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ORIGINAL RESEARCH ARTICLE

Associations of Work Posture, Work Period, Age, and Drinking Water Consumption with Musculoskeletal Complaints among Tofu Home Industry Workers in Sidoarjo

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ABSTRACT

Musculoskeletal complaints are common occupational health problems that can reduce workers' productivity and quality of life, particularly in informal home industries that rely on manual and physically demanding work. This study aimed to examine the associations of work posture, work period, age, and drinking water consumption with musculoskeletal complaints among tofu home industry workers in Areng-Areng Hamlet, Sidoarjo Regency, Indonesia. An analytical observational study with a cross-sectional design was conducted among 36 of 40 workers from two tofu home industries, selected by proportional random sampling. Work posture was assessed using the Rapid Entire Body Assessment (REBA), and musculoskeletal complaints were measured using the GOTRAK questionnaire based on SNI 9011:2021. Work period, age, and daily drinking water consumption were obtained through a structured questionnaire. Bivariate associations were examined using Spearman's rank correlation (α = 0.05). Most workers had high-risk work postures (52.8%), were aged ≥ 35 years (66.7%), consumed < 2.7 L of drinking water per day (55.6%), and reported moderate complaints (50.0%). Musculoskeletal complaints were positively correlated with work posture (r = 0.533; p = 0.001), work period (r = 0.467; p = 0.004), and age (r = 0.451; p = 0.006), and negatively correlated with drinking water consumption (r = −0.398; p = 0.016). Work posture, work period, age, and drinking water consumption were associated with musculoskeletal complaints among tofu home industry workers. Workstation improvement, reduction of awkward postures, and promotion of regular drinking during work are recommended as practical preventive measures.

Introduction

The rapid development of the modern era requires individuals to work continuously to meet their daily needs, making occupational health and safety (OHS) an essential element of a productive workforce. Non-ergonomic and unfavorable working environments may reduce productivity and increase the risk of occupational accidents and work-related diseases. Data from BPJS Ketenagakerjaan recorded 168,335 cases of occupational accidents and 91 cases of occupational diseases in the first semester of 2023 [1]. The increasing prevalence of sedentary work and poor ergonomic conditions are major contributors to musculoskeletal disorders (MSDs) [2]. Musculoskeletal complaints refer to disorders affecting muscles, joints, bones, tendons, and surrounding tissues, characterized by symptoms such as pain, stiffness, and discomfort, particularly as a result of non-ergonomic work activities [3]. In the United States, MSDs accounted for 30% of private-sector cases involving days away from work in 2018, with a median of 12 days away from work per case [4]. In Indonesia, the 2018 Basic

Health Research (Riskesdas) reported a prevalence of joint diseases, one component of musculoskeletal problems, of 7.3% [5].

Musculoskeletal complaints are influenced by various factors, including non-ergonomic working postures, excessive muscle strain, repetitive movements, and prolonged duration of employment. Workers with a work period of ≥ 5 years are at higher risk because of continuous exposure to occupational risk factors [6], [7]. Age also plays an important role, as increasing age is associated with reduced muscle strength and decreased work capacity [3]. Evidence from the WHO/ILO systematic review and meta-analysis further supports the relevance of ergonomic occupational exposures across both formal and informal economic settings, although the certainty of evidence varies according to the outcome and study design [8]. Recent reviews also emphasize that work-related musculoskeletal disorders are multifactorial: a 2024 systematic review and meta-analysis identified physical and psychosocial work exposures as important components of MSD risk, while a systematic review of manual occupations highlighted the central role of ergonomics in prevention and return-to-work strategies [9], [10]. These findings are relevant to small-scale food production, where workers perform physically demanding tasks with limited ergonomic resources.

