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Research article

Efficacy of an Omaha system-based remote ergonomic intervention program on self-reported work-related musculoskeletal disorders (WMSDs) — A randomized controlled study

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ABSTRACT

Purpose: Heavy biomechanical loadings at workplaces may lead to high risks of work-related musculoskeletal disorders. This study aimed to explore the efficacy of an Omaha System-based remote ergonomic intervention program on self-reported work-related musculoskeletal disorders among frontline nurses.
Materials and methods: From July to October 2020, 94 nurses with self-reported pain in one of the three body parts, i.e., neck, shoulder, and low back, were selected and were randomly divided into two groups. The intervention group received a newly developed remote program, where the control group received general information and guidance on health and life. Program outcome was evaluated by a quick exposure check approach.
Results: After 6 weeks, the intervention group exhibited significantly less stress in the low back, neck, and shoulder/forearms, compared to the control group ($p < 0.05$). In addition, the occurrence of awkward postures, such as extreme trunk flexion or twisting, was also significantly reduced ($p < 0.05$).
Conclusions: The newly developed Omaha System-based remote intervention program may be a valid alternative to traditional programs for frontline nurses during the COVID-19 pandemic, reducing biomechanical loadings and awkward postures during daily nursing operations.

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1. Introduction

Healthcare professionals, especially nurses all over the world, are highly vulnerable to work-related musculoskeletal disorders (WMSDs), experiencing high rates of neck, shoulder, and low back injuries [1–6]. In the US, nursing personnel had the highest rate of WMSDs at 249 per 10,000 workers in 2010, more than seven times the national average for all industries [7] and ranked among top five occupations with the largest cases of WMSDs in 2015. In China, recent nationwide surveys among nurses have consistently reported lower back, neck, and shoulders as the three most commonly injured body parts [8–12].

Although the precise cause is unclear, literature suggests that WMSDs have complex, multifactorial etiology. Commonly reported risk factors include (1) individual demographics, such as gender, age, and previous spinal complaint, (2) job physical exposures (e.g., manually lifting and lowering weights in workplaces, awkward postures, fast work pace, vibrations, etc.), and (3) psychosocial factors, such as anxiety, job burnout, and job satisfaction [3,13–20]. In healthcare facilities, nursing operations often involve unfavorable working conditions, such as forceful manual patient handling activities, awkward postures during intravenous therapies, drug administrations, and the replacement of drainage bags/catheters, which may result in high mechanical load and postural stress on nurses' low backs, necks, and shoulders [10,21–26]. In addition, nursing personnel suffering WMSDs may also experience increased psychosocial stress and negative emotions [27–29], resulting in poor job satisfaction and overall life quality [30–32], which may inevitably influence the quality of patient care.

To reduce WMSDs among nursing personnel, many workplace interventions have been developed and implemented, including ergonomics programs, on-site education, organizational policies, and the use of assistive patient handling equipment, aimed to improve caregivers' awareness of the unfavorable working conditions during daily nursing operations and attenuate the negative impact associated with these conditions [1,33–41]. In general, as noted by previous studies, workplace interventions should follow a multidisciplinary approach and coordinate all involved parties (e.g., management, nurses, patients, etc.) [42]. While the traditional intervention programs have been found effective in reducing the risk of WMSDs [43], the ongoing global pandemic of COVID-19 (SARS-CoV-2) has posed a great challenge to ergonomics practices in healthcare facilities, particularly hospitals. Commonly used mitigation measures, such as social distancing and working remotely, have substantially minimized in-person gatherings [44]. Nevertheless, healthcare facilities throughout the world have been short-staffed, resulting in disturbance of shift scheduling and more importantly, the increased job demand among the available caregivers. With the latest development in communication technology, remote intervention measures have been developed as an alternative, without the necessity of in-person meetings [45–48]. The Omaha System (OS) is a standardized classification system for nursing practice, including a problem classification system, an intervention system, and an outcome evaluation system [49]. The intervention system includes four categories: (1) education guidance and consultation, (2) treatment and procedure, (3) case management, and (4) supervision. In clinical practice, it has been used as a standardized tool to reduce patients' unhealthy behaviors and improve their cooperation with treatments through personalized and targeted nursing interventions and services [50]. Some studies have suggested promising results, applying a similar methodology to develop ergonomic interventions targeting WMSDs among nurses in the intensive care unit (ICU) [51]. Unfortunately, there is still a lack of understanding of the efficacy of an Omaha System based (OS-based) remote ergonomic intervention program with a larger sample of active nurses, rigorous methodology and experiment design, and a standardized framework. Therefore, this study aims to construct an OS-based remote intervention program for WMSDs derived from comprehensive findings from an extensive literature review, structured interviews of active nurses, and expert consultations, and evaluate the subsequent outcomes on self-reported symptoms among a relatively large sample of clinical nurses during the COVID-19 pandemic using a randomized controlled trial.

