ORIGINAL ARTICLE

Effectiveness of the Developed Hot-work Chair Prototype for Hot-work Workers: A Preliminary Study in the View of Ergonomics

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ABSTRACT

Introduction: Workers in a selected company currently performing hot work using inade-quate seating tools experience prolonged static and awkward body postures, leading to mus-cle discomfort and pain, especially in the buttocks, lower back, thighs, and other areas. This research aims to assess and compare the level of muscle discomfort between the control group, which continued their existing practices, and the experimental group, which used the newly developed hot work chair. **Methods:** The effectiveness of the hot work chair was evaluated using pre-test and post-test questionnaires, including a body discomfort chart assessed with a 100-millimeter Visual Analogue Scale (VAS). A total of 24 respondents were divided into two groups, with 12 respondents in each (control and experimental groups). The experimental group used the hot work chair, while the control group maintained their usual seating practices. Pre-tests and post-tests were conducted to assess muscle discomfort ratings before and after using the hot work chair. **Results:** Data analysis using the Wilcoxon Signed-rank test revealed a significant difference in the overall discomfort rating for the ex-perimental group between pre-test and post-test ($Z = -3.062$, $p = 0.002$). Conversely, there were no significant differences for the control group workers between pre-test and post-test for the specified body regions. Notably, the highest discomfort ratings, such as buttocks, were reduced from 77.50 ± 4.78mm to 37.00 ± 4.13mm during the post-test. The experimental group showed an overall discomfort rating reduction of 49% after using the hot work chair. The chair's seat, backrest, and knee support feature contoured cushions that adapt to various body postures, allowing multiple seating positions for users based on their requirements and working environment. **Conclusion:** The introduction of the hot work chair effectively re-duced muscle discomfort during extended hot work activities and improved body postures, thereby potentially reducing the risk of muscle discomfort leading to musculoskeletal disor-ders and other work-related injuries.
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Keywords: Muscle discomfort, hot works, product design specification, prototype design and development

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INTRODUCTION

Hot work includes flame-producing activities, spark-producing activities, and heat-producing activities, either through conduction, radiation, or convection (1). The hot work activities play the most important role in the offshore container's fabrication and framework structuring pro-cesses. The ergonomics objective is to fit machine and man together to improve the perfor-mance of the worker, reduce risks, stresses, and fatigue in the workplace (2). Hot work is re-quired in nearly every phase of structuring, fabrication, finishing, repairing, maintenance, and for product modification in metal fabrication industries where most of the time chairs are not available for related workers. Musculoskeletal disorders (MSD) among hot work workers have been contributed to by many ergonomic risk factors such as performing hot works in awkward positions, working for long hours, sitting for extended periods, maintaining static postures, and exposure to vibration (3). During hot works performed in a seated position, such as welding or other tasks involving heat or open flames, the body mechanisms involved can vary depending on the specific task, equipment used, and the worker's technique. However, here are some general body mechanisms that may be involved:

a) Seated Posture: Hot work tasks often require workers to sit for extended periods.

b) Arm and Hand Movements: In a seating position, the worker's arms and hands are usually actively engaged in manipulating tools or equipment.

c) Upper Body Stability: Seated hot work tasks often require upper body stability to maintain control and precision. The core muscles, including the abdominal and back muscles, play a crucial role in providing stability and balance.
d) Head and Neck Position: The worker's head and neck position can vary depending on the task and the need for visual focus.
e) Weight Shift and Adjustments: During hot works in a seating position, workers may need to shift their weight and make adjustments to maintain stability, reach different areas, or access tools or equipment.

