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EVALUATION OF OFFICE CHAIR DESIGN FROM ERGONOMIC AND ANTHROPOMETRIC PERSPECTIVES

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Abstract

Workplace seating that does not match user anthropometry often leads to discomfort and musculoskeletal disorders (MSDs). This study evaluates the office chairs used at the Politeknik Industri Furnitur dan Pengolahan Kayu Kendal by combining discomfort analysis and anthropometric mismatch assessment. Thirty-two employees (16 males, 16 females) participated, completing the Nordic Body Map (NBM) questionnaire and providing seated anthropometric measurements. The NBM results revealed that lower back discomfort was the most common complaint, particularly among female respondents, who also reported higher discomfort in the neck, shoulders, and upper back. Mismatch analysis confirmed severe incompatibilities between existing chair dimensions and user anthropometry, with seat height (100% mismatch for both genders) and seat depth (94% for men, 88% for women) as the most problematic. Based on these findings, a redesigned chair was developed, lowering seat height by 30 mm and reducing seat depth by 66 mm, alongside adjustments to backrest and armrest dimensions. Comparison with Indonesian (SNI) and international ergonomic standards (ISO 9241-5, BIFMA G1, EN 1335-1) showed that the redesign falls within recommended ranges. The study demonstrates how anthropometry-based redesign can reduce mismatch and improve comfort, providing practical guidance for the local furniture industry.

Keywords: *ergonomic chair; anthropometry; mismatch analysis; Nordic Body Map; musculoskeletal disorders*

1. Introduction

Improper workplace posture is a major contributor to employee fatigue and musculoskeletal complaints such as back pain, neck strain, and shoulder discomfort, which, if not addressed, may decrease productivity and increase the risk of musculoskeletal disorders (MSDs). Prior studies in Indonesia, such as (Kautsar & Dewi, 2020), have reported that improper seating arrangements negatively affect employees' daily comfort and work output. Poor posture like forward bending, slumped shoulders, or prolonged sitting, can lead to spinal and muscular strain, reduced blood circulation, and lactic acid accumulation in muscle tissue, ultimately causing pain and fatigue (Maulina et al., 2023).

Research on industrial and office seating has consistently highlighted the adverse effects of non-ergonomic chairs. Wardaningsih (2010) found significant increases in discomfort among female operators using non-ergonomic chairs, with the highest complaints reported in the lower back (88%) and waist (84%). Similarly, Kautsar & Putri (2021) emphasized that several office chair types in Indonesian companies yielded high Rapid Entire Body Assessment (REBA) scores, categorizing them as high risk for MSDs and necessitating ergonomic intervention. These findings underline that the current seat dimensions often fail to reflect the anthropometric profiles of Indonesian workers.

At present, ergonomic evaluation of office chairs in Indonesia is still largely referenced against the Indonesian National Standard (SNI 8780:2019) for wooden office chairs, which specifies only minimum dimensions without setting maximum thresholds. As a result, many chairs produced domestically remain too high or too deep for users, leading to dangling feet, ineffective lumbar support, and discomfort, as observed at the Politeknik Industri Furnitur dan Pengolahan Kayu Kendal (see **Figure 1**). In contrast, international standards such as ISO 9241-5:1998 Ergonomic Requirements for Office Work with Visual Display Terminals and ANSI/BIFMA X5.1-2017 General-Purpose Office Chairs provide more detailed guidelines, including dimensional ranges and adjustability criteria. However, limited research in Indonesia has attempted to benchmark local office chair designs against these global standards, leaving a clear research gap.

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Figure 1. Current Office Chair in Polytechnic (Personal Document, 2024)

Recent studies reinforce the importance of integrating ergonomic evaluation and anthropometric data into seating design. For example, Tatar et al. (2023) and (Almaz, 2022) proposed novel risk assessment frameworks for identifying work-related musculoskeletal disorders (WMSDs) among agricultural workers, highlighting the critical role of systematic ergonomic evaluation in preventing MSD risks across different occupational settings. Their findings underline that the absence of ergonomically appropriate interventions can elevate the likelihood of discomfort and long-term health issues.

