individual component dimensions and their interaction within the work system (Bridger, 2008). The model therefore represents the translation of the quantitative anthropometric requirements into a physical workstation configuration.

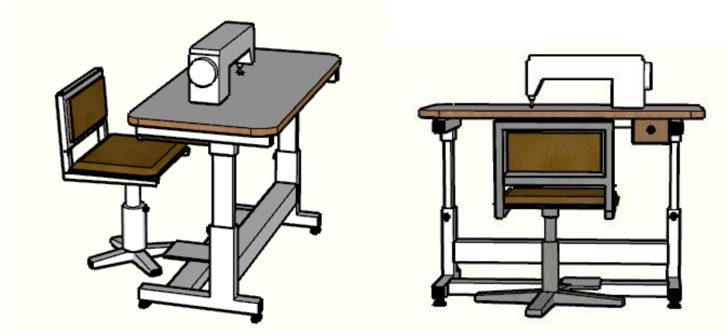

Figure 1. Redesigned Work Table and Chair for Sewing Operators: Front and Rear Views

The workstation also incorporates a 30 cm × 15 cm partitioned drawer on the right side of the operator to address the motion waste identified through the PTKTK analysis. The drawer contains two sections, with one section allocated for large and small scissors and the other for tweezers, bobbins, and measuring tape. Its placement was selected to maintain accessibility while minimizing the need for excessive reaching, searching, or trunk movement during sewing. This feature directly responds to the initial finding that the left hand experienced 21 seconds of idle time within a 47-second cycle, largely because the operator needed to search for sewing tools. After the proposed arrangement, cycle time was projected to decrease to 29 seconds, while hand-work efficiency increased from 70.21% to 82.75%. The integration of tool organization into the workstation is consistent with motion-economy principles, which emphasize the placement of frequently used objects within convenient reach to reduce unnecessary movements (Wignjosoebroto, 2003). The drawer therefore functions as both a storage component and an operational intervention that connects workplace organization with movement efficiency.

The differences between the existing workstation and the proposed design are summarized in Table 4, covering the chair, table, tool storage, work efficiency, and MSD-related ergonomic conditions. The existing chair used fixed dimensions that were not adequately matched to operator body characteristics, whereas the proposed chair provides an adjustable height range of 68.9–80.3 cm. The table similarly changes from a fixed configuration that may cause forward bending or shoulder elevation into an adjustable system ranging from 72.6–90.2 cm. Tool storage changes from an unorganized arrangement to a dedicated partitioned drawer, reducing the searching activity identified through the PTKTK assessment. Work efficiency is projected to improve through a reduction in cycle time from 47 seconds to 29 seconds, accompanied by an increase in efficiency from 70.21% to 82.75%. The proposed workstation also addresses the MSD risk associated with the upper neck, lower neck, and back by using dimensions derived from operator anthropometry. Ergonomic redesign studies indicate that modifying work facilities according to identified postural and physical workload risks can provide a direct intervention for reducing musculoskeletal exposure (Ansori et al., 2025).

Table 4. Comparison of Conditions Before and After the Proposed Improvement

No.	Component	Condition Before Improvement	Proposed Improvement
1	Work chair	Chair height was not compatible with operator body dimensions, resulting in a less ergonomic sitting position	Chair equipped with an adjustable mechanism with a height range of 68.9–80.3 cm
2	Work table	Table height was not compatible with the body dimensions of some operators, causing operators to bend forward or raise their shoulders	Table equipped with an adjustable mechanism with a height range of 72.6–90.2 cm
3	Tool storage	Sewing tools were placed irregularly, requiring operators to search for them during work	Partitioned drawer added as a dedicated storage area for sewing tools
4	Work efficiency	Cycle time of 47 seconds with work efficiency of 70.21%	Cycle time projected to decrease to 29 seconds with efficiency increasing to 82.75%
5	MSD risk	Operators experienced upper-neck, lower-neck, and back complaints associated with non-ergonomic working posture	Chair and table designed according to anthropometric data to reduce the risk of musculoskeletal disorders

The economic feasibility of the proposed workstation was assessed using the Bill of Material (BOM) calculation and comparison with available market alternatives. The total estimated cost for producing one set of the redesigned work chair and table was Rp2,606,090, consisting of Rp1,181,700 for the table, Rp424,390 for the chair, and Rp1,000,000 for fabrication services. Market observations indicated that a sewing table without adjustable features and a dedicated drawer was available at approximately Rp1,000,000, an adjustable sewing table without a drawer at approximately Rp1,500,000, and an adjustable chair at approximately Rp400,000. Although the proposed workstation has a higher initial cost than some conventional alternatives, the additional expenditure corresponds to adjustable dimensions, anthropometric compatibility, dedicated tool storage, and an integrated ergonomic configuration. The proposed design also addresses multiple problems identified through the empirical assessment, including the RULA score of 7, high NBM complaints in the back and neck, and motion waste associated with tool searching. Ergonomic investment should be evaluated in relation to the functional and human-system improvements produced by the intervention rather than acquisition cost alone (Ramdhani et al., 2025). The proposed workstation can therefore be considered technically and economically feasible as an integrated improvement for CV Barokah Gemilang Sejahtera because its design characteristics directly respond to the measured ergonomic risks and documented inefficiencies of the existing sewing workstation.

CONCLUSION

The identification of musculoskeletal complaints using the Nordic Body Map (NBM) demonstrated that sewing operators at CV Barokah Gemilang Sejahtera experienced dominant complaints in the upper neck, lower neck, and back regions. The complaint percentages reached 82% for the upper neck, 84% for the lower neck, and 91% for the back, indicating substantial physical discomfort associated with prolonged static sitting and repetitive sewing activities. The Rapid Upper Limb Assessment (RULA) produced a final score of 7, placing the existing working posture in the very-high-risk category and indicating the need for immediate corrective action. The Right-Hand–Left-Hand Process Chart (PTKTK) identified motion waste associated with searching for sewing tools, resulting in an initial work efficiency of 70.21%. These findings indicate that the existing workstation created both postural exposure and movement inefficiency during the sewing process. The ergonomic problems were associated with the interaction between operator anthropometry, fixed workstation dimensions, sewing-machine position, and disorganized tool placement. The results establish the need for an integrated workstation redesign that addresses musculoskeletal risk and motion waste simultaneously.

The proposed redesign was developed using anthropometric measurements from 14 sewing operators and incorporated adjustable dimensions for both the chair and work table. The chair was designed with an adjustable height range of 68.9–80.3 cm, a backrest height of 45.79 cm, a seat depth of 41.7 cm, and a seat width of 45.6 cm, while the work table was designed with an adjustable height range of 72.6–90.2 cm. A partitioned drawer measuring 30 cm × 15 cm was incorporated to provide organized storage for frequently used sewing tools and reduce unnecessary searching movements. The proposed workstation resulted in a projected reduction in cycle time from 47 seconds to 29 seconds and an increase in work efficiency from 70.21% to 82.75%. The redesign provides a more appropriate physical relationship between the operator and workstation components while supporting more efficient access to sewing tools. The total estimated production cost of Rp2,606,090 remains economically reasonable considering the adjustable features, anthropometric-based dimensions, and integrated tool-storage function. The proposed workstation is expected to improve working comfort, support more appropriate posture, reduce exposure to MSDs, and minimize motion waste among sewing operators.

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