Musculoskeletal injuries (MSIs) are prevalent among workers engaged in hot work, particu-larly welders. Female welders face an added risk due to subpar equipment design (1). Indi-viduals involved in hot work tasks are at a heightened likelihood of encountering musculo-skeletal disorders, encompassing problems like back injuries, shoulder pain, tendonitis, di-minished muscle strength, carpal tunnel syndrome, white finger, knee joint ailments, and oth-ers. These issues stem from various ergonomic hazards, including performing hot work in awkward positions, extended work durations, prolonged sitting, static postures, and exposure to vibrations (4). An improper body stance or awkward posture stands as a significant risk, potentially leading to muscular discomfort or pain for those who routinely engage in hot work. A conducted study identifies constrained awkward postures as the foremost contributor to occupational muscle injuries among various work stances (5). Essentially, three primary risk factors escalate the likelihood of developing musculoskeletal injuries in hot work set-tings: repetitive tasks that force operators into prolonged static positions or recurrent motions, activities demanding significant pressure and force application (such as pushing, pulling, and lifting), and improper postures like bent wrists or backward-tilted necks (6). In a separate study, it was found that welding workers who work in static conditions cause the blood flow to become slow, thus reducing the supply of nutrients to the muscles and then slowing the acid removal, excretory, healing, and recovery process in the affected muscle's region (7).

The configuration of a workplace can significantly impact body postures if workers can com-fortably adapt to it. The prevalent working postures in the chosen company's hot work in-volve performing tasks while sitting and using unsuitable tools for extended periods. Extensive evidence from a study highlights those prolonged sitting triggers discomfort among workers (1). Balancing worker capabilities and requirements through ergonomic workstation or equipment design poses a complex challenge in industrial contexts (8). In operations like welding, the physical dimensions of workplace design significantly influence production effi-ciency and the physical and mental well-being of workers. Poorly-designed equipment can lead to poor postures, resulting in static muscle strain, acute localized muscle fatigue, reduced productivity, and heightened health risks for welders (6). Crafting chairs for welding or other hot work mandates consideration of factors like workers' physical abilities, the weight of equipment, tool design, body mechanics during work, protective gear type, workspace condi-tions, and the range of body positions assumed during tasks (9). Performing hot work tasks like welding, grinding, and cutting poses various ergonomic challenges. These tasks often demand uncomfortable body positions, prolonged sitting without suitable chairs, extended work periods, exposure to vibration, and more. Within the welding fabrication industries, musculoskeletal disorders (MSDs) are a leading cause of occupational injuries and disabili-ties (8). Workers engaged in hot work are particularly prone to musculoskeletal disorders, which encompass issues like back injuries, shoulder pain, tendon inflammation, reduced muscle strength, carpal tunnel syndrome, white finger syndrome, knee joint problems, and others. An improper body posture or awkward positioning is a significant risk factor contrib-uting to these injuries among hot work personnel (10). For this research study, a company specializing in the production of offshore containers and metallic covers for the oil, gas, and service industries over the past two decades was selected. Among all processes involved in offshore container production, the activities of shearing, forming, and fabricating metal parts stand out as the most hazardous due to the frequent engagement in hot work and the require-ment for substantial manpower. The development of a hot work chair prototype followed a three-stage process, which was adapted from Pugh's total design process model (11).

Stage 1 of the design process involved identifying musculoskeletal pain and ergonomic risk factors causing discomfort among hot work employees during their activities at the selected company. The insights and feedback gathered in this stage informed Stage 2, where the proto-type of the hot work chair was conceptualized and designed. The ergonomic risk factors and discomfort locations identified guided the chair's design. A Pugh chart was employed to evaluate various design options and compare them against criteria established in Stage 1. Several designs were developed, assessed, and after comprehensive evaluation, design 5 was selected as the optimal choice for the hot work chair prototype. This prototype incorporated features such as an adjustable backrest, seat height, and angle to accommodate diverse body postures and user comfort during both short and extended hot work sessions. The backrest and kneeling pad were made detachable for situations where they are not needed. The devel-oped hot work chair boasts significant features aimed at improving the body postures and work performance of hot work employees at the selected company. The thick and heavy-duty dual-layer cushions ensure enduring comfort during prolonged hot work tasks. The robust wheel castors facilitate easy movement of the chair both indoors and outdoors, and the sturdy brakes on the castors enhance safety by preventing slips, trips, and falls. The overall proto-type assembly process is illustrated in Figure 1.