Workers' lifestyle factors, particularly nutrition and hydration, also contribute to musculoskeletal health. Nutrients such as calcium, vitamin D, protein, and omega-3 fatty acids are essential for maintaining bone strength, muscle elasticity, and joint function [11]. Adequate hydration is equally important, considering that intervertebral discs contain approximately 80% water and the human body consists of about 60% water [12], [13]. Drinking water consumption has been reported to influence musculoskeletal complaints among workers [14]. Water transports nutrients through the bloodstream, lubricates joints through synovial fluid, and maintains tissue elasticity, thereby contributing to injury prevention [15], [16]. Conversely, dehydration may reduce muscle flexibility and accelerate tissue degeneration [17], and adequate water intake has been reported to reduce the risk of dehydration-related muscle tension and pain [18]. Occupational heat-safety guidance recommends accessible drinking water and regular opportunities to hydrate, and recent evidence among Australian mine workers shows that water consumption practices and heat-related symptoms are relevant occupational health concerns [19], [20]. However, evidence directly linking self-reported drinking water consumption to musculoskeletal complaints remains limited, and a causal pathway should not be assumed without objective hydration measures.

Musculoskeletal complaints are found not only in large-scale industries but also in micro, small, and medium enterprises (MSMEs), including informal home industries [2]. One of the growing home industries in Sidoarjo Regency is the tofu home industry in Tropodo Village, Krian District, which plays a significant role in the local economy as a source of income and employment. Tofu production is largely manual and may expose workers to awkward postures, prolonged standing, repetitive movements, manual material handling, and heat generated during boiling; recent research in small tofu factories in Indonesia has highlighted musculoskeletal risk in this setting [21]. Preliminary observation showed that workers stand for long periods, bend during filtering, molding, and cutting, and perform repeated wrist flexion and rotation when pressing tofu. The processes from filtering to molding are carried out by a single worker, and heavy raw materials are lifted manually without assistive devices. The soybean boiling process generates hot steam, creating a high-temperature working environment that increases fluid loss through sweating, while slippery floors add a further risk of slips that may contribute to musculoskeletal problems.

Several studies have examined factors associated with musculoskeletal complaints; however, studies that analyze drinking water consumption together with ergonomic and individual factors remain limited, particularly among tofu home industry workers. Therefore, this study aimed to examine the associations of work posture, work period, age, and drinking water consumption with

musculoskeletal complaints among tofu home industry workers in Areng-Areng Hamlet, Tropodo Village, Krian District, Sidoarjo Regency.

Materials and Methods

Research Design and Location: This analytical observational study used a cross-sectional design and was conducted in two tofu home industries in Areng-Areng Hamlet, Tropodo Village, Krian District, Sidoarjo Regency. Because exposures and outcome were assessed during the same period, the design was used to estimate associations and did not permit determination of temporal sequence or causality.

Population and Sample: The study population consisted of all 40 active workers in the two tofu home industries. The minimum sample size, calculated using the Slovin formula with a 5% margin of error, was 36 workers. Respondents were allocated proportionally to the number of workers in each industry and then selected randomly within each industry (proportional random sampling). The independent variables were work posture, work period, age, and drinking water consumption, and the dependent variable was musculoskeletal complaints.

Data Collection and Instruments: Work posture was assessed by direct observation of the main production tasks using the Rapid Entire Body Assessment (REBA) and categorized into the standard risk levels (negligible, low, medium, high, and very high). Musculoskeletal complaints were assessed using the work-related musculoskeletal disorders (*Gangguan Otot Rangka Akibat Kerja*, GOTRAK) questionnaire based on SNI 9011:2021; total scores were classified as low (12–71), moderate (72–132), and high (133–192). Work period, age, and daily drinking water consumption were obtained through structured interviews using a questionnaire. Work period was categorized as < 5 and ≥ 5 years and age as < 35 and ≥ 35 years. Self-reported drinking water consumption was categorized as < 2.7 and ≥ 2.7 L/day, using the lower limit of the recommended daily water intake for adults as the operational cut-off.

Data Analysis: Data were processed through editing, coding, entry, and tabulation and analyzed using SPSS software. Univariate analysis described the characteristics of the respondents and the distribution of each variable. Bivariate associations between each independent variable and the ordinal category of musculoskeletal complaints were examined using Spearman's rank correlation. The strength and direction of each association were expressed as Spearman's correlation coefficient (r), and statistical significance was assessed using a two-tailed test at $\alpha = 0.05$.

