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STUDYING WORK-RELATED MUSCULOSKELETAL DISORDERS, CARTILAGE DEGRADATION AND SYNOVITIS IN SUGAR INDUSTRY WORKERS

BY

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Abstract

Introduction: Work-related musculoskeletal disorders (WMSDs) are common among those employed in the sugar industry. Aim of Work: To determine the prevalence of WMSDs and measure the serum levels of two biomarkers associated with cartilage degradation and synovitis in some Egyptian sugar factory workers. **Materials and Methods:** Forty-two male workers and forty-two male administrative controls were chosen from a sugar factory located in Kafr El-Sheikh governorate, Egypt. The Standardised Nordic Questionnaire (SNQ) was administered using a validated version. Serum indicators of cartilage breakdown (cartilage oligomeric matrix protein, or COMP) and synovitis (hyaluronic acid (HA)) were assessed in each subject. **Results:** The current study revealed a significant high prevalence of musculoskeletal complaints (59.5%) during the last 12 months before the study as well as significant elevation in the serum levels of COMP and HA among the sugar factory workers when compared with their administrative controls. Additionally, among the exposed workers, there were significant correlations between the levels of tested biomarkers and their age, Body Mass Index (BMI), years of employment, and the number of affected anatomical regions. Linear regression analysis showed that the duration (years) of employment is the only significant independent predictor for the serum levels of COMP and HA. **Conclusion and Recommendations**: Sugar factory workers experience a high prevalence of WMSDs, with underlying articular cartilage degradation and synovitis that could be attributed to some personal and occupational factors (age, BMI and duration of employment). Therefore, protective ergonomic interventions and education programs should be adopted to improve working conditions and limit WMSDs in sugar industry workers.

Keywords: Work-related musculoskeletal disorders (WMSDs); Cartilage degradation; cartilage oligomeric matrix protein; Synovitis; hyaluronic acid; Sugar industry.

Introduction

Work-related musculoskeletal disorders (WMSDs) constitute a major health issue in both developed and developing nations. Research suggests that WMSDs have a significant role in worker disability and absenteeism across a wide range of occupational categories. These diseases cause financial losses that impact not just the worker but also the organisation and society overall (Karkousha and Elhafeza, 2017).

Workers in the sugar industry usually carry out detailed activities that frequently require them to adopt static, prolonged working postures, conduct fine motor skills in uncomfortable positions, and utilise high-frequency vibration equipment, all of which have been linked to the development of WMSDs (Baxi et al., 2016; Aremu et al., 2022).

Any joint structure that starts to deteriorate due to wear and tear and becomes less flexible might have musculoskeletal problems. These illnesses often appear as pain, swelling, and loss of mobility in the joints. Recent studies on MSDs have highlighted the use of biochemical markers for understanding the pathology and progression of joint degeneration which usually precede the radiological findings and even the clinical manifestations (Dinçel, 2018).

Water, lipids, non-collagenous proteins, and collagens make up the extracellular matrix of joints. Proteoglycans, cartilage oligomeric matrix protein (COMP), hyaluronan or hyaluronic acid (HA), aggrecan, fibulin, and glycoproteins such follistatin-like protein 1 (FSTIL-1) are examples of non-collagenous proteins. Osteoblasts produce non-collagenous proteins, which give joints their elasticity, strength, and flexibility. These proteins are released into the synovial fluid during cartilage erosion, which causes inflammation in the joints. According to some research, these proteins function as biomarkers and might be helpful for diagnosing and tracing the progress of arthritis (Kumavat et al., 2021).

COMP present in ligaments and tendons, a non-collagenous glycoprotein generated from cartilage that acts as a catalyst in the synthesis of collagen fibrils. COMP is a marker for cartilage degeneration because it is secreted into the joint synovial fluid during traumas and early-stage arthritis (Papaneophytou et al., 2022; Baygutalp and Duysak, 2023).

Additionally, the degree of synovitis in the case of cartilage extracellular matrix fragments is reflected by serum HA (Chen et al., 2020). N-acetyl glucosamine and D-glucuronic acid units alternatively repeat to form HA, a non-sulfated glycosaminoglycan. Previous research has shown that the concentration of HA in the blood is related to both the number of affected joints and the severity of the arthritis (Saruga et al., 2021; Papaneophytou et al., 2022).

According to the published data, no previous studies investigated both biomarkers among Egyptian sugar industry workers.