Following the development of the hot work chair design into a prototype, initial testing was conducted in Stage 3 to compare the discomfort level of the designed prototype with the cur-rent seating practice as a preliminary assessment. During this stage, five hot work workers were randomly selected to use the developed hot work chair prototype at the company. These participants completed a muscle discomfort survey using a 100-mm Visual Analog Scale (VAS) for their usual seating practices over a 3-hour period. The initial evaluation indicated that the designed and developed hot work chair is fully functional, providing support and comfort to workers during hot work activities. However, a comprehensive study is needed to compare the muscle discomfort levels between pre-test and post-test sessions (experimental and control groups) among hot work workers. This will help gauge the effectiveness of the designed and developed hot work chair (12).

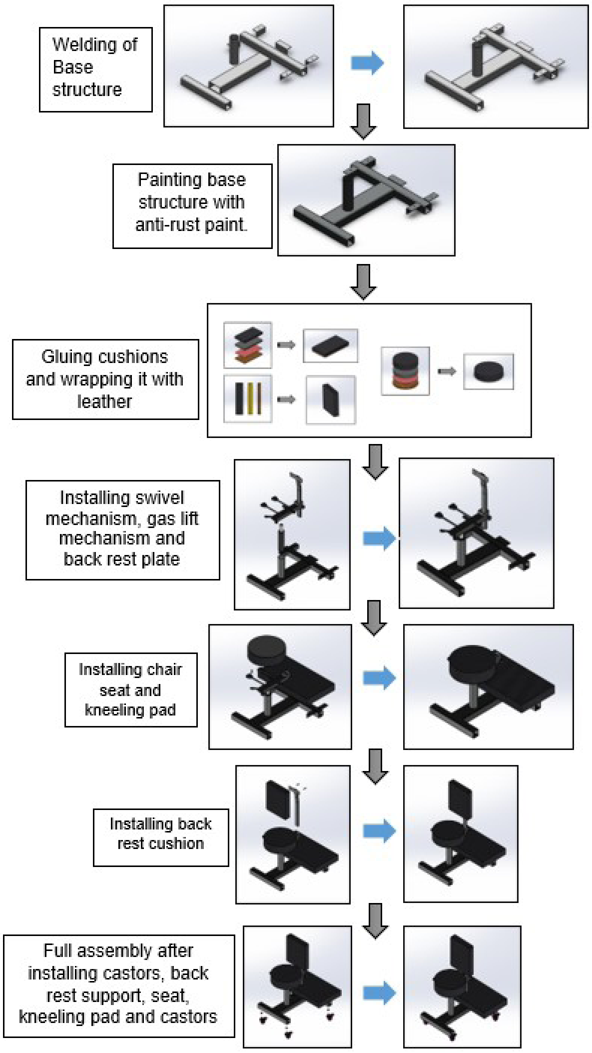

Figure 1: Overall overview of the prototype assembly

Crafting an ergonomic workspace is persistently challenging due to the complexities of ac-commodating various body postures for workers. A properly designed workplace can notably influence body postures if workers can effectively adapt. Extensive research reveals those prolonged sitting leads to worker discomfort (13). Designing workstations or equipment in the manufacturing industry with an ergonomic approach requires a delicate balance between worker capabilities and demands (14). Inadequate equipment design can induce improper postures, leading to static muscle strain, acute localized muscle fatigue, diminished produc-tivity, and heightened health risks for welders (9). Analyzing and designing chairs for hot work necessitates considering elements such as the worker's physical abilities, tool weights, design specifics, body mechanics during work, protective gear, workspace conditions, and the array of body positions relevant to the tasks (15). Devising suitable seats for specific tasks presents a significant challenge. An appropriate chair can offer correct cushions, lumbar sup-port through backrest adjustments, adjustable armrests, a five-legged base for stability, and depth settings for optimal comfort during hot work. A suggested approach involves an adjust-able chair height based on user size and adaptability to fixed-height work surfaces. The inclu-sion of wheels in the chair design facilitates short-distance mobility for workers (16).

