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An ergonomic focus evaluation of work-related musculoskeletal disorders amongst operators in the UAE network control centres

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A R T I C L E I N F O

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A B S T R A C T

Work-related musculoskeletal disorders (WMSDs) have rapidly increased during the last decade, but only a few descriptive surveys have been conducted in the United Arab Emirates (UAE). This study investigated the prevalence of WMSDs and analysed their ergonomic risks amongst operators in the network control rooms across two government organisations, X and Y, in the UAE. Essential data were collected by the Nordic Musculoskeletal Questionnaire (NMQ) and the Maastricht Upper Extremity Questionnaire (MUEQ) from online surveys and direct observations based on the Rapid Office Strain Assessment (ROSA) and the Rapid Upper Limb Assessment (RULA) form and ergonomic measurements for the working environments, respectively. Fifty-three and eighteen operators participated from Organisations X and Y. This study found a high presence of WMSDs in both organisations over the past 12 months. In Organisation X, individual, work-related physical and psychosocial risk factors of high BMI, educational level, morning work shift, high job duration, lack of exercise habit, awkward body posture, high job demand, low job control, and low work social support were associated with WMSDs in different body areas ($p < 0.05$). In Organisation Y, older age, high BMI, high job duration, lack of exercise habits, unergonomic workstations, awkward body posture, low break time, high job demand, and stress level were associated with WMSDs in different body areas ($p < 0.05$). The control room operators' most affected body areas were the back, eyes, and neck. Several efficient ergonomic intervention ideas were explored to lessen the detrimental effects of WMSDs and preclude the development of WMSDs amongst the control centre operators.

1. Introduction

Work-Related Musculoskeletal Disorders (WMSDs), including lower back pain, carpal tunnel syndrome, and tendonitis, are among the most common occupational health issues faced by industry employees around the world [1]. The intricate nature of jobs/tasks often involves repetitive motions, heavy lifting, and prolonged periods of awkward postures, thereby amplifying the risk of WMSDs amongst workers [2]. Given the multifaceted challenges associated with WMSDs, it is imperative to explore comprehensive strategies to effectively mitigate these prevalent disorders and foster a safer working environment for every employee/worker [3].

WMSDs have increased rapidly during the last decade and became the fifth leading cause of disability-adjusted life years (DALYs) lost in the United Arab Emirates (UAE), accounting for 189,869 of all DALYs in 2019 [4]. However, studies about the prevalence of WMSDs were carried out in the health sector only, with rates ranging between 68 % and 83 % amongst dentists [5] and 47.4 % amongst

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nurses [6]. Thus, it is essential to explore other industry sectors since different industries' employees may face unique challenges causing WMSDs. In developed countries, for example, control centres or rooms are critical for public utilities, agencies, and organisations to manage their operations. There are different types of control rooms depending on the industries they serve. They are usually found in nuclear power plants, airports, transportation facilities, police stations, and aerospace [7]. However, this study focuses on control rooms of electric network operations in government utility organisations of the UAE. The control room operators oversee power generation, transmission, and distribution of resources. The International Organisation for Standardisation (ISO 11064-4) demonstrates different configurations of control rooms [8].

Control room operators are responsible for intensive monitoring, controlling, and maintaining the network 24 h a day. They must be attentive to the network and prevent unwanted outages. Besides, they must restore the power supply within the target by maintaining the system's reliability. Due to the work nature of control room operators, the control room job is considered an occupation with a high risk of developing WMSD symptoms in the long term. Several studies revealed that 73 %–89 % of control room operators experienced musculoskeletal symptoms (assessed by the application of the Nordic Musculoskeletal Questionnaire - NMQ), particularly in the lower back, neck, shoulders, and eyes [[9–11]]. This was due to the individual's overexposure to work-related physical, environmental, and psychosocial hazards. The physical risk factors involve static activities, awkward postures, insufficient time for recovery, and workstation design [[11–17]]. The environmental risk factors are extreme temperature, poor lighting, and noise. Whilst psychosocial risks encompass job demand, job control, and the availability of management support. Those factors suggest strong associations between working natures such as sedentary behaviours and the risk of WMSD [16,17].

Various assessment tools can be applied to identify those ergonomic risk factors and related hazards. However, there are no studies found on WMSDs amongst the control room operators in the UAE. Thus, this study aims to investigate the prevalence of WMSDs and analyse their ergonomic risk factors amongst the control room operators in the electric network operations across two government organisations in the UAE. To achieve the study aims, the following research objectives are articulated:

1) Determine the prevalence rates of WMSDs in different body regions amongst the control room operators.
2) Investigate the connection between the individual, work-related physical, and psychosocial factors with WMSDs.
3) Analyse the contribution of direct ergonomic designs with anthropometric measurements and working environment to WMSDs.
4) Provide ergonomic suggestions to prevent WMSDs within the control centres.

The findings from this study could be significant to the operators, control room supervisors, and safety and health coordinators in the electric network operations control rooms. This study may provide an opportunity to understand the work-related risk factors that contribute to WMSD symptoms amongst the control room operators in the UAE and be beneficial to developing strategies and implementing interventions to prevent WMSD development in the control centres/rooms.

2. Materials and methods

2.1. Research design

A cross-sectional study was performed amongst control room operators in two government organisations, X and Y, of the UAE. Organisation X has two electricity control rooms, which manage the distribution phase of the network, excluding the generation and transmission phases. Whilst organisation Y has one main network operation control centre, which controls the generation, transmission, and distribution phases. Permission to access control rooms was obtained from the human resources department of the two organisations. Before participating, all operators signed an informed consent form, assuring anonymous and voluntary involvement.