Aim of Work

To determine the prevalence of WMSDs and measure the serum levels of two biomarkers associated with cartilage degradation and synovitis in some Egyptian sugar factory workers.

Materials and Methods

Study design: A comparative cross-sectional study.

Place and duration of the study: This study was conducted in a beet sugar factory located in Kafr El-Sheikh governorate, Egypt from December 2023 to January 2024. The studied factory produces white sugar, molasses and livestock feed.

Study sample: The PS Power and Sample Size Calculations Software, version 3.1.2 for MS Windows, was used to calculate the sample size. The Chi test was used to compare two proportions from independent samples in a prospective research. The power was set at 80%, the groups' ratio at 1, and the α-error level was fixed at 0.05. According to earlier research (Mourad, 2021), 76.5% of workers and 34.4% of administrative staff had musculoskeletal illnesses which was considered the primary outcome. Therefore, in order to achieve the requisite power and detect an actual difference of 30% in the prevalence of musculoskeletal problems, the minimum optimal sample size for each group should be 42 individuals.

Inclusion criteria: each participant had to be actively engaged in the industrial process for a minimum of one year. **Exclusion criteria**: the presence of any rheumatic, autoimmune, or infectious pathology. Individuals who had diseases that might affect the serum levels of COMP and/or HA such as cardiovascular and inflammatory diseases in addition to hepatic or renal

failure were excluded from this study. Additionally, those with a history of musculoskeletal system-related surgeries or accidents, as well as those who work jobs other than their primary employment at the factory, were not allowed to participate in this study.

The control group: Forty-two matched individuals without a history of exposure to the process of the sugar industry were chosen as the control group from the administrative division of the factory under study. After using the aforementioned exclusion criteria, the individuals were chosen based on similarities in sex, age, body mass index (BMI), socioeconomic status, and specific medically significant behaviours (such as smoking) to the exposed sugar plant workers.

Study methods:

I. **Questionnaire:** A face-to-face questionnaire was used to collect the data. It asked about the personal information (such as age, height, weight, and smoking habit) and the full occupational history, including the duration of employment. In this study, the validated Arabic version of Standard Nordic Questionnaire of Musculoskeletal Symptoms (SNQ) was utilised to investigate the documented instances of WMSDs within the group of respondents. A "musculoskeletal symptom" is any pain or discomfort experienced during the 12 months before the start of the study in at least one of the nine anatomical regions (neck, shoulders, elbows, wrists/hands, upper back, lower back, hips/thighs, knees, and ankles/feet) (Iti et al., 2016; Mourad, 2021). The response rate from both employees and administrative personnel was 100% overall.

II. **Laboratory investigations**

To avoid haemolysis, venous blood samples were drawn, kept at 4°C, and processed in 4 hours. Every sample that was utilised was transparent and clear. This is how serum biomarkers' values were ascertained: Serum samples were centrifuged for 20 minutes at 4°C at 2500 rpm, and then diluted 1:100 for COMP and 1:8 for HA. Using the Human COMP Quantikine ELISA Kit (assay range: 30-9000 pg/mL) and the Hyaluronic acid Quantikine ELISA Kit (assay range: 2-600 ng/mL), respectively, from Bioassay Technology Laboratory (BT LAB) (Shanghai, China), the levels of COMP and HA were determined according to the kit's manufacturer's instructions, with no modifications. For COMP and HA,

the intra- and inter-assay coefficient of variation (CV) was less than 8 and 10%, respectively.

Consent

Following a thorough description of the present study's targets, each participant willingly provided a written informed consent to participate in the research.

Ethical approval

The Research Ethical Committee of the Faculty of Medicine, Cairo University, Egypt, approved the study. The ethical approval number is (N-518-2023). The chief executive officer (CEO) of the plant under study granted his approval.

Data Management

The statistical software for the social sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA) was used to code and input the data. For quantitative variables, the mean, standard deviation, median, minimum, and maximum were used to summarise the data; for categorical variables, the frequencies (number of the cases) and relative frequencies (percentages) were used. For normally distributed quantitative variables, group comparisons were performed using the unpaired t-test; for non-normally distributed quantitative variables, the non-parametric Mann-Whitney test was employed. The Chi-square (X^2) test was used to compare categories of data. When the anticipated frequency was less than five, the Fisher Exact test was utilised instead. A 95% confidence interval for the odds ratio (OR) was computed. The Spearman correlation coefficient was used to perform correlations between quantitative variables. To find independent predictors of COMP and HA, linear regression analysis was used. P-values were deemed statistically significant if they were less than 0.05.