MATERIALS AND METHODS

This study was conducted at the selected company in Pulau Indah, Selangor. This company is heavily involved in metal fabrication and metal-related manufacturing processes. The study took place at the selected metal container fabrication company for a duration of six months in the year 2020. The efficacy of the developed prototype in lowering body discomfort ratings was tested by comparing pre-test and post-test sessions in two groups. The estimated standard deviation, estimated larger mean, and estimated lower mean for the influence of active lum- bar support on the seated comfort of workers using a VAS scale were 30.2, 57.2, and 19.0, respectively. Below is the equation used to calculate the sample size (17).

$$N = \frac{2\sigma^2 (z1\text{-}\alpha/2 + z1\text{-}\beta)^2}{(\mu1\text{-} \mu2)^2}$$

Where,

1-α/2= The desired level of significance. In this study, z1-α/2 = 1.96, since the significance level is 95%

1-β = The desired power. In this study, the z1-β = 0.842 since the desired power is 80%.

The calculation of estimated sample size:

n = 2 (30.2)2 x (1.96 + 0.842)2 / (57.2 – 19.0)2

= 9.81 ≈ 10 respondents

Based on the calculation, each control group and experimental group is supposed to have 10 respondents. However, an additional 20% dropout rate was added to the calculated samples. The new sample size will be as below.
N = 10 + (20% x 10)

= 10 + 2 = 12 respondents

There is a total of 24 respondents selected for this phase 2 of this study where each control group and experimental group have 12 respondents.

Specific inclusion and exclusion criteria were established for this research. Inclusion criteria specified that workers' ages should fall between 20 and 50 years. Additionally, all respond- ents were required to possess at least 1 year of experience in hot work at the selected compa- ny for data accuracy. Exclusion criteria encompassed workers over 50 years of age, those with less than 1 year of experience in hot work, and those undergoing medical treatment for musculoskeletal disorders. Only those meeting inclusion and exclusion criteria were selected.

The effectiveness of the hot-work chair compared with their current seating practices was assessed using a pre-test and post-test questionnaire that consists of a body discomfort chart, which was evaluated using a 100-millimeter Visual Analog Scale (VAS). The questionnaire in the pre-test and post-test encompassed four sections: Section A covered Socio- Demographic background, Part B captured Medical History, and Part C comprised the Body Discomfort Chart (BDC). Sections A and B were directly drawn from Appendix 1 and Ap- pendix 4 of the 2017 Ergonomic Risk Assessment guidelines, using the exact questions to ensure questionnaire reliability and accuracy. Part C, the Body Discomfort Chart (BDC), was adapted from a previous study, a recognized tool for pinpointing discomfort locations due to hot work while seated (6). This chart is established as valid and reliable for assessing discom- fort locations (10). The intensity of discomfort was gauged using a 100mm Visual Analog Scale (VAS), where respondents marked their discomfort level on a line ranging from 0mm (no discomfort) to 100mm (extreme discomfort) (18).

After briefing participants on the study's objectives and the evaluation process, written con- sent was obtained. The control and experimental groups were formed using simple random sampling. The experimental group (n=12) utilized the developed hot work chair prototype for 10 hours, 6 working days, with a total of 12 weeks to complete one cycle. Pre and post-tests, using the muscle discomfort rating questionnaire, were conducted with a one-week interval. Both groups answered the first questionnaire on Monday morning (pre-test) and the second questionnaire on Saturday evening after a 6-day period (post-test). The working hours for both the control group and the experimental group is 10 hours per day. During the study dura- tion, all respondents were requested to work for a maximum of 10 hours only with approval from their manager to prevent other factors like worker fatigue or stress from affecting the assessment results. The control group (n=12) underwent pre- and post-tests at the same inter- vals (10 hours, 6 working days, with a total of 12 weeks) as the experimental group but fol- lowed their regular seating practices during hot work. The comparison of current seating practices and the hot-work chair prototype developed in this research study is as follows:
1. Current seating practice
- Some workers just squatting and kneeling on the floor while performing hot- works
- Some workers use improper tools to sit while performing the hot- works

2. Developed Hot-work chair prototype
- Adjustable back rest which can be converted to chest rest
- Knee support which can used for seating position
- Detachable back rest based on seating needs
- Seat, Back rest, and Knee support have cushion with contour shape to support back posture
- Movable chair with attached with strong wheels with brake.
- Providing multiple types of seating position based on the needs