The total number of operators in organisations X and Y are 66 and 18, respectively. Due to the national military service duties, only 53 participants from organisation X participated in this study. Because of the shift work nature, only male operators are allocated in both organisations' control centres. The working hours involve the morning shift from 7:00 to 15:00, the afternoon shift from 15:00 to 23:00, and the night shift from 23:00 to 7:00. They follow an eight-day cyclic rotating schedule, including two days off.

Fundamental data were collected by the Nordic Musculoskeletal Questionnaire (NMQ) and the Maastricht Upper Extremity Questionnaire (MUEQ) from online surveys and observational methods based on the Rapid Office Strain Assessment (ROSA) and the Rapid Upper Limb Assessment (RULA) form and ergonomic measurements for the working environments, respectively. Table 1 summarises assessed methods, ergonomic risk factors, and expected outcomes from this study. As shown in Table 1, questionnaire

Table 1
Summary classification of assessment methods and ergonomic factors.

Methods	Ergonomic factors	Outcomes
Questionnaires & interview	Individual characteristics	Age, BMI, exercise habit, educational level, and job experience
	Work-related physical and psychosocial	Work shift demand, workstation, body posture, break time, job control, job demand, social support, and stress level
Observational risk assessments	NMQ and MUEQ	Workstation, body posture, job control, job demand, break time, and work social support
	ROSA	Evaluation of the chair, monitor, telephone, keyboard, and mouse
	RULA	Form of posture, static work, and repetitions carried out at work
Direct measurements	Anthropometry	Measurement of participants' body and workstation dimensions
	Working environment	Temperature, lighting, and noise

surveys, interviews, direct observational risk assessments, and anthropometric and working environment measurements were adopted for expected outcome measurements. The specially designed online self-reported questionnaire was distributed amongst operators in both organisations. The total score concerns workers' opinions of psychosocial and ergonomic factors in their work environment [18].

The interview was based on operators' perceptions of workplace stress. The interview questions were rated on a 5-point Likert scale [19]. The total score determines the stress level of the operator: low-stress level (score <20 points), moderate stress level (21–25 points), severe stress level (26–30 points), and critical stress level (31–40 points), respectively. In addition, participants' awareness levels of the WMSDs topic were captured in the questionnaire.

2.2. Risk assessments

Risk assessments were thoroughly carried out by multiple visits to the control rooms of both organisations X and Y. The assessments were further conducted with direct observations based on the ROSA and RULA forms. The ROSA assessment measured the risks associated with computer workstation arrangements and evaluated the action level. It consisted of three sections: the chair section (2–9 points), the monitor and phone section (1–9 points), and the mouse and keyboard section (1–9 points) [20]. The RULA assessment captured the operator's inappropriate work postures and evaluated their exposures to the WMSD risks. This method examined several body parts: Section A contained the arm, forearm, and wrist, and Section B contained the neck, trunk, and legs. The RULA score was then used to provide an action level for the examined posture, emphasising the action necessary to correct it.

Each control room's environmental factors: temperature, lighting, and noise levels were measured by a temperature data logger, light meter, and integrating sound level meter (Extech Model RS-232), respectively. The data were evaluated by the ISO11064-6 standard, which is about the Ergonomic design of control centres - Part 6: Environmental requirements for control centres [8]. A regular tape meter measured the operator's anthropometric data and console dimensions. This helped determine the appropriate adjustment to eliminate the awkward posture risks contributing to developing WMSDs. The body dimensions chosen were compared to the workstation ones adopted from ISO 7250-1, which is about basic human body measurements for technological design - Part 1: Body measurement definitions and landmarks [21].

2.3. Ethical endorsement

Formal letters were sent to both organisations with comprehensive demonstrations of the surveys' aims. The Department of Health and Safety from both organisations approved study proposals and procedures to protect their operators. Before conducting the surveys, ethical permissions were collected from the two organisations. Ethical approval ensured the participants' confidentiality as conveying the questionnaire results. The participants signed an informed consent form before participating.

Table 2
Personal and job details of organisations X and Y.

Factors		Organisation X (n = 53)	Organisation Y (n = 18)
		Frequency value (%) or mean value (± SD)	
Age	20–24	3 (5.7 %)	2 (11.1 %)
	25–29	35 (66.0 %)	2 (11.1 %)
	30–34	10 (18.9 %)	2 (11.1 %)
	35–39	1 (1.9 %)	2 (11.1 %)
	40–44	1 (1.9 %)	1 (5.6 %)
	45–49	0 (0 %)	2 (11.1 %)
	50–54	2 (3.8 %)	4 (22.2 %)
	55 and above	1 (1.9 %)	3 (16.7 %)
Weight		88.74 ± 21.14	83.63 ± 12.77
Height		173.20 ± 5.16	173.6 ± 10.50
BMI	Normal	18 (34.0 %)	5 (27.8 %)
	Overweight	16 (30.2 %)	9 (50.0 %)
	Obesity	19 (35.8 %)	4 (22.2 %)
Educational level	High school graduate	0 (0 %)	1 (5.6 %)
	Bachelor's degree	49 (92.5 %)	15 (83.3 %)
	Postgraduate (master's degree or/and PhD)	4 (7.5 %)	2 (11.1 %)
Job experience	1–5	23 (43.4 %)	6 (33.3 %)
	6–10	26 (49.1 %)	3 (16.7 %)
	Over 10 years	4 (7.5 %)	9 (50.0 %)
Exercise habits	I don't exercise	18 (34.0 %)	5 (27.8 %)
	Once a week	9 (17.0 %)	3 (16.7 %)
	2–4 days a week	20 (37.7 %)	8 (44.4 %)
	5–7 days a week	6 (11.3 %)	2 (11.1 %)
Work shift demand	Morning shift	50 (94.3 %)	15 (83.3 %)
	Afternoon shift	3 (5.7 %)	2 (11.1 %)
	Night shift	0 (0 %)	1 (5.6 %)