Results

Table (1): The studied groups' mean, standard deviation, median and range of age, BMI, smoking status, duration of work, and serum levels of COMP and HA.

	Exposed (No=42)					Control (No =42)					P value
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	
Age (years)	41.00	11.41	41.50	21.00	59.00	40.12	10.86	40.50	22.00	59.00	0.718
BMI (kg/m^2)	30.51	5.03	29.60	20.20	39.70	31.45	4.89	32.40	22.50	39.70	0.384
Smoking (pack. year)	11.55	7.09	12.00	0.00	22.00	10.74	7.16	12.00	0.00	23.00	0.595
Duration of work (years)	14.12	7.54	12.50	2.00	30.00	13.21	9.55	13.00	1.00	29.00	0.661
COMP (pg/ml)	111.05	30.79	121.80	45.60	148.60	56.17	9.06	54.60	45.30	70.21	**< 0.001***
HA (ng/ml)	56.64	41.61	49.63	1.90	178.26	25.80	13.37	22.84	1.97	56.12	**< 0.001***

SD= Standard deviation; BMI= Body Mass Index; COMP= Cartilage Oligomeric Matrix Protein; HA= Hyaluronic acid. *P-value < 0.05 denotes statistical significance.

Table (1) showed that the age, BMI, smoking status, and duration of work did not differ statistically between the sugar factory workers and the control group. In comparison to the controls, the exposed group's blood levels of COMP and HA had significantly higher means, medians, and ranges (p-value <0.001).

Table (2): Prevalence of musculoskeletal complaints by anatomical region over the previous 12 months in each group of study participants.

Anatomical site	Exposed (No=42)		Control (No=42)		X^2	P value	OR	95% CI	
	Count	%	Count	%				Lower	Upper
Lower back	17	40.5%	8	19.0%	4.613	**0.032***	2.890	1.078	7.749
Wrist and hand	15	35.7%	5	11.9%	6.563	**0.010***	4.111	1.332	12.690
One or both knees	14	33.3%	5	11.9%	5.509	**0.019***	3.700	1.192	11.488
Neck	13	31.0%	3	7.1%	7.721	**0.005***	5.828	1.519	22.350
Shoulder	8	19.0%	2	4.8%	4.086	**0.043***	4.706	0.935	23.673
One or both ankles and feet	6	14.3%	1	2.4%	3.896	0.109	6.833	0.785	59.479
One or both hips and thighs	5	11.9%	0	0.0%	5.316	0.055	-----	-----	-----
Upper back	4	9.5%	2	4.8%	0.718	0.676	2.105	0.364	12.169
Elbow	3	7.1%	1	2.4%	1.050	0.616	3.154	0.315	31.622
Total prevalence	25	59.5%	11	26.2%	9.528	**0.002***	4.144	1.646	10.435

*P-value < 0.05 denotes statistical significance.

Table (2) showed that there was a statistically significant increase in overall prevalence of musculoskeletal complaints among the exposed workers (59.5%) compared to controls (26.2%). In the exposed workers, lower back, hand/wrist, knees, neck, and shoulder were the most affected anatomical sites with statistically significant higher frequencies compared with the control group. Regarding the prevalence of affection in the ankle/foot, hip/thigh, upper back, and elbow areas, although there was a higher frequencies compared to the controls but it didn't reach a statistically significant difference.

Table (3): Spearman's correlation between the serum levels of both measured biomarkers and the general characteristics of the exposed group (No=42)

		COMP	HA
Age (years)	**R**	0.431	0.439
	P value	**0.014***	**0.015***
BMI (kg/m²)	**R**	0.365	0.452
	P value	**0.017***	**0.013***
Duration of work (years)	**R**	0.482	0.652
	P value	**0.003***	**<0.001***
Smoking (pack.year)	**R**	0.043	0.170
	P value	0.788	0.282
COMP	**R**	-	0.091
	P value	-	0.565

COMP= Cartilage Oligomeric Matrix Protein; HA= Hyaluronic acid;

BMI= Body Mass Index. *P-value < 0.05 denotes statistical significance.