Research Ethics: This study obtained ethical approval from the Health Research Ethics Commission of Poltekkes Kemenkes Surabaya (No. EA/4080/KEPK-Poltekkes_Sby/V/2026). All respondents provided written informed consent before participation, and participant confidentiality and anonymity were maintained throughout the study.

Results

Respondent Characteristics

The distribution of the study variables is presented in Table 1. More than half of the workers had high-risk work postures (52.8%), and a further 11.1% had very high-risk postures. Slightly more than half had a work period of < 5 years (52.8%), and two-thirds were aged ≥ 35 years (66.7%). More than half of the workers consumed < 2.7 L of drinking water per day (55.6%), and half reported moderate musculoskeletal complaints (50.0%).

Table 1. Distribution of Respondents by Work Posture, Work Period, Age, Drinking Water Consumption, and Musculoskeletal Complaints (n = 36)

Variable and Category	n	%	Variable and Category	n	%
Work Posture (REBA)			**Age**		
Negligible	0	0.0	< 35 years	12	33.3
Low	0	0.0	≥ 35 years	24	66.7

Variable and Category	n	%	Variable and Category	n	%
Medium	13	36.1	**Drinking Water Consumption**		
High	19	52.8	< 2.7 L/day	20	55.6
Very high	4	11.1	≥ 2.7 L/day	16	44.4
Work Period			**Musculoskeletal Complaints (GOTRAK)**		
< 5 years	19	52.8	Low	10	27.8
≥ 5 years	17	47.2	Moderate	18	50.0
			High	8	22.2

REBA, Rapid Entire Body Assessment; GOTRAK, Gangguan Otot Rangka Akibat Kerja (work-related musculoskeletal disorders).

Bivariate Analysis

The cross-tabulation of each variable against the level of musculoskeletal complaints and the results of Spearman's rank correlation are presented in Table 2. All four variables were significantly associated with musculoskeletal complaints. Work posture showed the strongest positive correlation ($r = 0.533$; $p = 0.001$), followed by work period ($r = 0.467$; $p = 0.004$) and age ($r = 0.451$; $p = 0.006$). High complaints were found in 50.0% of workers with very high-risk postures and in 31.6% of those with high-risk postures, but in none of those with medium-risk postures. Drinking water consumption showed an inverse correlation ($r = −0.398$; $p = 0.016$): none of the workers consuming ≥ 2.7 L/day reported high complaints, compared with 40.0% of those consuming < 2.7 L/day.

Table 2. Cross-Tabulation and Spearman's Rank Correlation of Work Posture, Work Period, Age, and Drinking Water Consumption with Musculoskeletal Complaints

Variable and Category	Musculoskeletal Complaints, n (%)			Total (n)	p-value	Spearman's r
	Low	Moderate	High			
Work Posture					**0.001**	**0.533**
Negligible	0 (0.0)	0 (0.0)	0 (0.0)	0		
Low	0 (0.0)	0 (0.0)	0 (0.0)	0		
Medium	7 (53.8)	6 (46.2)	0 (0.0)	13		
High	3 (15.8)	10 (52.6)	6 (31.6)	19		
Very high	0 (0.0)	2 (50.0)	2 (50.0)	4		
Work Period					**0.004**	**0.467**
< 5 years	8 (42.1)	10 (52.6)	1 (5.3)	19		
≥ 5 years	2 (11.8)	8 (47.1)	7 (41.2)	17		
Age					**0.006**	**0.451**
< 35 years	7 (58.3)	4 (33.3)	1 (8.3)	12		
≥ 35 years	3 (12.5)	14 (58.3)	7 (29.2)	24		
Drinking Water Consumption					**0.016**	**−0.398**
< 2.7 L/day	4 (20.0)	8 (40.0)	8 (40.0)	20		
≥ 2.7 L/day	6 (37.5)	10 (62.5)	0 (0.0)	16		
Total	**10 (27.8)**	**18 (50.0)**	**8 (22.2)**	**36**		

Row percentages are shown. p-values and correlation coefficients (r) were obtained from Spearman's rank correlation (two-tailed, $\alpha = 0.05$).