The questionnaire session took around 20 minutes for both groups. No instances of non- compliance or incomplete experimental testing were observed. All 24 samples completed the follow-up stage without any losses. No respondents discontinued the intervention, and no exclusions occurred. All respondents were successfully analyzed, and their data were collect- ed. IBM SPSS Version 26 was employed for data analysis, converting information from questionnaires into Microsoft Excel spreadsheets. Univariate and bivariate analyses were em- ployed, utilizing a 95% confidence level, 80% power, and a significance level of $p<0.05$. The Kolmogorov-Smirnov test assessed data distribution normality. Given the non-normal distri- bution of prototype evaluation data, non-parametric tests were applied. The Wilcoxon Signed-rank test was used to compare data between control and experimental groups, with discomfort rated above 30mm indicating its presence (14).

This study was approved by Ethics Committee for Research involving Human Subjects Universiti Putra Malaysia (Reference Number: JKEUPM-2022-214).

RESULTS

Section A and B of the questionnaire: Sociodemographic and Occupational profile of selected hot work workers
There are twenty-four hot work workers from the chosen

company selected as respondents in this final stage of the study to evaluate the effectiveness of the designed and developed hot work chair. They have been divided equally into control and experimental groups, each con- sisting of twelve respondents. The respondents' demographic data from Section A of the questionnaire during the pre-test for both the control and experimental groups were tabulated in Table I. No significant difference was identified between the workers in each group. The mean age for the control group is 36.08 ± 6.37 years, while for the experimental group, it is 37.42 ± 6.13 years. Next, the mean height for the control group is 161.92 ± 4.36 cm, and for the experimental group, it is 164.50 ± 5.68 cm. This is followed by the weight range for the control group, which is 70 – 101 kg, and for the experimental group, it is 68 – 95 kg. The cor- relation between sociodemographic and muscle discomfort ratings shows a strong positive significant correlation between the years of hot work experience and the age of workers ($p < 0.01$, $r = 0.763$) and a moderate positive correlation between the years of hot work experience and overall discomfort ratings ($p < 0.01$, $r = 0.374$). There is also a significant correlation between the age of workers and overall discomfort ratings ($p < 0.01$, $r = 0.300$). Section B of the questionnaire did not record any past medical history related to ergonomics or musculo-skeletal disorders.

Section C of the questionnaire: Distribution of Discomfort Ratings

Throughout the study, respondents from both the control and experimental groups completed the questionnaires once their shifts concluded. As illustrated in Figure 2, the control group respondents exhibited similar discomfort ratings for most specific body regions in both the pre-test and post-test phases. When comparing discomfort across different body regions, the buttocks had the highest recorded discomfort rating, measuring 73.67 ± 12.75 mm in the pre- test and 72.17 ± 12.58 mm in the post-test among control group workers. Following this, the thigh and knee regions displayed notable discomfort. Specifically, the thigh had a discomfort rating of 71.75 ± 8.99 mm in the pre-test and 72.75 ± 9.13 mm in the post-test, while the knee region scored 73.08 ± 10.10 mm in the pre-test and 71.50 ± 10.17 mm in the post-test. Other body regions, including the calf, shoulder, neck, upper back, and lower back, also reported discomfort ratings surpassing 60 mm. The collective discomfort ratings for control group re- spondents were 67.17 ± 8.04 mm in the pre-test and 67.58 ± 8.039 mm in the post-test. Mus- cle discomfort among hot work workers arises from factors like prolonged bending, sitting on unsuitable surfaces, frequent awkward body postures, and others (19).

Figure 3 displays the outcomes of the experimental group, which demonstrates a noticeable contrast between pre-test and post-test muscle discomfort ratings for specific body regions. During the pre-test phase, the buttocks exhibited the highest discomfort rating at 77.50 ± 4.78 mm, which then decreased to 37.00 ± 4.13 mm in the post-test. A similar trend was observed for the thigh region, with a pre-test discomfort rating of 76.08 ± 5.32 mm decreasing to 38.83 ± 3.157 mm in the post-test. Additionally, the discomfort ratings for the knee region, which initially stood at 74.17 ± 5.65 mm during pre-test, diminished to 36.75 ± 5.065 mm in the post-test. Other body regions, including the calf, shoulder, neck, upper back, and lower back,

all experienced substantial reductions in discomfort ratings between pre-test and post-test. Specifically, the calf's discomfort rating decreased from 69.58 ± 9.70 mm to 34.75 ± 3.11 mm, while the shoulder's rating