Table (3) showed that there were positive and statistically significant (p-value <0.05) correlations between the serum levels of the two investigated biomarkers and the following variables: age, BMI, and duration of work. However, no statistically significant relationship was found between the levels of both biomarkers and the exposed workers' smoking status. Furthermore, there was no statistically significant link between the exposed participants' blood levels of the two studied biomarkers.

Table (4): Linear regression analysis to detect significant independent predictors of COMP and HA among the exposed group (No=42).

Model		Unstandardized Coefficients		Standardized Coefficients	t	P value	95.0% Confidence Interval for B	
	B	Std. Error	Beta		Lower Bound		Upper Bound	
COMP	(Constant)	63.771	16.400		3.888	<0.001	30.625	96.918
Duration of work	1.153	0.386	0.427	2.990	**0.005***	0.374	1.933	

Model		Unstandardized Coefficients		Standardized Coefficients	t	P value	95.0% Confidence Interval for B	
	B	Std. Error	Beta		Lower Bound		Upper Bound	
HA	(Constant)	38.019	18.975		2.004	0.052	-76.368	0.330
	Duration of work	2.309	0.446	0.633	5.174	**< 0.001***	1.407	3.211

COMP= Cartilage Oligomeric Matrix Protein; HA= Hyaluronic acid. *P-value < 0.05 denotes statistical significance.

Table (4) showed that the duration of work was the only statistically significant independent predictor of the higher serum biomarkers' levels.

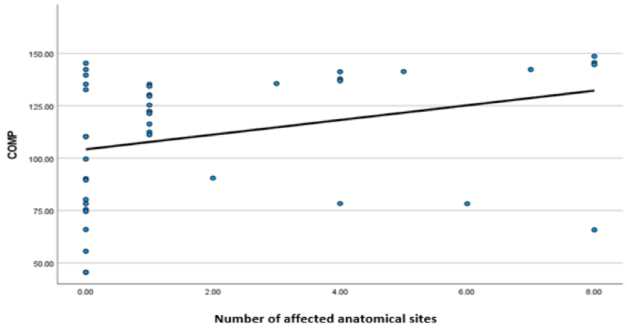

Figure (1): Correlation between the serum levels of cartilage oligomeric matrix protein (COMP) and the number of affected anatomical sites among the exposed group.

Figure (1) showed a statistically significant positive correlation between the number of the affected anatomical regions and the serum levels of COMP among the exposed workers (r = 0.447, p-value = 0.003).

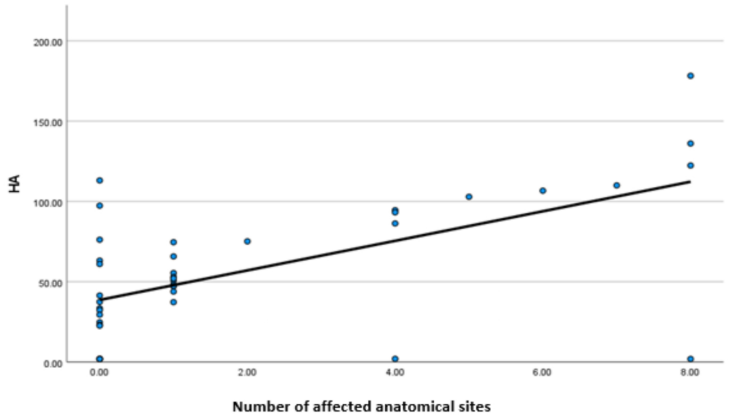

Figure (2): Correlation between the serum levels of hyaluronic acid (HA) and the number of affected anatomical sites among the exposed group.

Figure (2) showed a statistically significant positive correlation between the number of the affected anatomical regions and the serum levels of HA among the exposed workers (r = 0.520, p-value <0.001).

Discussion

Most sugar plants have deficient occupational health and safety procedures in place, and occasionally the infrastructure and rules are insufficient to address the health risks. As a result, the employees face the risk of musculoskeletal problems, repetitive strain injuries, and workplace accidents.

Regarding the investigated biomarkers, although there was no statistically significant difference between the exposed and control groups as regards their socio-demographic characteristics, the findings indicated that the exposed sugar factory workers had substantially higher serum levels of COMP and HA (p-value <0.001) than their controls (Table 1); this might indicate early cartilage degradation and synovitis among sugar plant workers who are subjected to high physical loads.