The positive coefficients for work posture, work period, and age indicate that higher exposure categories were associated with higher complaint categories, whereas the negative coefficient for drinking water consumption indicates that the higher consumption category was associated with lower complaint categories.

Discussion

Work posture was significantly and positively associated with musculoskeletal complaints ($r = 0.533$; $p = 0.001$), indicating a moderate positive association; workers exposed to more non-neutral postures tended to report greater complaints. This association may be explained by the physical demands of tofu production. During filtering, molding, and cutting, workers were observed to bend the head forward, rotate the neck, and flex, twist, and laterally bend the trunk. They also stood for

prolonged periods, manually lifted loads exceeding 5 kg, and performed repetitive movements. These demands were compounded by inadequate workstation design, including worktables positioned below waist level and the absence of lifting aids, which required workers to deviate repeatedly from neutral postures and maintain awkward positions for extended periods.

Non-neutral postures increase the biomechanical load on muscles, joints, and supporting tissues. Manual handling of heavy raw materials and the use of tools that rely primarily on physical strength can lead to work fatigue [22], and the greater the deviation of the body from its natural posture, such as excessive trunk bending or rotation, the higher the risk of musculoskeletal complaints [23]. Mismatches between workstation design and job demands often force workers to maintain uncomfortable positions, thereby increasing the likelihood of injury [24]. This finding is consistent with a significant association between work posture and musculoskeletal complaints reported among roof tile industry workers [25] and with the association between heavy manual work and pain in the shoulders, waist, and back [3]. At a broader level, Greggi et al. identified work-related musculoskeletal disorders as a major occupational health problem and emphasized the contribution of physical and ergonomic exposures [10], while Hacay Chang et al. highlighted the relevance of ergonomic conditions and working environments for manual workers [9]. Accordingly, musculoskeletal complaints among tofu home industry workers should be viewed not solely as an individual problem but also in relation to the physical demands and ergonomic characteristics of the workplace.

Work period was positively associated with musculoskeletal complaints ($r = 0.467$; $p = 0.004$), indicating a moderate positive association. High complaints were reported by 41.2% of workers with a work period of ≥ 5 years, compared with 5.3% of those with < 5 years. Workers with longer work periods have experienced repeated exposure to repetitive movements, manual material handling, prolonged standing, and non-neutral postures over an extended period, which may lead to accumulated physical strain. Length of employment has also been associated with the development of non-ideal work habits [26]. Although experience improves task familiarity, repetitive work performed over long periods can accelerate muscle fatigue, tissue injury, and inflammation [7]. This finding is consistent with studies among tofu factory workers in Semarang [27], briquette workers, among whom a work period of ≥ 5 years was associated with increased complaints [28], and farmers [29]. A 2024 systematic review and meta-analysis among nurses likewise found that longer length of service was associated with a higher risk of work-related musculoskeletal disorders (WMSDs), together with heavy workload and long working hours [30]. Although the occupational context differs, these findings support prolonged exposure as a contributor to musculoskeletal problems. Because ergonomic knowledge and work techniques were not assessed in this study, differences in work practices between newer and more experienced workers should be interpreted cautiously.

Age was significantly and positively associated with musculoskeletal complaints ($r = 0.451$; $p = 0.006$), indicating a moderate positive association; older workers tended to report more complaints than younger workers. This may be related to age-related declines in muscle strength, physical work capacity, and muscular endurance, which reduce tolerance to physically demanding tasks such as lifting, pressing, and maintaining bent postures. When such demands are not adjusted to workers' capacities, older workers may experience greater strain and fatigue. Increasing age has been associated with reduced muscle strength and work capacity [3], physical strength tends to decline with advancing age [22], and musculoskeletal complaints tend to increase from approximately 35 years of age [23]. Significant associations between age and musculoskeletal complaints have been reported among home-based cracker industry workers [31], among workers with GOTRAK complaints in the neck, shoulders, upper back, lower back, and legs [32], and among laundry workers [33]. Internationally, a systematic review of WMSDs among computer users identified older age as a risk factor alongside repetitive movements and awkward postures [34], and a meta-analysis among nurses found a higher likelihood of WMSDs in workers aged > 35 years [30]. Despite differences in occupational settings, these findings

support the relevance of age to musculoskeletal health among workers performing physically demanding tasks.