2.4. Statistical analysis

For the descriptive analysis, categorical variables were represented by frequencies and percentages, whereas continuous variables were characterised by means and standard deviations. The independent variables included individual characteristics and work-related physical and psychosocial risk factors. The dependent variables were the different body parts of WMSDs. The Shapiro-Wilk test checked the collected data to assess data normality. The data followed a non-normal distribution, so the Chi-Square nonparametric test was performed to examine any relationship between the independent and dependent variables. *P*-value <0.05 was considered statistically significant. The Spearman correlation was applied to explore the correlation between ROSA and RULA final scores and their contribution to WMSDs. The magnitude of correlation was interpreted as follows: $0.10 < r < 0.29$ = weak; $0.30 < r < 0.49$ = moderate; $0.50 < r < 1.0$ = strong, respectively [22]. The Statistical Package for Social Sciences (SPSS) software (Ver. 26, SPSS, Inc., Chicago, IL, USA) was used to analyse the data.

3. Results

3.1. Participant and job details

Fifty-three operators from Organisation X (response rate of 80.3 %) and 18 operators (response rate of 100 %) from Organisation Y participated in this study. The personal and job details of both organisations are summarised in Table 2. As shown in Table 2, the following important aspects were found in the participants and job details from organisation X:

1) Most participants were between 25 and 29 years old (66.0 %).
2) All of them had a college education.
3) 35.8 % of the operators were under the obesity category of BMI.
4) The duration of average job experience was between 6 and 10 years (49.1 %).
5) There were 20 operators (37.7 %) who exercised 2–4 days a week, whilst 18 (34.0 %) did not have any exercise.

On the other hand, the following details are found on the participants and job details from organisation Y:

1) Most operators were between 50 and 54 years old (22.2 %).
2) Most of them had a bachelor's degree (83.3 %).
3) Half of the operator's BMI was classified as overweight.
4) The duration of average job experience was over ten years (50.0 %).
5) Eight operators (44.4 %) exercised 2–4 days a week.

As found in Table 2, operators from both organisations showed high job demands in the morning shift. Besides, thirty-four operators (65.38 %) in Organisation X and nine (50 %) in Organisation Y lacked WMSD knowledge.

3.2. WMSDs in different body parts

Table 3 presents the prevalence of MSS, the reporting of disability, and absence from work due to discomfort in various body parts during the past 12 months. As uncovered in Table 3, in Organisation X, the majority of the operators had WMSD symptoms in one or more body areas. The most affected body areas are the lower back and eyes (71.7 %), neck (67.9 %), knees (58.5 %), and shoulder (52.8 %). Moreover, the effects of WMSD symptoms on reducing the operators' work activity were mainly caused by lower back pain (54.72 %), neck pain (41.52 %), knee pain (33.96 %), and shoulder pain (32.08 %). Thus, lower back, eyes, and neck disorders accounted for most sick leaves taken from work.

Organisation Y also showed that most of the operators had WMSD symptoms in one or more body areas. The most affected body areas were the eyes (61.1 %), upper back (55.6 %), lower back (50.0 %), neck (44.4 %), shoulder (27.8 %), ankle (27.8 %), and knees (11.1 %). Most of the sick leaves were due to lower back pain (11.11 %).

Table 3
Summary of the prevalence of annual WMSDs (%) amongst two authorities', X and Y, operators during the past 12 months.

Org.	Symptom	Neck	Shoulder	Elbow	Wrists	Upper. Back	Lower. Back	Hips/Thighs	Knees	Ankles	Eyes
X	Preve.[a]	67.9	52.8	24.5	35.8	49.1	71.7	18.9	58.5	22.6	71.7
	Disabil.[b]	41.5	32.1	16.7	24.5	30.2	54.7	9.4	34.0	13.2	30.2
	Sick Lv.[c]	17.3	11.3	5.8	3.8	17.0	24.5	4.0	15.1	7.6	20.8
Y	Preve.[a]	44.4	27.8	11.1	5.6	55.6	50.0	22.2	11.1	27.8	61.1
	Disabil.[b]	27.8	6.0	0.0	0.0	33.0	33.0	6.0	0.0	6.0	33.3
	Sick Lv.[c]	5.6	5.6	0.0	0.0	0.0	11.1	0.0	0.0	0.0	5.6

[a] Preve.: Prevalence.
[b] Disabil.: Disability, and.
[c] Sick Lv.: Sick Leave.

3.3. Work-related physical and psychosocial factors

Table 4 demonstrates the outcomes of physical and psychosocial factors from the Maastricht Upper Extremity Questionnaire (MUEQ) and workplace stress interviews. As found in Table 4, organisation X had greater frequency (or mean) values in the job control and job demand and body posture domains in both factors. In addition, the operator's stress scale varied from a low level to a critical one. Whilst organisation Y revealed higher frequency (or mean) values in the job control, body posture, and work social support domains. Moreover, the dominant workplace stress levels were low and moderate, except for one operator at a severe level.

3.4. Association between the risk factors and WMSDs

Table 5 summarises the significant relationship between the individual, physical and psychosocial risk factors, and musculoskeletal symptoms (MSS) in different body parts amongst operators in organisation X. As found in Table 5, organisation X showed no clear association between the age factor, break time, and stress level with WMSDs. Table 5 also presents the relationship between the individual, physical and psychosocial factors, and MSS in different body parts amongst operators in organisation Y. As found in Table 5, organisation Y showed no relationship between the educational level, work shift demand, job control, and work social support with WMSDs.