According to the published data, no previous studies investigated these two serum biomarkers among sugar factory workers. Furthermore, it was noted that elevated COMP serum levels in rheumatoid arthritis patients may serve as a feasible marker for articular cartilage degeneration assessment and may indicate increased cartilage

turnover (Skoumal et al., 2003; Posey and Hecht, 2008). In addition, it has been claimed by Syversen et al. (2009) that prognostic indicators such as COMP and other biomarkers of cartilage and bone will be more helpful than existing ones, which include anti-cyclic citrullinated peptide (ACCP), radiographic damage early in the course of articular illness, and manifestations of inflammation.

According to Majeed et al. (2004), elevated systemic levels of HA may serve as a valuable prognostic marker for arthritis by serving as an early sign of joint structural deterioration. As stated by Elliott et al. (2005), extracellular matrix (ECM) cells locally manufacture HA. Haemoglobin and its fragments are released into the systemic circulation as a consequence of the ECM's degradation and turnover. Increased HA production and release from inflammatory joints is believed to be a reflection of localised synovial lining inflammation and, to a lesser degree, cartilage deterioration.

More recent studies ascertained that serum level of COMP could be considered a potential indicator or predictor of early joint destruction through cartilage breakdown in addition to its usefulness in the diagnosis and monitoring of arthritis within the study environment (Sweilam et al., 2018; Akinmade et al., 2021; Kumavat et al., 2021). Other studies confirmed the utility of serum HA as a marker for synovitis and a prognostic indicator for joint inflammation (Sasaki et al., 2015; Saruga et al., 2021; Papaneophytou et al., 2022).

The Standardised Nordic Questionnaire (SNQ) results showed that the prevalence of musculoskeletal problems was substantially higher among the workers in the sugar factory under study (59.5%) compared to their controls (26.2%) (Table 2). This statistically significant high prevalence among the exposed workers resulted from manual work activities of the sugar industrial process that predisposed workers to musculoskeletal disorders. Similarly, a recent study reported that the 12-month prevalence of work-related musculoskeletal disorders among sugar factory workers in Jinja; Eastern Uganda; was 53% (Babatunde et al., 2023). In another study done among workers of an Indian sugar-producing factory, most of the studied population (83.1%) had experienced some form of musculoskeletal symptoms (Durai et al., 2019).

Concerning the percentages of the

body regions' affection, it was found that the lower back (40.5%), wrist/hand (35.7%), knees (33.3%), neck (31%) and shoulder (19%) were the top five regions of affection with statistically significant higher percentages of musculoskeletal symptoms among the studied sugar factory workers if compared with the administrative controls (Table 2). A recent study was conducted in two Ugandan sugar factories. The highest prevalence of MSDs was in the lower back region (> 30%), followed by the upper back region (>20%), then wrist/ hands (>10%), shoulder (>10%), neck (>7%), knee (>6%), and finally the ankle/ feet which showed the lowest prevalence of affection (about 5%) (Aremu et al., 2022). Moreover, in a cross-sectional study done among sugar factory workers in Jinja, Eastern Uganda, and the lower back region showed the highest prevalence of musculoskeletal symptoms (52.2%). The prevalence of musculoskeletal symptoms in the upper back, wrist/hand and shoulder regions were 36.3, 19.2 and 17.2%, respectively (Babatunde et al. 2023). Studying musculoskeletal disorders among workers of Iranian and Indian sugar-producing factories revealed the highest MSD prevalence was reported in the knees (58.6%) and the lower back (54.3%) (Choobineh et al., 2009; Durai et al., 2019). Also, a recent Egyptian study conducted at a sugarcane factory at Luxor Governorate, reported that 68.2% of workers had back pain (Maky et al., 2020). It is important to note that the administrative staff members in the current study continued to have the possibility of experiencing some musculoskeletal problems. They displayed a comparable march of the exposed manufacturing workers for the most afflicted body areas, but with noticeably smaller percentages. This may be due to the administrative staff's lack of ergonomic knowledge and expertise, their application of a continuous work pattern for prolonged periods of time without sufficient breaks, their maintenance of awkward and static postures, and the unfavorable ergonomic conditions of their workplaces (Ibrahim and Gaafar, 2024).