Drinking water consumption was significantly and negatively associated with musculoskeletal complaints ($r = -0.398$; $p = 0.016$), indicating a moderate inverse association; workers with higher water consumption tended to report fewer complaints. Most workers had access to drinking water at the workplace, and some brought personal water bottles. The owner reportedly provided approximately four gallons of drinking water and replenished the supply when depleted. Nevertheless, more than half of the workers (55.6%) consumed less than 2.7 L/day, suggesting that the availability of drinking water alone may not ensure adequate intake, as individual drinking behavior and work practices also influence hydration.

Adequate fluid intake is important for maintaining hydration and physical function during work, and the recommended total daily water intake for adults is approximately 2.7–3.7 L [35]. Adequate water consumption helps maintain body hydration, supports muscle recovery, and reduces the risk of muscle pain and cramps [14]. Water is involved in nutrient transport, maintenance of tissue elasticity, and joint lubrication through synovial fluid [15], [16], and a loss of approximately 3%–4% of body water may weaken muscle strength and physical performance [18]. These mechanisms may help explain the inverse association observed in this study, particularly because tofu workers perform physically demanding tasks in a warm environment. In a systematic review and meta-analysis covering workers from more than 40 occupations, Flouris et al. reported that occupational heat exposure was associated with physiological heat strain, increased urine specific gravity, and reduced productivity [36], and Roca et al. showed that workplace hydration strategies, including adequate access to drinking water, can help prevent dehydration among workers exposed to heat [37]. The present finding is consistent with a significant correlation between drinking water consumption and musculoskeletal complaints among concrete production workers, in whom higher water intake was associated with fewer complaints [38]. Morrissey et al. also emphasized that fluid requirements vary with individual characteristics, work intensity, environmental conditions, and rest-break schedules, and recommended ensuring accessible drinking water and encouraging regular fluid intake during work [19].

This study has several limitations. First, the cross-sectional design does not establish the temporal sequence between the studied factors and musculoskeletal complaints and therefore precludes causal inference. Second, the sample consisted of only 36 workers from two tofu home industries, which limits statistical power and the generalizability of the findings. Third, drinking water consumption and musculoskeletal complaints were self-reported, creating potential recall and information bias. Fourth, the analysis was limited to bivariate Spearman correlation and did not adjust for potential confounders such as working hours, workload, physical activity, body mass index, previous musculoskeletal problems, or psychosocial factors; in particular, age and work period may be correlated with each other. Finally, heat exposure was not measured objectively, for example with the wet-bulb globe temperature (WBGT). Future studies should involve larger samples, objective measurements of hydration and heat exposure, and multivariable analyses.

Conclusions

Work posture, work period, age, and drinking water consumption were significantly associated with musculoskeletal complaints among tofu home industry workers. Workers with non-ergonomic postures, longer work periods, older age, and lower water intake tended to report higher levels of complaints, indicating that these complaints are related to both occupational and individual factors. Tofu home industry owners are encouraged to improve workstation ergonomics, for example by adjusting worktable height and providing simple lifting aids, to reduce prolonged awkward postures, and to promote regular drinking during work alongside the drinking water already provided. Further

research involving larger populations and additional occupational and physiological variables is recommended to strengthen the evidence on musculoskeletal risk factors in informal industries.

Declarations

Author Contributions: Conceptualization, R.A.F., D.N., and S.A.; methodology, R.A.F. and D.N.; investigation and data collection, R.A.F.; formal analysis, R.A.F.; writing—original draft preparation, R.A.F.; writing—review and editing, D.N. and S.A.; supervision, D.N. and S.A. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on reasonable request from the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

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