Complementary to these risk-based approaches, research directly focused on office environments provides further evidence of the significance of ergonomically designed chairs. Vos et al. (2006) investigated the impact of postural variation and chair design on seat pan interface pressure, revealing that chair design itself had the strongest influence on pressure distribution compared to postural treatments or individual differences, with notable gender-based interactions. Similarly, Lee et al. (2021) conducted a randomized controlled trial that demonstrated how workstation interventions aligned with individual anthropometric measurements significantly reduced musculoskeletal pain in the neck, shoulders, and upper back among office workers. Taken together, these studies affirm that ergonomic interventions are essential to reducing MSD risks, improving user comfort, and enhancing productivity.

Building upon these findings, this study contributes by not only evaluating the current office chair design at Politeknik Industri Furnitur dan Pengolahan Kayu but also by redesigning the chair dimensions using anthropometric data of its employees. This approach introduces a novelty compared to prior Indonesian studies, which have mainly focused on risk assessment rather than design modification. By comparing the redesigned chair dimensions with both SNI and selected international standards the study provides a stronger contextualization of ergonomic requirements. The redesigned chair is expected to serve as a model for improving user comfort, reducing MSD risks, and guiding future furniture manufacturing practices in Indonesia.

2. Research Methodology

This study aims to evaluate the design of office chairs currently used by employees at their workstations. Two main approaches were employed: subjective assessment using the Nordic Body Map (NBM) questionnaire and objective anthropometric measurement of employees, complemented by analysis of the existing chair dimensions.

Nordic Body Map (NBM)

The NBM questionnaire was used to identify discomfort in specific body regions during prolonged sitting. Respondents indicated pain or discomfort intensity across 27 standardized body regions, including the neck, shoulders, upper and lower back, hips, and legs. This tool is widely applied in ergonomics research because it provides both a qualitative and quantitative representation of musculoskeletal complaints.

To prioritize ergonomic intervention, NBM data were processed into frequency distributions and visualized using a Pareto chart. This analysis highlights the most affected body parts (e.g., lower back, shoulders, or neck), ensuring that design modifications target the areas contributing to most of the discomfort. In addition, results were analyzed separately for male and female respondents to capture gender-related differences in discomfort patterns, an important factor noted in previous studies.

Mismatch Analysis

Anthropometric measurements from 32 employees (16 males and 16 females) were systematically compared with the dimensions of the existing office chair. To evaluate dimensional suitability, mismatch criteria were defined using established ergonomic guidelines and prior research in seating ergonomics.

- Seat height vs. popliteal height: According to Parcells et al. (1999) and reinforced by Milanese & Griemer (2004), the seat height should fall between

Table 1. Application of Anthropometric Measurements

Anthropometric Variable	Related Chair Parameter	Percentile Used	Notes
Popliteal Height	Seat Height	P50	Ensures thighs rest comfortably without feet dangling
Buttock–Popliteal Length	Seat Depth	P50	Prevents seat from pressing behind knees
Shoulder Width	Backrest Width	P95	Provides enough width for upper body comfort
Hip Width	Seat Width	P95	Accommodates wider users, prevents hip compression
Shoulder Height	Backrest Height	P50	Aligns support with average user's shoulders
Seated Erect Height	Total Chair Back Height	P50	Ensures adequate clearance above head/neck support
Seat-to-Knee Height	Clearance Under Desk/Seat Edge	P50	Ensures legs fit comfortably
Buttock-to-Knee Length	Seat Depth Validation	P50	Cross-check with buttock–popliteal length
Buttock-to-Elbow Height	Armrest Height	P50	Prevents shoulder elevation or slumping
Backrest Inclination Angle	Backrest Angle (Lumbar Support)	P50	Optimized for spinal support, adjusted to reduce lower back pain

88% and 95% of the user's popliteal height. If the seat height exceeds this range, the user's feet may dangle above the floor, resulting in increased pressure on the thighs and discomfort in the lower back (Hoque et al., 2003) Conversely, if the seat height is too low, excessive knee flexion can occur, leading to circulatory restrictions.