2. Methods

This study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the Second Hospital of Hebei Medical University (#2020-R032). All participants provided written informed consent. We calculated the study sample size using the following sample size calculation formula.

$$n1 = n2 = (U\alpha + U\beta)^2 2P(1 - P) \Big/ \left(P^1 - P^2\right)^2$$

Referring to the relevant literature [52], $P^1 = 0.4847$, then we set $P^2 = 0.145$ according to our study goal, took both sides $\alpha = 0.05$, $\beta = 0.10$, obtained the following: $u_{0.05/2} = 1.96$, $u_{0.01} = 1.282$. We substituted them into the formula and got $n1 = n2 \approx 43$, for a total sample size was 86. Considering a loss to follow-up rate of 5%–10 %, the required sample size was determined to be 94 participants.

2.1. Participants

From July to October 2020, recruitment meetings were held at a local tertiary hospital located in Hebei Province, China, to explain the study and attract potential nurses to participate. A total of 94 clinical nurses from eight clinical departments provided written, informed consent to participate in this study. Employers paid nurses regular wages, and respondents received no incentives for participation. Inclusion criteria included: (1) current qualification/certificate as a nursing practitioner, (2) at least three years of clinical experience, (3) experience of positive symptom(s) (i.e., pain, numbness, soreness, and reduced activities) within the past year at the following body part(s) (i.e., low back, neck, and shoulder), lasting at least one day, and (4) regular internet access to the online survey. It should be noted that, in China, a department rotation program takes about two years, during which nurses are periodically relocated across multiple departments. Therefore, nurses with at least three years of clinical experience are more likely to be stationed in one particular department. Nordic musculoskeletal questionnaire (NMQ) was used to assess the musculoskeletal symptoms. Several exclusion criteria were also applied, including (1) nurses in training/residency, (2) nurses with congenital spinal disorders, such as spinal deformities/abnormalities (e.g., scoliosis, kyphosis, lordosis, etc.) and degenerative diseases (e.g., bulging and/or herniated disc), and (3) for females, being pregnant or with a history of pregnancy within the past year. For the convenience of study management in the presence of COVID-19, participants were grouped by their corresponding departments, one researcher put the paper representing eight departments into a sealed envelope, and the other researcher randomly selected the envelope. The odd number of departments were regarded as the intervention group (IG), and the rest were regarded as the control group (CG). Each group consisted of four departments (see Fig. 1 for details).

2.2. Intervention protocol

Based on independent reviews from two investigators regarding the intervention measures reported in the literature (i.e., a total of 11 randomized controlled trial studies [30,53–62]; see Table 1, the initial intervention program was drafted, using Omaha System as the framework, which included two modules (i.e., Information and Exercise). The Information module consisted of materials on the importance of preventing WMSDs and effective measures to control the risk factors, such as “do not bend over more than 20°”, “bend your knee, not your back”, etc. The Exercise module was based on a previously developed exercise program (China copyright registration certificate 2021-L00058684), supervised by the rehabilitation expert. On the other hand, a subset of 12 nurses volunteered to participate in a semi-structured interview. During this interview, these nurses responded to questions, such as “How much do you know about WMSDs, such as neck, shoulder, or low back pain?”. A detailed description has been reported elsewhere [63]. In general, these answers were used to assess clinical nurses’ initial awareness and current knowledge of WMSDs and to help determine the format and duration of the intended intervention program. As a result, some modifications were made to the original program [63]. This revised program was then externally reviewed twice by senior management and experts in psychology and rehabilitation and pilot-tested to ensure the feasibility and applicability of the program, as well as the safety and well-being of the participants. Meanwhile, the final program schedule and time allocation for each module were also determined. As a result of careful considerations of both experts’ opinions and nurses’ feedback, the overall intervention program was designed to take six weeks [63].