3.5. Observational risk assessment of ROSA and RULA

Table 6 summarises the results of the ROSA and RULA ergonomic risk factors from both organisations. The ROSA approach evaluated the control room's workstations. The final score of Organisation X was 4.3 which indicates a warning level. The ROSA result also showed significant scores in the mouse and keyboard sections. On the contrary, the ROSA final score of Organisation Y was 5.7, which requires immediate ergonomic interventions. The chairs, monitors, and phone sections significantly contributed to the scores. Furthermore, the results of the postural analysis obtained by the RULA assessment revealed that most of the operators in Organisation X were exposed to medium and high-risk levels. In Organisation Y, most of the operators' sitting postures showed high and very high-risk levels to the RULA results. There was a significant relationship between the ROSA and RULA scores of Organisation X ($r = 0.35$, $p = 0.01$) and Y ($r = 0.61$, $p = 0.008$), respectively.

3.6. Environmental issues

Each control room environment was examined by measuring the temperature, lighting, and noise levels during the morning and afternoon shifts. Fig. 1 shows the average of ten readings of the environmental factors of workstation dimensions and operators' body measurements. Fig. 1 also displays the results of measurements of temperature, lighting, and noise levels in three control room locations during the morning shift (MS) and afternoon shift (AFS). Although the environmental factors measured are within the recommended ranges, they are still slightly above the optimal ranges for office work, which could potentially cause discomfort or fatigue for operators in the long term. It would be useful to investigate ways to reduce noise levels and optimize temperature and lighting conditions to improve operator comfort and performance. The sample size and location coverage of the control rooms were relatively small, and the measurement period was not long enough. Thus, it would be helpful to conduct further studies with larger sample sizes and a longer measurement period to ensure the representativeness of the results.

Table 7 shows the mean (±SD) values of workstation dimensions and operators' body measurements in two organisations. The workstation dimensions include seat surface height (SSH), seat depth (SD), backrest height (BH), seat backrest width (SBW), and console height (CH). The operators' body measurements include popliteal height (PH), buttock popliteal length (BPL), shoulder height (SH), sitting elbow height (SHE), and shoulder breadth (SB).

Although the mean values of workstation dimensions and operators' body measurements are within the range of anthropometric data for the respective population groups, it is still important to note that there is significant individual variability in anthropometric measurements, which means that some operators may still experience discomfort or suboptimal ergonomic fit. Therefore, it is

Table 4
Summary of physical and psychosocial factors from organisations X and Y.

Factors		Organisation X (n = 53)	Organisation Y (n = 18)
		Frequency value (%) or mean value (± SD)	
MUEQ	Workstation (0–6)	0.64 ± 0.94	0.94 ± 1.3
	Body posture (0–24)	10.87 ± 3.03	11.06 ± 3.83
	Job control (0–36)	20.79 ± 3.61	23.00 ± 2.70
	Job demand (0–28)	11.98 ± 3.16	8.28 ± 3.79
	Break time (0–16)	7.30 ± 2.13	6.67 ± 2.30
	Work social support (0–16)	9.87 ± 1.69	10.50 ± 1.42
Work Stress Level	Low	29 (54.7 %)	12 (66.7 %)
	Moderate	20 (37.7 %)	5 (27.8 %)
	Severe	2 (3.8 %)	1 (5.6 %)
	Critical	2 (3.8 %)	0 (0.0 %)

Table 5
Statistical analysis of individual, work-related physical and psychosocial risk factors: Statistical analysis of Organisations X and Y (*. $p < 0.05$, Chi-Square Test).