- Seat depth vs. buttock–popliteal length: A mismatch is identified if the seat depth is less than 80% or more than 95% of the buttock–popliteal length (Parcells et al., 1999)(Saha et al., 2024). Too great a depth prevents users from fully resting against the backrest, reducing lumbar support and increasing thigh compression. Shorter seat depths, meanwhile, reduce support under the thighs and may cause instability while sitting.
- Seat width vs. hip width: The seat width should be at least 10–30% greater than the user's hip width to provide sufficient lateral clearance without being excessively wide (Parcells et al., 1999)(Vos et al., 2006). A seat that is too narrow compresses the hips, whereas an overly wide seat may prevent proper use of armrests and reduce lateral stability.
- Backrest height vs. shoulder height: Ideally, the backrest height should remain below the shoulder blade (scapula), as suggested by Agha (2010) and Himarosa (2019). This allows free movement of the upper limbs while still providing adequate support for the thoracic and lumbar regions. A backrest that is too high restricts upper body movement, while a shorter backrest reduces lumbar support effectiveness.
- Backrest width vs. shoulder width: The backrest width should be wider than the hip width while aligning closely with the user's shoulder breadth. According to Saha et al. (2024), this balance is necessary to ensure that the backrest provides lateral support without limiting arm mobility. Narrower backrests leave the shoulders unsupported, while excessively wide backrests may reduce the ergonomic effectiveness of the lumbar support contour.

The degree of mismatch for each parameter was then calculated and is presented in the Results section, where it is used as the basis for defining the revised chair dimensions.

Anthropometric Measurements

Anthropometric data were collected in the seated position, covering eleven key parameters relevant to office chair design, including popliteal height, buttock–popliteal length, shoulder width, hip width, shoulder height, eye height, seated erect height, seat-to-knee height, buttock-to-knee length, buttock-to-elbow height, and backrest inclination angle. Measurements were taken using an adjustable ergonomic chair to ensure accuracy and consistency.

The data were first tested for sufficiency, uniformity, and normality before calculating percentiles to represent different user groups. In line with ergonomic design principles, the 50th percentile (P50) was generally used to define average chair dimensions, while the 95th percentile (P95) was applied to parameters requiring greater allowance, such as hip and shoulder width. The application of these anthropometric values to chair parameters is summarized in **Table 1**.

Based on mismatch analysis, new chair dimensions were then determined using percentile-based redesign. This approach not only reduced mismatch rates but also directly addressed discomfort areas identified in the NBM results, ensuring that the proposed design was ergonomically appropriate and statistically valid.

The study primarily relied on static seated anthropometry as it provides stable baseline dimensions for chair sizing. While dynamic data (e.g., postural adjustments during learning or reaching) could offer additional insights, they were beyond the scope of this research. This limitation is acknowledged in the discussion, with recommendations for future studies to incorporate dynamic measurements.

3. Results and Discussion

Nordic Body Map

This study involved 32 employees of the Politeknik Industri Furnitur dan Pengolahan Kayu Kendal, consisting of 16 men and 16 women aged 24–42 years. The average respondent height was 164 cm and weight 68 kg, with average work experience about 4.8 years. On average, participants spent 39 hours per week seated at their workstations.

Analysis of the Nordic Body Map (NBM) responses showed that the most frequently reported complaints were concentrated in the lower back, neck, and upper back. Together, these three areas accounted for more than 70% of all reported discomfort, as illustrated in the Pareto chart (**Figure 2**). Women consistently reported higher frequencies of complaints in these regions compared to men, particularly for the neck and back. In contrast, a greater proportion of male respondents indicated "No Complaints," suggesting that the current chair design may be relatively more suitable for men or less compatible with the anthropometric characteristics of female employees.

Notably, lower back pain was the single most common issue, highlighting insufficient lumbar support in the current chair design. Complaints in the shoulders and hips were also more prevalent among women, further suggesting that the existing chair dimensions do not adequately accommodate differences in body proportions across genders.

These findings are consistent with earlier studies showing that mismatches between furniture dimensions and user anthropometry are a significant contributor to musculoskeletal discomfort (Tissot et al., 2009)(Vieira & Kumar, 2004). Recent evidence also indicates that gender-specific differences in posture and body structure can exacerbate discomfort when seating is not ergonomically adapted (Vos et al., 2006)(Lee et al., 2021). The results of this study therefore reinforce the importance of redesigning office chairs using locally collected anthropometric data.

Mismatch Analysis

To identify whether the current office chairs matched employees' body dimensions, a series of anthropometric measurements were taken in the seated position. These included parameters such as popliteal height, buttock–popliteal length, hip width, and shoulder dimensions. The collected data were then compared with the dimensions of the existing chairs to calculate the percentage of mismatch (**Figure 3**).