2.3. Protocol for the intervention group

All IG subjects participated in the intervention program via an OS-based approach. Detailed implementation procedures are included in Table 2. A brief description of the procedures is provided below. First, a multidisciplinary intervention team was formed, including eight head nurses (i.e., one from each department), two investigators, two quality control experts, one rehabilitation expert, and two occupational health graduate students. The team’s primary functions included (1) managing the participating nurses, (2) implementing the intervention program and collecting data, (3) monitoring and maintaining the quality of the implementation, (4) providing guidance on exercise and addressing related questions and concerns, and (5) assisting with daily communication and data collection.

As the core piece of this remote intervention program, multiple online social networking groups were established to execute specific functions. WeChat© (Tencent Technology Company Limited, Shenzhen, China) was used to publish notifications and share information. DingTalk© (Alibaba Group Holding Limited, Hangzhou, China) was used to implement the actual intervention program, interact with the participants, and monitor their performance, through a hybrid framework, including live broadcasts of the

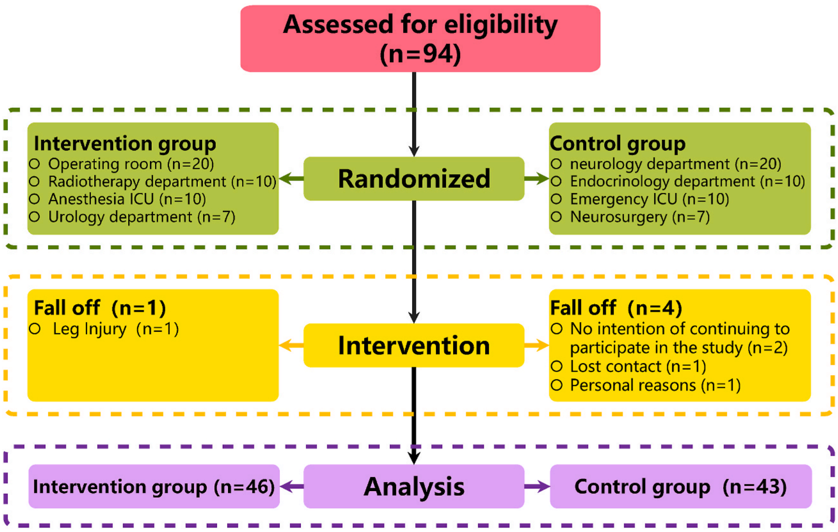

Fig. 1. Flow diagram of the inclusion and exclusion of study participants.

Table 1
Basic information of included literature.