Independent Variables	Dependent Variables (Body Parts Troubled) – Organization X									
	Neck	Shoulder	Elbow	Wrist	Upper Back	Low Back	Hips/ Thighs	Knees	Ankles	Eyes
Age	P = 0.44	P = 0.57	P = 0.15	P = 0.11	P = 0.55	P = 0.34	P = 0.16	P = 0.34	P = 0.22	P = 0.39
BMI	P = 0.39	P = 0.49	P = 0.59	P = 0.02*	P = 0.26	P = 0.03*	P = 0.16	P = 0.51	P = 0.06	P = 0.56
Educational Level	P = 0.74	P = 0.34	P = 0.03*	P = 0.10	P = 0.27	P = 0.88	P = 0.14	P = 0.47	P = 0.02*	P = 0.09
Job Experience	P = 0.17	P = 0.31	P = 0.03*	P = 0.61	P = 0.59	P = 0.30	P = 0.01*	P = 0.88	P = 0.02*	P = 0.49
Exercise Habits	P = 0.27	P = 0.20	P = 0.38	P = 0.16	P = 0.01*	P = 0.53	P = 0.49	P = 0.36	P = 0.21	P = 0.90
Shift Demand	P = 0.96	P = 0.62	P = 0.00*	P = 0.26	P = 0.53	P = 0.84	P < 0.00*	P = 0.37	P = 0.00*	P = 0.15
Workstation	P = 0.47	P = 0.15	P = 0.06	P = 0.06	P = 0.01*	P = 0.24	P = 0.06	P = 0.61	P = 0.10	P = 0.61
Body Posture	P = 0.01*	P = 0.05	P = 0.08	P = 0.01*	P = 0.13	P = 0.06	P = 0.41	P = 0.07	P = 0.04*	P = 0.01*
Job Control	P = 0.56	P = 0.03*	P = 0.18	P = 0.06	P = 0.67	P = 0.57	P = 0.01*	P = 0.17	P = 0.43	P = 0.51
Job Demand	P = 0.43	P = 0.04*	P = 0.09	P = 0.06	P = 0.09	P = 0.65	P = 0.14	P = 0.11	P = 0.34	P = 0.65
Break Time	P = 0.52	P = 0.13	P = 0.21	P = 0.37	P = 0.19	P = 0.53	P = 0.11	P = 0.64	P = 0.72	P = 0.19
Work Support	P = 0.14	P = 0.14	P = 0.15	P = 0.59	P = 0.37	P = 0.36	P = 0.60	P = 0.03*	P = 0.30	P = 0.38
Stress Level	P = 0.43	P = 0.37	P = 0.46	P = 0.26	P = 0.38	P = 0.42	P = 0.62	P = 0.05	P = 0.60	P = 0.34
Independent Variables	Dependent Variables (Body Parts Troubled) – Organization Y									
	Neck	Shoulder	Elbow	Wrist	Upper Back	Low Back	Hips/ Thighs	Knees	Ankles	Eyes
Age	P = 0.04*	P = 0.18	P = 0.20	P = 0.36	P = 0.14	P = 0.31	P = 0.02*	P = 0.20	P = 0.24	P = 0.05
BMI	P = 0.15	P = 0.78	P = 0.22	P = 0.49	P = 0.96	P = 0.01*	P = 0.27	P = 0.22	P = 0.14	P = 0.33
Educational Level	P = 0.54	P = 0.58	P = 0.68	P = 0.83	P = 0.54	P = 0.12	P = 0.43	P = 0.68	P = 0.14	P = 0.08
Job Experience	P = 0.03*	P = 0.75	P = 0.29	P = 0.14	P = 0.89	P = 0.57	P = 0.17	P = 0.29	P = 0.75	P = 0.01*
Exercise Habits	P = 0.31	P = 0.63	P = 0.12	P = 0.44	P = 0.56	P = 0.03*	P = 0.02*	P = 0.12	P = 0.63	P = 0.08
Shift Demand	P = 0.06	P = 0.58	P = 0.30	P = 0.83	P = 0.54	P = 0.48	P = 0.11	P = 0.30	P = 0.58	P = 0.19
Workstation	P = 0.09	P = 0.53	P = 0.01*	P = 0.18	P = 0.13	P = 0.01*	P = 0.02*	P = 0.01*	P = 0.02*	P = 0.53
Body Posture	P = 0.19	P = 0.43	P = 0.46	P = 0.66	P = 0.09	P = 0.05*	P = 0.25	P = 0.46	P = 0.11	P = 0.23
Job Control	P = 0.07	P = 0.07	P = 0.54	P = 0.76	P = 0.28	P = 0.40	P = 0.34	P = 0.54	P = 0.80	P = 0.16
Job Demand	P = 0.18	P = 0.17	P = 0.95	P = 0.99	P = 0.15	P = 0.04*	P = 0.57	P = 0.95	P = 0.63	P = 0.10
Break Time	P = 0.21	P = 0.04*	P = 0.69	P = 0.67	P = 0.12	P = 0.42	P = 0.21	P = 0.69	P = 0.64	P = 0.03*
Social Support	P = 0.16	P = 0.76	P = 0.36	P = 0.29	P = 0.07	P = 0.10	P = 0.39	P = 0.36	P = 0.06	P = 0.12
Stress Level	P = 0.04*	P = 0.59	P = 0.05	P = 0.26	P = 0.43	P = 0.16	P = 0.07	P = 0.05	P = 0.59	P = 0.25

Table 6
Results of the observational risk assessments of ROSA and RULA.

Risk Assessments		Organisation X (n = 53)	Organisation Y (n = 18)
		Frequency value (%) or mean (± SD)	
ROSA – Section A: Chair (2–9)		3.60 ± 0.66	5.72 ± 1.60
ROSA – Section B: Monitor and phone (1–9)		3.68 ± 0.73	4.33 ± 1.24
ROSA – Section C: Mouse and keyboard (1–9)		4.11 ± 0.82	3.89 ± 1.02
ROSA final score (0–10)		4.30 ± 0.70	5.72 ± 1.60
ROSA level	Low (score <3)	0 (0.0 %)	0 (0.0 %)
	Warning region (3–5)	52 (98.1 %)	11 (61.1 %)
	Necessity of ergonomic Intervention (score >5)	1 (1.9 %)	7 (38.9 %)
RULA – Arms, forearms, and wrist posture		5.25 ± 0.78	6.44 ± 1.25
RULA – Neck, trunk, and lower extremity posture		4.64 ± 1.19	5.17 ± 1.34
RULA final score (1–7)		4.94 ± 0.97	5.83 ± 1.29
RULA level	Low (1–2)	0 (0.0 %)	0 (0.0 %)
	Intermediate (3–4)	21 (39.6 %)	4 (22.2 %)
	High (5–6)	27 (50.9 %)	7 (38.9 %)
	Very high (7)	5 (9.4 %)	7 (38.9 %)

recommended to provide adjustable workstations and seating options to accommodate individual differences.