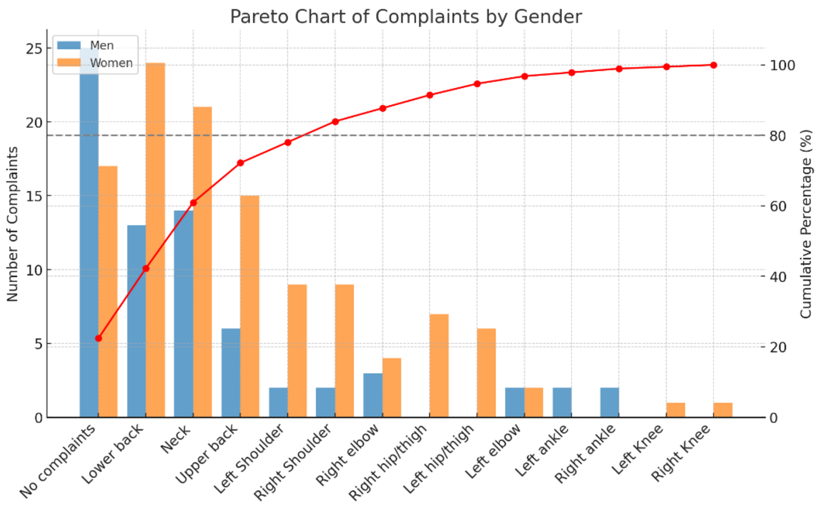


Figure 2. Pareto Chart of Aches/Pain Appearing in Certain Body Parts

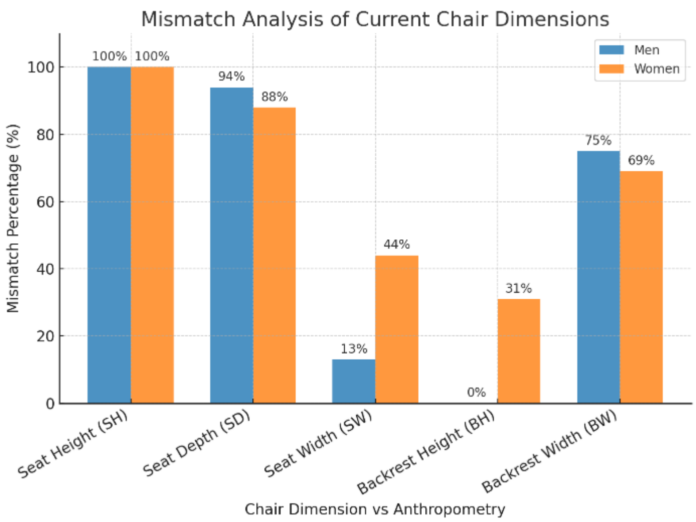
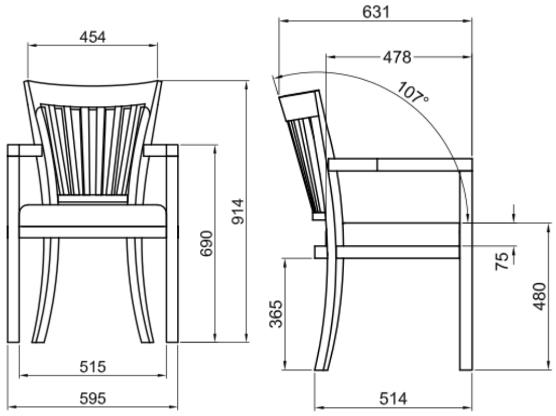
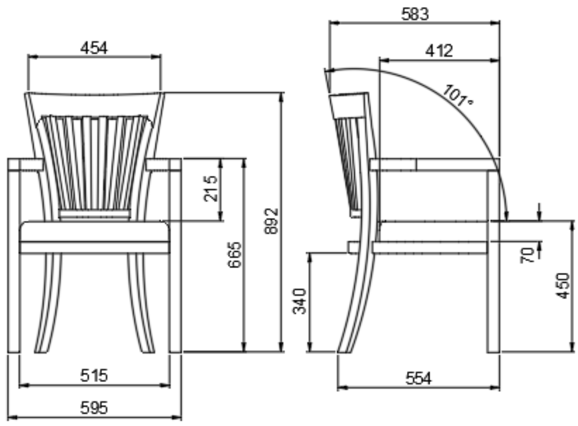