Author, year	Country	Sample size		Intervention program		Intervention time	Evaluation tool	Conclusion
		T	C	T	C			
Jianhe [40], 2017	China	50	50	Knowledge training on Wechat platform: the harm, factors and self-treatment methods of WMSDs	Conventional control	5 months	General data questionnaire	Cognitive scores increased significantly, and pain intensity decreased significantly
Jun [41], 2019	China	101	104	Introducing WMSDs knowledge, conduct routine education of daily protection and exercise, and implement planned behavior training	Health education	40 min/time，1 time/w, for 4 weeks and followed up for 8 weeks	VAS, Protective awareness questionnaire	Reduce pain increase, strong awareness of protection
Shuhui [42], 2006	China	60	60	1. Lifestyle intervention: life posture; 2. Dietary intervention; 3. Exercise intervention; 4. Manual therapy and drug treatment	Manipulation therapy and medical therapy	A total of 4 weeks	Self-reported pain intensity	Lifestyle intervention can promote the recovery of patients with neck and shoulder pain
Wenjie [43], 2015	China	50	50	Exercise: Arm extension against the wall; Head and hand struggle; Lean back; Swing arm and neck; Standing arm exercises; neck swing; Standing arm practice; Hold your elbow from behind; Back touching exercise	Blank	30min/time，3 times/w, a total of 10 weeks	VAS SF-12	Neck and shoulder exercises can reduce the pain intensity and improve the quality of life
L. Bellido-Fernández [44], 2018	Spain	9	9	Abdominal low-pressure gymnastics exercise	Manipulation therapy	30 min/time, 2 times/week, in the first 3 weeks, once/week for the remaining 2 weeks	NRS ODI	Both groups had reduced pain levels and improved disability
Hiroyuki [45], 2019	Japan	1430	1799	Stretch exercise: Active exercise to stretch your back	Blank	6 months	FABQ	Effectively reduce pain and relieve pain deterioration
Pardis [46], 2018	Iran	18	18	Multi-step core stability training: including 34 core stability training movements	Blank	3 times/day, for 8 weeks	VAS SF-36	The SF-36 and VAS scores were significantly improved in the intervention group
Maryam [47], 2019	Iran	25	25	Traditional Chinese medicine acupoint massage: Baihui point, Neiguan point, Yongquan point, etc	Placebo control	3 times/week for 3 weeks	SF-36	The Quality of life has been improved significantly
Naser Dehghan [48], 2016	Iran	52	50	Knowledge training, guidance to change bad body posture, and identify nonergonomic factors to improve	Blank	8 weeks	NMQ RULA	The prevalence of WMSDs was significantly reduced as compared to the control group
Warming [49], 2008	America	203	134	1. Train nurses in handling and transferring patients; 2. Physical exercise	Traditional patient handling method	60min/time, 2 times/week for 8 weeks	NRS	There was a significant decrease in the pain level
Melinda Jaromi [50], 2018	Hungary	67	70	Apply the practice and patient handling techniques to distribute written materials	Simple life instruction	20 min/day, 5 days/week for 12 weeks	VAS	The VAS scores were significantly lower in the intervention group nurses than in the control group

ODI： Oswestry Disability Index; NRS： Numerical Rating Scale; RDQ：Roland–Morris Disability Questionnaire; NMQ：Nordic musculoskeletal disorders questionnaire; RULA：Rapid Upper Limb Assessment; RS:Low Back Pain Rating Scale; SF:Quality of Life Scale; VAS：Visual Analog Scale.

Table 2
Remote intervention program for nurses with neck, shoulder, and low back pain based on the Omaha system.