Table 1: Distribution of Socio-demographic and occupational profiles between the control group and experimental group (N=24)

Body Region	Control group (n=12)	Experimental group (n=12)	Z statistic	p-value
Age				
Mean ± SD	36.08 ± 6.37	37.42 ± 6.13	-0.445	0.657
Range	26 – 45	28 – 46		
Height				
Mean ± SD	161.92 ± 4.36	164.50 ± 5.68	-1.246	0.213
Range	155 - 171	155 – 172		
Weight				
Mean ± SD	84.00 ± 8.62	80.50 ± 8.50	-1.009	0.313
Range	70 – 101	68 – 95		
BMI (kg/m^2)				
Mean ± SD	32.03 ± 4.14	29.77 ± 3.04	-1.413	0.158
Range	25 - 40	25 – 36		
Working hours				
Mean ± SD	10 ± 0.0	10 ± 0.0	0.000	1.000
Range	10	10		

** p-value is significant at p<0.01

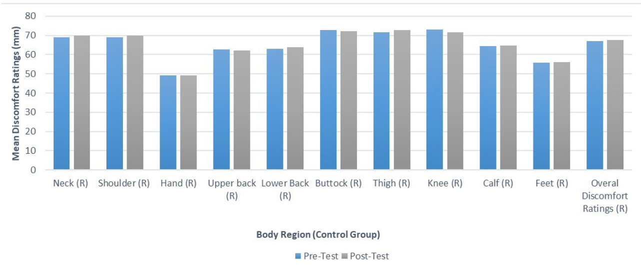

Figure 2: Distribution of discomfort ratings based on body regions by control group from Pre-test and Post-test

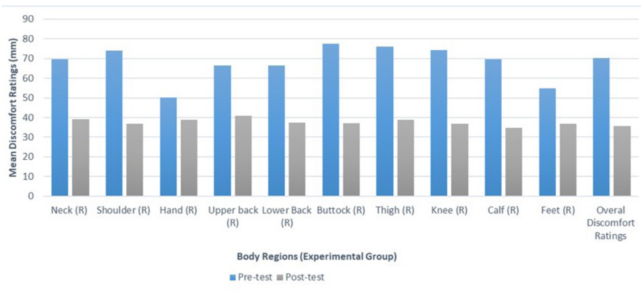

Figure 3: Distribution of discomfort ratings based on body regions by experimental group from Pre-test and Post-test

dropped from 73.92 ± 8.21 mm to 36.67 ± 6.33 mm. The up- per back's discomfort ratings decreased from 66.33 ± 6.29 mm to 40.92 ± 5.90 mm, and the lower back's discomfort rating experienced a reduction of 43.86% from pre-test to post-test. The overall discomfort ratings for the experimental group in the pre-test were 70.33 ± 3.47 mm, which significantly decreased to a score of 35.67 ± 3.77 mm during the post-test, reflect- ing a notable 49% reduction in discomfort ratings following the use of the hot work chair. Three studies focusing on ergonomic interventions were conducted in different settings: a garment factory, workshop, and office. These studies reported a considerable reduction in self-reported musculoskeletal pain immediately after the implementation of interventions (20).

The data analysis using the Wilcoxon Signed-rank test showed that the muscle discomfort ratings of all specified body regions for the experimental group are significantly different between pre-test and post-test evaluation results, including the neck (Z = -3.062, p = 0.02), shoulders (Z = -3.062, p = 0.02), hand (Z = -2.941, p = 0.002), upper back (Z = -3.062, p = 0.002), lower back (Z = -3.062, p = 0.002), buttocks (Z = -3.062, p = 0.002), thigh (Z = - 3.063, p = 0.002), calf (Z = -3.061, p = 0.002), knee (Z = -3.061, p = 0.002), and feet (Z = - 3.062, p = 0.002). The overall discomfort rating for the experimental group between the pre- test and post-test also shows a significant difference with Z = -3.062, p = 0.002. However, there were no significant differences for control group workers between the pre-test and post-test for the same specified body regions. The details of the mean and median scores for the body discomfort ratings between the pre-test and post-test have been tabulated in Table II.