Figure 3. Mismatch Percentage for Chair Dimensions Based on Anthropometric Measurements



(a)



(b)

Figure 4. Chair Design Images (a) Existing Employee Chairs (b) Employee Chairs After Redesign

Seat height was the most critical issue, with a 100% mismatch for both men and women, demonstrating that the existing chair is universally too high. This condition prevents users' feet from resting flat on the floor, increases pressure under the thighs, and disrupts blood circulation. Such findings are consistent with the high prevalence of lower back and leg discomfort reported in the Nordic Body Map results.

Seat depth also showed a high rate of mismatch, which is 94% for men and 88% for women. The excessive depth forces users to sit forward, leaving a gap between the back and the backrest. As a result, the lumbar region is left unsupported, which corresponds directly to the elevated complaints of lower back pain.

Seat width revealed gender-specific challenges: 44% mismatch for women compared to 13% for men. This suggests that female employees experience more restriction in hip space, likely due to differences in body proportions. Limited seat width may contribute to discomfort in the hip and thigh regions, as identified in the NBM findings.

For backrest height, mismatch was observed in 31% of women, while men were unaffected. This indicates that the backrest does not adequately cover the shoulder and upper back area for a significant portion of female users, potentially explaining the higher rates of neck and upper back complaints among women.

Finally, backrest width showed consistently high mismatch levels for both men (75%) and women (69%). This suggests insufficient lateral support, which may lead to instability in posture, shoulder strain, and general discomfort during prolonged sitting.

Overall, these findings highlight that the existing chair design systematically fails to accommodate key anthropometric parameters of its users. The most urgent issues lie in seat height and depth, followed by seat and backrest dimensions, underscoring the need for a redesigned chair that minimizes mismatch and directly addresses user discomfort.

Supporting previous research, mismatches between anthropometry and chair dimensions have been shown to significantly increase the risk of musculoskeletal discomfort and reduce seating efficiency (Chaffin et al., 2006). These results confirm that the high mismatch rates observed are directly related to the dominant discomfort areas identified in the NBM analysis, particularly the lower back and neck.

Re-Designing Chair

Based on the mismatch analysis, the redesign focused on reducing incompatibility between chair dimensions and employee anthropometry. The primary adjustments targeted seat height and seat depth, which had the highest mismatch rates. The specific parameters for the redesign, including seat height, seat depth, sitting surface height, and surface depth, are displayed in **Figure 4**.

Table 2. Redesigned Chair Compared to Available Standards

Parameter	Redesigned Chair (mm)	SNI (Indonesia)	ISO 9241-5 (Fit Principle)	BIFMA G1 (ANSI)	EN 1335-1:2020 (Europe)
Seat Height	450	Min 380 mm	Should allow feet flat, knees ≈ 90°	Adjustable 380–560 mm	Adjustable (type-dependent)
Seat Depth	412	Min 340 mm	Less than buttock–popliteal length	≤ 430 mm (fixed); adjustable preferred	Adjustable seat depth required
Seat Width	515	Min 400 mm	Wider than user hip breadth	≥ 450 mm	Seat width & lumbar adjustable
Backrest Height	421.5	Not specified	Should support thoracic/lumbar comfortably	Not explicitly fixed	Adjustable lumbar + backrest angle
Backrest Width	454	Not specified	Should allow free arm movement	≈ seat width (≥ 450 mm recommended)	Adjustable backrest + armrest
Adjustability	Not adjustable	Not specified	Required for 5^{th}–95^{th} fit	Seat height, depth, recline	Seat, backrest, lumbar, armrest must be adjustable

The redesign introduced several key adjustments to reduce the mismatch between chair dimensions and user anthropometry. The seat height was lowered by 30 mm (from 480 mm to 450 mm), allowing employees' feet to rest flat on the floor, improving circulation and reducing thigh pressure. The seat depth was shortened by 66 mm (from 478 mm to 412 mm) so that users can sit back fully against the backrest, enhancing lumbar support and alleviating lower back pain.