The SSH and SD are higher in Organisation X compared to Organisation Y, whilst BH and SBW are higher in Organisation Y. The console height (CH) is higher in Organisation X compared to Organisation Y. The popliteal height (PH) and buttock popliteal length (BPL) are slightly higher in Organisation X, while the shoulder height (SH) and sitting elbow height (SHE) are slightly higher in Organisation Y. The shoulder breadth (SB) measurements for Organisation Y seem to be incorrect, as the values are the same as the sitting elbow height (SHE) measurements. Overall, the workstation dimensions and operators' body measurements in both

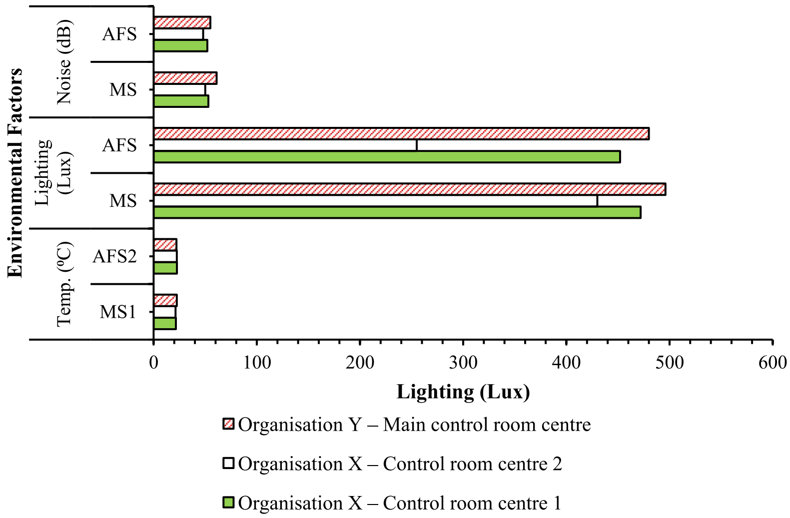

Fig. 1. Summary of mean values of the control room working environment - MS: Morning shift and AFS: Afternoon shift, respectively.

Table 7
Summary of the workstation dimensions' mean (±SD) values and operators' body measurements.

	Parameters in cm	Organisation X (n = 53)	Organisation Y (n = 18)
Workstation	Seat surface height (SSH)	50.1 ± 6.35	45.9 ± 6.43
	Seat depth (SD)	44.5 ± 0.00	44.7 ± 2.52
	Backrest height (BH)	65.5 ± 0.00	56.8 ± 4.73
	Seat backrest width (SBW)	50.8 ± 0.00	44.1 ± 3.72
	Console height (CH)	75.7 ± 0.03	73.7 ± 0.63
Operators' Body	Popliteal height (PH)	51.8 ± 3.83	50.9 ± 4.22
	Buttock popliteal length (BPL)	53.9 ± 6.52	53.2 ± 8.83
	Shoulder height (SH)	57.0 ± 6.36	53.2 ± 8.83
	Sitting elbow height (SHE)	20.0 ± 5.63	21.6 ± 4.23
	Shoulder breadth (SB)	47.7 ± 3.97	21.6 ± 4.23

organisations are within the range of recommended ergonomic guidelines, indicating a suitable ergonomic design of the control room workstations.

Fig. 2 reflects the results of anthropometric measurements and workstation mismatches and compatibilities. In Organisation X, most of the control room workstations were compatible with the operator's body. Only a 53 % mismatch was addressed between the console height, setting elbow, and popliteal height. Whilst, in Organisation Y, a 78 % mismatch was found between the seat surface height and popliteal height; a 78 % mismatch between the seat depth and buttock popliteal length; a 72 % mismatch between the seat backrest width and shoulder breadth; and a 61 % mismatch between the console height and setting elbow, respectively.

4. Discussion

4.1. Prevalence of MSS

The results from this study identified a high presence of WMSDs in the past 12 months amongst the control room operators in both organisations of X and Y. Organisation X showed a higher proportion of MSDs compared to other global studies. Bazazan et al. examined the effect of a posture correction-based intervention on the occurrence of MSS amongst control room operators in an Iranian petrochemical plant [10]. They showed 89 % of annual MSS, which is accordant with the findings of the organisation Y rate in the present study. However, another study reported a lower rate (73 %) of WMSDs in a petrochemical control centre than the result from the current study [9].

Although the control room operators of both Organisations X and Y reported different distributions of pain exposures in their body areas, the most affected body ones were the back (lower and upper), eyes, and neck. These findings are consistent with prior studies, indicating that the job nature of holding a static workload affected the operators' spine along with the awkward posture of a flexed neck [10,23]. The current study also found that many operators in Organisation X could not perform their regular duties and had to take sick leaves to recover. Regardless of the pain developments, however, the operators in Organisation Y continued their jobs, which might cause severe injuries and job hindrances in the long term [24].