Table II: Mean and Median score for the body discomfort ratings between pre-test and post-test (N=24)

Body Region	Group	Mean (Median)		Z statistic	p-value
		Pre-test	Post-test		
Neck	Control	69.00 (70.00)	69.83 (71.50)	-1.852	0.064
	Experimental	69.50 (71.00)	39.25 (36.50)	-3.062	0.002*
Shoulder	Control	68.92 (71.00)	70.00 (74.00)	-0.717	0.474
	Experimental	73.92 (76.00)	36.67 (35.50)	-3.062	0.002*
Hand	Control	49.08 (50.50)	49.33 (51.00)	-0.493	0.622
	Experimental	50.08 (50.00)	38.92 (40.00)	-2.941	0.002*
Upper back	Control	62.75 (64.50)	62.25 (63.50)	-0.902	0.367
	Experimental	66.33 (65.00)	40.92 (40.00)	-3.062	0.002*
Lower back	Control	63.08 (64.50)	63.92 (64.00)	-1.271	0.204
	Experimental	66.50 (67.50)	37.33 (37.50)	-3.062	0.002*
Buttock	Control	72.67 (75.00)	72.17 (73.00)	-0.040	0.968
	Experimental	77.50 (77.00)	37.00 (38.00)	-3.062	0.002*
Thigh	Control	71.75 (73.50)	72.75 (75.00)	-1.438	0.151
	Experimental	76.08 (75.50)	38.83 (39.50)	-3.063	0.002*
Calf	Control	73.08 (72.50)	71.50 (73.00)	-1.041	0.298
	Experimental	74.17 (75.00)	36.75 (35.00)	-3.061	0.002*
Knee	Control	64.50 (67.00)	64.83 (69.00)	-0.238	0.812
	Experimental	69.58 (70.50)	34.75 (35.00)	-3.061	0.002*
Feet	Control	55.83 (56.50)	56.17 (57.50)	-0.449	0.653
	Experimental	54.83 (54.50)	36.67 (38.00)	-3.062	0.002*
Overall discomfort	Control	67.17 (69.00)	67.58 (70.00)	-0.583	0.560
	Experimental	70.33 (70.00)	35.67 (35.00)	-3.064	0.002*

** p-value is significant at p<0.01

DISCUSSION

Based on the sociodemographic and occupational profile survey conducted, there is no signif- icant difference in the mean BMI between the control group and the experimental group. Age and the duration of exposure to hot work could be considered contributing factors for the fre- quency and severity of back and other musculoskeletal injuries associated with improper body positioning. Workers who are getting older are subject to a cumulative degeneration process and loss of flexibility that might increase the possibility and exposure level to these types of musculoskeletal injuries. For a company, the working experience of its employees is a crucial element for the sustainability of its business operations. Therefore, a hot work chair that has been designed and developed based on the needs of the workers could reduce muscle discomfort issues, improve the working postures of the workers, and increase the production of the company.

This research study has successfully investigated the efficiency of the developed prototype of the hot work chair among the selected respondents. In the pre-test phase, both the control and experimental group respondents reported elevated levels of discomfort ratings for various body regions, including buttocks, thigh, knee, calf, shoulder, neck, upper back, and lower back. These discomforts were attributed to ergonomic risk factors identified during a separate initial study by the researcher. The initial ergonomic risk assessment pinpointed awkward body postures, repetitive movements, and sustained static postures as key factors affecting hot work employees. Further assessment using the Quick Exposure Check (QEC) indicated a high risk for body parts such as the back, shoulder, arm, and neck. During the pre-test, work- ers continued the prevalent practice of using metal sheets and plastic containers as makeshift seating during welding, grinding, and other hot work tasks (12). Hot work workers suffer from muscle discomfort due to bending over prolonged duration, sitting on floors or any non- suitable materials, frequent awkward body postures, and others (19). This extended duration of non-ergonomic seating exacerbated muscle discomfort and pain across body regions. The lack of appropriate knee, back, and chest support, along with the adoption of awkward body positions, elevated ergonomic risks for workers.