Direction category	Target/guide	Description of intervention	Intervention forms and effective participation criteria	Intervention time and frequency
Teaching, guidance, and consultation (TGC)	**Anatomy/physiology, behavior modification, teaching, and discipline**	The first dimension Related concepts of neck, shoulder, and low back pain; knowledge of human spine anatomy; poor posture of the neck, shoulder, and back; risk factors and things that harm the neck, shoulder, and back The second dimension Publicity and education of common awkward postures in nursing operation and daily life The third dimension Application of the principles of human mechanics (enlarging the supporting surface, reducing the deviation of the gravity line, reducing the volume of the object to be transported, etc.) in nursing The fourth dimension Explanation of the reasonable postures of nurses' common nursing operations (turning the patient over and patting their back, tidying up the bed unit, desk work, etc.), with a total of 10 common nursing operations The fifth dimension Explanation of the correct postures of nurses in daily life, such as correct sitting, lying, and standing postures The sixth dimension Self-relief methods for neck, shoulder, and low back pain (e.g., hot/cold compress, massage, acupuncture points, etc.) and using protective equipment (slip, belt, transfer pad, moving board, etc.)	Dingding group for online; live broadcast time is every Monday from 18:30–19:00, but participants can re-watch it within 1 week. Effective viewing criteria: ① viewers need to watch the video in its entirety, and the viewing time is the same as the video time; then, ② after each class, an in-class quiz was added, and the passing rate was 70 % for effective listening. Viewers who score lower than 70 % will be reminded to watch again and supervised by the researcher.	Weeks 1–6, 20–30 min/time/week; instructor: research team member. Course QR code (scan the following code in DingTalk):
Treatments and procedures (TP)	**Relaxation/breathing techniques, deep breathing exercises,**	Send each nurse a video of "Mindfulness Meditation Journey," which includes deep breathing exercises and "Cell Regeneration" mindfulness meditation music to relieve muscle tension	During the first week, a video conference via DingTalk was held from 21:00–21:30. Then, during weeks 2–6, the nurses exercised on their own but checked in 5 days a week. Those who did not check in were reminded by the researcher.	Weeks 1–6, 15–20 min/time/day, 5 days/week, 6 weeks in total; instructor: research team member.
	sports, and health care	Teach nurses to perform daily exercises for the neck, shoulder, and low back		
Case management (CM)	**Support system**	Always pay attention to nurses' neck, shoulder, and low back pain; encourage nurses to use hospital resources to perform activities to improve neck, shoulder, and low back pain; and develop individual rehabilitation plans for nurses in need	The exercise compliance questionnaire was used to investigate the compliance of nurses; to ask them about neck, shoulder, and low back pain; and to provide care and support	Research participants: research team and nurses
Supervise (S)	**Behavior modification**	In the Dingding group, nurses were encouraged to use correct postures to perform nursing operations and exercises and to track their neck, shoulder, and low back pain		

information module, monitoring of the participants' online activities and readily feedback/guidance, one-on-one coaching via video conference, etc. During the process, IG participants had to exercise by themselves and check in with the progress tracker by uploading exercise photos. Investigators then reviewed the photos and decided if additional guidance was necessary (see Fig. 2). The detailed intervention program is listed in Table 2.

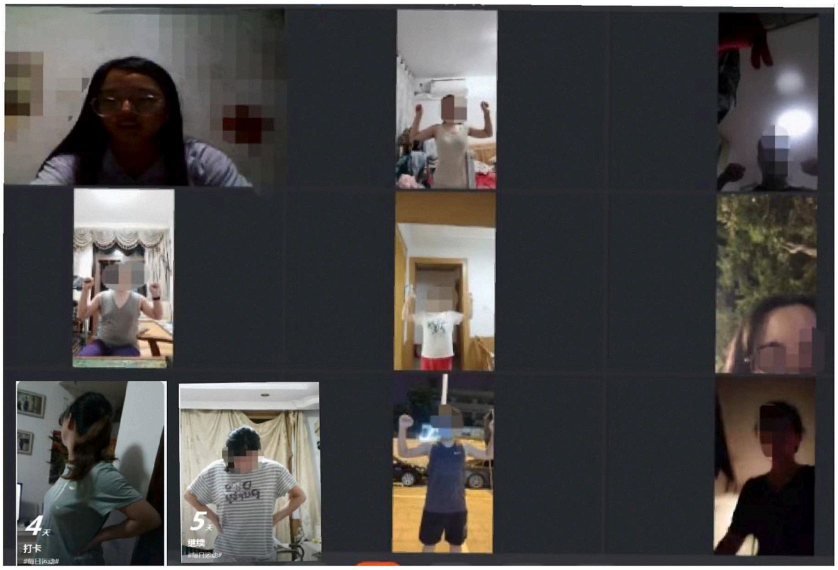

Fig. 2. Remote training images.

2.4. Protocol for the control group

The intended intervention program was also provided to all CG participants once at the end of the study, including all information and exercise modules. During the study, CG participants received routine guidance on work and life from the management, and were able to approach the investigators with questions, such as the proper working postures, and concerns of bodily discomfort at any time. The purpose of offering such feedback to CG participant was to help them receive current information and enhance their awareness and knowledge of WMSDs, as an effective alternative to self-administered online searching or web browsing.