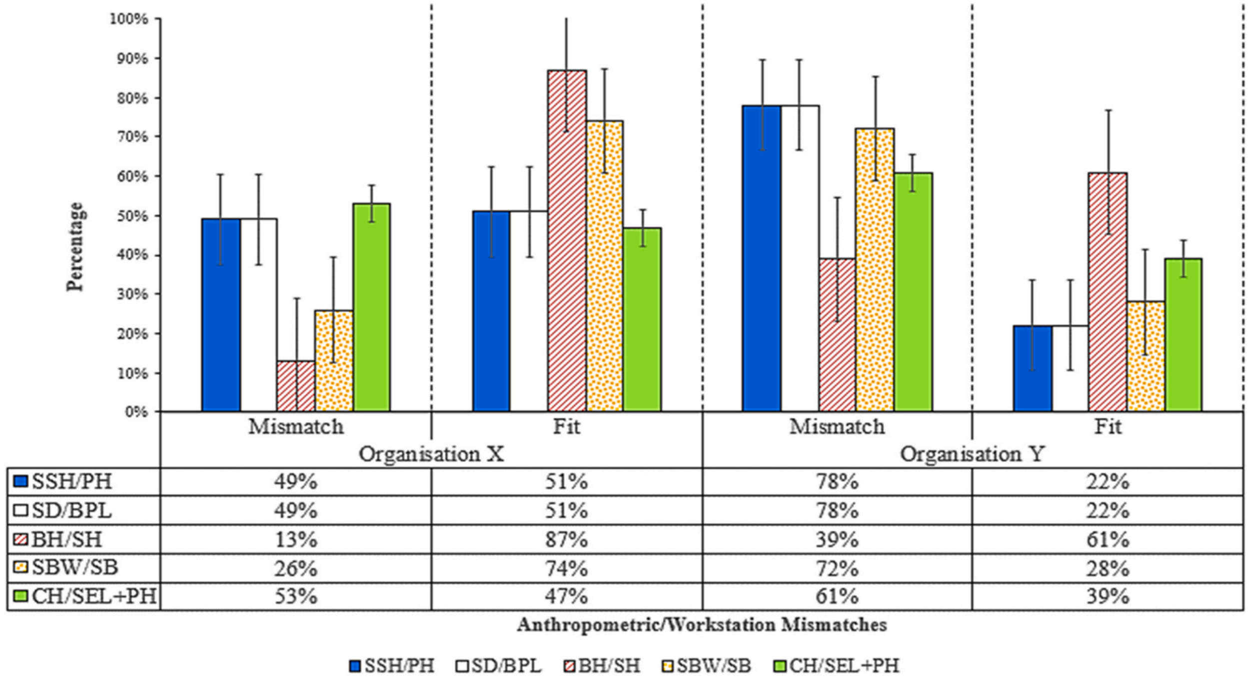

Fig. 2. Anthropometric/workstation mismatches and compatibility in Organisations X and Y.

4.2. Risk factors and WMSDs

Data analysis on the personal factors revealed that the operator's age in organisation Y was strongly associated with WMSDs in the neck and hip region. This can be explained by the high number of operators aged 50–54 years in organisation Y. This supports the study of Maliska et al. who uncovered a significant correlation between the age group of 50–55 years and neck pains [25]. But organisation X showed that the age factor had no relationship with WMSDs because most operators were aged 25 to 29. A similar result was found in the study of Dinar et al. [26].

It was also uncovered that the BMI index was associated with MSDs in the operators' lower backs from both organisations. Recent studies reported similar associations between the BMI index and MSDs in lower back pains [25,27]. Biomechanical stresses on weight-bearing joints seem to be mainly caused by being overweight or obese. Hence, it would be essential to change the worker's sitting posture [[28–30]].

Organisation X also showed a specific relationship between the educational levels and shift works with MSDs. This finding implies that operators with good knowledge of MSDs may have better job autonomy [27]. In Organisation X, most operators had worked for 6–10 years, showing a higher risk of elbow, hip, and ankle injuries. Whilst, in Organisation Y, most operators had worked for over ten years and had an increased risk of neck pains and eye strains.

This study also found that most operators in both organisations did not have exercise habits. There was a significant relationship between exercise habits and MSD pains in the back and hip areas. Several studies also affirmed that regular exercise significantly prevented MSS, especially in the back region [23].

Moreover, the two organisations showed differences in the final scores of work-related physical risk factors in MUEQ. Organisation Y revealed higher workstation and body posture scores than Organisation X. Piranyeyseh et al. [26] and Adegoke et al. [31] reported that workers who suffered from MSDs were sitting in an unergonomic posture, which often happened due to an unsuitable workstation.

Another critical factor is the break time domain, which helps reduce the muscular stress and fatigue of the operators. According to Dinar et al. [26], frequent short breaks could reduce musculoskeletal pains. This point was found in the data analysis of Organisation Y, where the operators had a low average break time. It contributed to a more significant association with MSD developments in the shoulder and eye regions.

Several studies have highlighted the substantial effect of work-related psychosocial risk factors on WMSDs [10,32]. High work demands and low social support have shown a significant association with the development of MSDs in the neck region. This was consistent with the analysis results of Organisation X, which revealed the elevated risks of shoulder, hips, and knees to higher job demand, low job control, and low social support scores.

The job demand also developed discomforts in the lower back, as found in the Organisation Y analysis. These work-related psychosocial factors might influence workplace stress. Thus, as reported in some studies, stress plays a crucial role in developing WMSDs [31]. This finding was also observed in the analysis of Organisation Y, which addressed a clear relationship between stress and neck discomfort. From the interview session, some of the operators' stress levels were identified as severe and critical levels. They seemed to be mainly caused by emotional well-being, high workload, difficulty expressing feelings or opinions about the job conditions, and lack of recognition or reward for good performance [33,34].

The control room's working environment also may impact the operators' productivity and lead to WMSDs [26]. According to the measurement results on the control room environment, the temperature and lighting aspects were consistent with the recommendation of ISO 11064-6. However, the noise level was above the threshold range. Field observations identified that loudspeakers were a source of distraction, which could be avoided by using headphones and further reduced by adding floor mats and panelled walls.

4.3. Risk assessments and anthropometric analysis

The survey results from the NMQ and MUEQ were confirmed by visual observations and anthropometric measurements in the electric control centres. In Organisation X, the safety and health department provided ergonomic chairs and footrests. Thus, the ROSA final score was in the warning region, indicating poor optimisation of the equipment. But the mouse and keyboard showed the highest scores in the ROSA result. Most of the operators used the mouse in line with their shoulders but kept it with a pinch grip. Also, most keyboards were arranged at an angle of $>15^\circ$, which led to wrist extension. As found in Table 5, there was a significant association between the body posture of operators and wrist pain ($p = 0.008$).