In addition, the results showed statistically significant positive correlations between the serum levels of both biomarkers (COMPA and HA) and the age, BMI, and duration of employment (Table 3). These associations were found to be important in examining several

individual and occupational risk factors for MSDs among the exposed sugar plant workers. Prior research has demonstrated a correlation between the age of the participants under investigation and the levels of COMP and HA in their serum (Singh et al., 2014; Papaneophytou et al., 2022). As reported by Minetto et al. (2020), musculoskeletal tissues exhibit a reduction in ligament flexibility, a loss of muscle strength, increased bone fragility, and a loss of cartilage resilience as people grow up. These changes enhance the body's vulnerability to MSDs. Moreover, because older people have a reduced capacity to metabolise HA, blood HA levels may rise with increasing age (Ding et al., 2005).

Referring to the significant correlation between BMI and the serum levels of COMP and HA among the exposed factory workers, a previous study supports the same findings with the serum level of COMP (Papaneophytou et al., 2022) and another study reported a statistically significant increase in the circulating levels of HA fragments in individuals with obesity (Romo et al., 2022). Because being overweight can exacerbate the effects of mechanical stress on the weight-bearing joints, workers with higher BMIs appear to have more stress on their musculoskeletal tissues (Shiri et al., 2010).

Moreover, the positive correlation between the duration of employment and the serum levels of the studied biomarkers (COMP and HA) was statistically significantly higher among the exposed workers (Table 3). Furthermore, the results of the linear regression analysis indicate that, among the factory workers under study, the only significant independent predictor for the levels of serum biomarkers (COMP and HA) was the period of employment (Table 4). More years of employment means higher exposure to physical workload. An earlier study demonstrated that intensive and prolonged physical activity significantly affects the serum levels of COMP and HA among the studied participants (Pruksakorn et al., 2013). The biomarkers representing the inflammatory bone, synovium, and cartilage responses to exercise and mechanical stress were examined in more recent studies. Among those biomarkers were HA and COMP. The study came to the conclusion that factors including body weight,

load, and activity duration affect the biomarker levels, which vary in response to different activities (Cattano et al., 2017).

The study findings also detected the absence of a statistically significant correlation between the serum levels of both measured biomarkers (COMP and HA) and the smoking status of the studied exposed workers (Table 3). Consistent with these results, the serum levels of COMP did not show any statistically significant difference with various smoking statuses of the studied German patients suffering from osteoarthritis (Riegger et al., 2020). Another cross-sectional observational study confirmed the lack of a statistically significant correlation between the serum levels of HA and the smoking history of the studied participants (Papakonstantinou et al., 2019). In the current work, most of the studied exposed factory workers were considered light smokers with smoking packs/year ranging from zero to 22 and a median of 12.

Additionally, no statistically significant correlation was observed between the serum levels of COMP and serum levels of HA among the exposed subjects (Table 3). The same results were obtained during the study of serum biomarker of cartilage metabolism (COMP) and serum biomarker of synovitis (HA), among patients with knee osteoarthritis (Papaneophytou et al., 2022). This finding could draw attention to the notion that the degree of cartilage degradation doesn't necessarily have to be the same as in the case of synovitis.

The significant association between the serum levels of both biomarkers (COMP and HA) and the number of affected joints (Figures 1 and 2) among the studied participants was confirmed by several previous studies (Clark et al., 1999; Filkova et al., 2009; Sasaki et al., 2013). Other studies significantly correlate between the levels of serum biomarkers and the severity of arthritis (Kambayana et al., 2014; Singh et al., 2014; Papaneophytou et al., 2022).

Conclusion and Recommendations

The current study's findings supported the hypothesis that the examined sugar plant workers had a significant prevalence of WMSDs. It was imperative to take remedial action to mitigate this occupational hazard. Creating sitting-standing workstations on the production line and doing away with uncomfortable postures and manual handling of large

loads should be the main goals of an ergonomic intervention program in the workplace. It is also advised to create a suitable work-rest cycle, employ mechanical tools like conveyor belts to move sugar castings and bags, and lessen the weight of the sugar bags that needed to be handled by hand. In addition, workers should have access to health education and training programs to broaden their understanding of the risks to their health at work. Periodic evaluation of employees' health state is also essential for early identification of the consequences of workplace hazards. Finally, to improve the reliability and objectivity of the study's findings, more research on the biomarkers that were looked at in this one as well as the addition of other biomarkers of bone and cartilage turnover in larger populations are required.

Conflict of Interest

None

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None

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