However, the newly designed hot work chair prototype demonstrated its potential by signifi- cantly reducing discomfort levels compared to the pre-test phase. This research study found a substantial difference in muscle discomfort ratings before and after using the hot work chair prototype within the experimental group. Notably, discomfort ratings for the buttocks, thigh, knee, neck, calf, shoulder, upper back, and lower back exhibited marked reductions. The overall discomfort ratings for the experimental group decreased from 70.33 ± 3.47 mm in the pre-test to 35.67 ± 3.77 mm in the post-test, indicating a noteworthy 49% reduction in dis- comfort after implementing the hot work chair. The other body regions including calf, shoul- der, neck, upper back, and lower back previously scored high discomfort ratings during the pre-test but then reduced significantly during the post-test. The intervention of the hot work chair was shown to be remarkably effective across various body regions, indicating that workers experienced increased comfort and reduced muscle discomfort or pain when utilizing the designed prototype. The hot work chair's intervention particularly benefited the buttock and thigh area, relieving pressure on the ischium. Notably, the buttock-thigh region experi- ences the highest-pressure during seating, which can be exacerbated in the absence of proper back or chest support, hindering effective pressure distribution (21). The prototype of the de- veloped hot work chair features a robust cushioned seat that provides genuine comfort and support. By mitigating the development of musculoskeletal issues due to strenuous muscle activities from awkward postures, a proper chair or support can prove beneficial (22). Reduced discomfort associated with cushions with higher elasticity, decreased energy absorp- tion, and improved stiffness (r=0.4-0.9) (23).

The adaptable hot work chair has been engineered with a contoured cushioned seat, backrest, and knee support, accommodating various body postures. The chair's mobility is facilitated by sturdy attached wheels, ensuring ease of operation, handling, and maintenance. Its flexibil- ity empowers users to adopt multiple seating positions tailored to their needs and work envi- ronment. This encourages ergonomic body postures during work and enhances worker satis- faction and comfort during job tasks. Research reviews consistently support the use of chair interventions to mitigate musculoskeletal problems among workers engaged in prolonged sitting periods. However, the full extent of a chair intervention's effectiveness, especially concerning symptom recurrence and associated care costs, necessitates further investigation
(20). To achieve optimal results, it's essential to ensure that all affected workers utilize the designed chair correctly and effectively. Ergonomic advantages are realized through team- work, fostering a comfortable work environment and safe postures, ultimately contributing to more productive and prosperous hot work operations while safeguarding the long-term well-being of hot work personnel.

CONCLUSION

A prototype of a hot work chair has been successfully designed and developed in this re- search study, incorporating feedback from workers, an extensive literature review, and prod- uct design specifications. The operational, structural, and functional aspects of the prototype were effectively tested with selected workers, demonstrating its initial potential to reduce muscle discomfort ratings and improve the working body postures of hot-work employees. A significant difference in muscle discomfort ratings was observed between the pre-test and post-test sessions in the experimental group. Overall, the designed and developed hot work chair has proven its effectiveness in reducing muscle discomfort ratings among workers en- gaged in hot work tasks like welding, grinding, and metal cutting in a seated position, thus potentially reducing the risk of developing musculoskeletal disorders (MSD) and other ergo- nomic issues. To enhance the developed hot work chair and guide future research, several recommendations are noteworthy. First, expanding the participant pool to include hot work workers from comparable companies with similar work environments can improve research accuracy and yield more broadly applicable results. Larger sample sizes enhance research reliability. Additionally, beyond analysing work postures, considering factors like worker stress, workload, and personal life is recommended, as these elements may affect health and contribute to muscle discomfort. Furthermore, assessing the hot work chair's effectiveness in a clinical laboratory with tools like electromyography tests can provide a more comprehen- sive evaluation. Lastly, enhancing the chair's design with ergonomic features such as detach- able armrests, adjustable bases, and larger chest rests can broaden its utility beyond the metal fabrication industry, making it suitable for various other sectors.

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