Furthermore, the RULA final score was at a high-risk level. Most operators were working with a position of a flexed neck, raised shoulders, and strained legs. This was due to the console height, setting elbow, and popliteal height mismatch. Such poor stances forced the operators to compensate for the differences by leaning forward and being unable to utilise the backrest, thus causing an awkward posture with a muscle strain on the neck and upper back [29,33]. This finding supported that improper postures increased neck and ankle pains ($p < 0.05$), as well as unsuitable workstations increased upper back discomfort ($p = 0.006$). The overall correlation between the ROSA and RULA approaches shows a considerable association between the ergonomic risk of workstations and operators' postures, which contribute to WMSDs ($r = 0.352$, $p = 0.01$).

In organisation Y, the ROSA scores revealed that inadequate workstation conditions: chairs, monitors, and phones led to improper upper and lower limb postures. Most operators were sitting at a low and non-adjustable seat height (knee at $< 90^\circ$). Based on the anthropometric measurements, a mismatch was found between the seat surface and popliteal height. This finding was also affirmed by the statistical analyses, highlighting a strong association ($r = 0.61$, $p = 0.008$) between the ROSA and RULA approaches. According to recent research [30], operators tend to move forward, forming an angle between their spine and thigh and using their legs for support. Thus, the statistical analysis from the present study confirmed a significant relationship between the hip/thigh and ankle with the workstation ($p < 0.05$).

Non-adjustable seat depth also contributed to a mismatch between the seat depth and buttock popliteal length, resulting in WMSD in the knee region ($p = 0.006$). Most of the chair armrests were too high or too low with a firm and non-adjustable surface. This caused incompatibility between the set elbow and console height, leading to a kyphotic posture with a raised shoulder. Hence, it is urged to replace the existing chairs with ergonomic ones.

Additionally, some of the monitors were far from the operators' view, resulting in twisted necks. All the workstations also lacked document holders, which caused extra pains in the shoulder and neck regions. Furthermore, there were several phones, and each one was dedicated to a specific task. The ROSA phone results showed that the phone was too far to reach (more than 30 cm), causing awkward postures of abducted arms and twisted trunk. Comparable results on such issues were also reported by Matos & Arezes [35].

4.4. Suggested treatments of WMSDs

As found on the causes of WMSDs amongst the operators, they are complex and multifactorial. To treat WMSDs, a multimodal approach is recommended that targets both underlying causes of pain and the associated functional limitations. Treatment options may include medication (and/or surgery), restriction of movement, and application of heat or cold. Additionally, physical therapy, occupational therapy, and exercise interventions are often recommended to improve pain relief and restore function. The application of heat or cold therapy can also be used to manage pain symptoms.

Several studies have shown that exercise interventions, including stretching and strengthening workouts and yoga can effectively reduce pains and improve functions in individuals with WMSDs by promoting circulation and reducing muscle tension [[36–40]]. Yoga-based exercises resulted in effective for painful disorders of muscles, tendons, and nerves (such as carpal tunnel syndrome, tendonitis, thoracic outlet syndrome, and tension neck syndrome) [41–43], shoulder pain [40], wrist and forearm disorders [39,41,44], and tension headache and cervicogenic headache [45,46]. Overall, individualized and multimodal approaches that address the underlying causes of WMSDs are recommended for optimal pain relief and rehabilitation [47].

5. Conclusion

This study investigated the prevalence of WMSDs and analysed their causal risk factors amongst the network control centre operators to introduce ergonomic interventions for preventing WMSD development from two government organisations, X and Y, in the UAE. Based on the survey results and ergonomics observations, this study found a high occurrence of WMSDs in both organisations over the past 12 months. The control room operators' most affected body areas were the back, eyes, and neck.

Individual, work-related physical and psychosocial risk factors were strongly associated with WMSDs in different body areas. The significant risk factors in Organisation X were high BMIs, educational levels, morning work shifts, high job durations, lack of exercise habits, awkward body postures, high job demands, low job controls, and low social support. The significant risk factors in Organisation

Y were older ages, high BMIs, high job durations, lack of exercise habits, poorly designed ergonomic workstations, awkward body postures, low break times, high job demands, and stress.

The environmental noise factor was found to be above the threshold limits. The high RULA final score in Organisation X replicates that the operators were working with a flexed neck, raised shoulders, and strained legs due to the mismatched designs between the console heights, setting elbows, and popliteal heights. Organisation Y also showed high ROSA and RULA final scores. This indicated that postural problems were mainly caused by disarranged workstation equipment such as monitors, phones, and chairs. Moreover, there was a higher mismatch rate between the operator's body measurements and the dimensions of the workstations, which led to awkward postures.

To lessen the detrimental effects of WMSDs and preclude the development of WMSDs, various initiatives should be established for the control room operators in the government authorities. Therefore, mitigation arrangements should be developed for both organisations' control rooms to prevent musculoskeletal effects and create safe and healthy environments.

6. Strength and limitation

This study has key strengths; it is one of the very first research evidence on WMSDs amongst control room operators in the UAE. Although WMSDs and ergonomic risk management have not been well-defined, this study provides evidence-based proof of the issue. This study also identifies the prevalence of WMSDs and encourages the development of domain-specific prevention schemes for the control centre/room operators. But this study has a low sample size, limiting and generalising the results. Hence, future studies should consider the control rooms of other divisions in both organisations. More participants will benefit from future studies to conduct further detailed statistical analyses such as binary logistic regression to predict the optimal WMSD predictor risk factors. Also, psychosocial risk factors' effects on WMSDs are restricted by limited numbers of sample sizes so need to be improved.

Ethics approval

This study was approved by the Department of Health and Safety from both government organisations in the UAE. The approval contained "NON DISCLOSURE TERMS & CONDITIONS" by written consent of both organisations' management departments. The ethics approval was also agreed upon by not using any information obtained for any purpose other than the approved purpose.

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No additional information is available for this paper.

CRediT authorship contribution statement

In-Ju Kim: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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