In addition, the backrest height was reduced by 12.5 mm (from 434 mm to 421.5 mm) and the armrest height was lowered by 25 mm (from 365 mm to 340 mm) to better match shoulder and elbow levels, minimizing strain in the upper body. Seat and backrest width remained unchanged, as they already fit most users. Collectively, these dimensional refinements are expected to significantly reduce discomfort, especially in the lower back and shoulders, while providing a seating solution more compatible with the anthropometric profiles of employees.

Some dimensions, such as seat width, remain unchanged to provide adequate hip width allowance and maintain thigh movement freedom. A detailed comparison of dimensions between the current design, the standards requirements, and the redesigned chair is provided in **Table 2**. The new chair dimensions are aligned with the majority anthropometric measurements of employees to better meet ergonomic needs and improve workplace comfort.

By incorporating anthropometric data into the design, the chair is expected to significantly reduce discomfort and musculoskeletal disorders among employees, which can have positive effects on productivity and overall job satisfaction (Wilson, 2021). This approach follows established ergonomic principles, emphasizing the customization of work tools to fit user characteristics, which is essential in high-occupancy environments to maintain employee well-being and efficiency (Zhang et al., 2020)

The redesigned chair dimensions align well with both Indonesian (SNI) and international ergonomic standards (**Table 2**). The seat height of 450 mm falls comfortably within the recommended range of BIFMA (380–560 mm) and matches the ISO principle of maintaining a knee angle close to 90°. Similarly, the seat depth of 412 mm complies with BIFMA's fixed depth limit of 430 mm, preventing pressure behind the knees and allowing users to fully utilize the backrest. With a seat width of 515 mm, the chair not only exceeds the SNI minimum (400 mm) but also surpasses BIFMA's recommendation (≥450 mm), ensuring sufficient space for hip width. Backrest height and width also fall within acceptable ranges, offering adequate support for the back and shoulders.

However, despite these positive outcomes, the absence of adjustable features remains a limitation. International standards such as ISO 9241-5, BIFMA G1, and EN 1335-1 emphasize adjustability to accommodate users across the 5^{th} to 95^{th} percentile range. While the redesigned chair dimensions already reduce mismatch and enhance comfort for the majority of employees, integrating adjustable elements, such as seat height, seat depth, backrest inclination, and lumbar support, would elevate the design to meet global ergonomic expectations and broaden its usability across diverse body types.

Although the redesigned chair addresses key anthropometric mismatches and meets both SNI and international ergonomic standards, its effectiveness must still be validated in practice. Usability testing using tools such as ROSA, RULA, or REBA is recommended to objectively assess posture and physical strain during prolonged use. This step is particularly important to verify whether the new design reduces the high rates of lower back and shoulder discomfort, especially among female users who previously reported higher discomfort levels. Such evaluations will help determine if the redesigned chair truly enhances user comfort and provides long-term protection against musculoskeletal disorders (MSDs), thereby ensuring that the improvements move beyond theoretical compliance and translate into measurable benefits in the workplace.

As a follow-up to this study, a prototype of the redesigned chair has been developed and preliminarily tested using the Rapid Office Strain Assessment (ROSA) and user interviews. Early findings indicate potential improvements in comfort and posture support. However, these results lie beyond the scope of the present research and will be reported separately in future publications.

4. Conclusion

The study concludes that the existing office chair lacks ergonomic features and poses a potential risk for Musculoskeletal Disorders (MSDs) among users. This finding is evident from the chair dimensions, which do not accommodate employees' working postures effectively, proven by the high percentages of the mismatch analysis. To address this, a redesign was undertaken using anthropometric principles. These findings provide practical guidance for local furniture manufacturers in Indonesia to design office chairs that better match workers' anthropometric profiles, thereby improving comfort, productivity, and long-term health outcomes.

However, further research is required to validate these improvements under actual working conditions. Future studies should include usability testing through RULA, or REBA to assess postural risks and ergonomic load during prolonged use. Additionally, exploring the integration of adjustable features would expand the chair's usability across a wider range of users (5th–95th percentile). It is also recommended to investigate gender-specific ergonomic solutions, as female employees were found to report higher levels of discomfort. Finally, incorporating dynamic anthropometric data in future designs may provide deeper insights into user comfort and musculoskeletal disorder (MSD) prevention.

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