2.5. Workplace ergonomics assessments

The Quick Exposure Check (QEC) [64] was used to assess workplace exposures to musculoskeletal risk factors affecting the back, shoulder/arm, wrist/hand, and neck. The overall outcome measure consisted of two parts, including (1) expert evaluations and (2) participant self-assessments. Assessment results were interpreted according to previously established metric (see Table 3). Secondly, a specially developed online questionnaire (Wenjuanxin, Changsha Ranxing Information Technology Co., Ltd, Hunan, China) was also administered among all participants to collect demographic data, work schedule, work-related mental pressure, and self-reported postural stress at work, such as trunk flexion and twisting. Detailed guidance was provided among the DingTalk group.

Two rounds of data collection were performed. At baseline, two investigators independently observed and video-taped each participant's daily nursing activities, and subsequently assigned their scores, while participants were also asked to provide their self-assessment results, after which the overall QEC scores and the corresponding risk levels were subsequently determined. At the end of the 6th week, a second data collection was performed following the same procedures.

2.6. Statistical analyses

Frequencies and percentages were calculated for categorical variables (e.g., gender, education level, physical exercise, etc.). For continuous variables (e.g., work time, etc.), mean values and standard deviations or medians and interquartile ranges were calculated, depending on the distributions of data. χ^2 test was used to examine the differences in ergonomic load and body positions among the two participant groups. Statistical analyses were conducted using SPSS (version 26, IBM Corp., Armonk, NY, USA). Statistical significance was at $p < 0.05$.

Table 3
Quick Exposure Check (QEC) scores and the corresponding risk levels.

	Risk Levels			
	Low	Medium	High	Extremely High
Back, Shoulder/Arm, and Hand/Wrist	10 to 20	22 to 30	32 to 40	42 to 56
Neck	4 to 6	8 to 10	12 to 14	16 to 18

3. Results

Out of the 94 participants at baseline, five were lost during the follow-up (i.e., one from the IG and four from the CG), resulting in a total of 89 participants (i.e., IG: 46; CG: 43). Descriptive statistics regarding the IG and CG are provided in Table 4. Both groups were dominantly female (>65 %, $p = 0.139$), who received a bachelor's degree (>90 %, $p = 0.331$), and had no routine physical exercise (>65 %, $p = 0.666$). In addition, both groups reported similar daily working schedule, around 8 h ($p = 0.216$).

3.1. Comparisons of risk assessments at baseline and after 6 weeks

Results of risk assessment comparisons are presented in Table 5. At baseline, based on the Quick Exposure Check (QEC), both IG and CG participants were at similar levels of risk of low back, neck, shoulder/arm, hand/wrist, work rhythm and work pressure disorders ($p > 0.05$). Most of the participants were at high or extremely high risk of low back (i.e., 76 % for IG and 81 % for CG), neck (71 % vs. 81 %), and shoulder/arm (63 % vs. 72 %). Most of the participants were at medium or high risk of hand/wrist (78 % vs. 74 %). After 6 weeks, most IG participants were at high or extremely high risk of low back, neck, and shoulder/arm significantly lower than those among the CG participants (9 % vs. 44 %; 7 % vs. 58 %; 9 % vs. 37 %; $p < 0.05$). And, most IG participants were at medium or high risk of low back (6 %), significantly lower than those among the CG participants (65 %; $p < 0.05$).

3.2. Comparisons of postural stresses at work

Results of postural stresses assessment comparisons are presented in Tables 6 and 7. At baseline, both IG and CG participants were at similar proportions of back, neck, and other awkward postures ($p > 0.05$). After 6 weeks, the proportion of back lean forward sharply, neck lean forward sharply, turn around, turn around while bending over, trunk often repeats the same movement, stay bent over for a long time, and maintain a turned posture for a long time significantly in IG participants lower than those among the CG participants (0 % vs. 30 %; 32 % vs. 46 %; 70 % vs95; 35 % vs. 77 %; 43 % vs. 67 %; 43 % vs. 84 %; 22%vs. 49 %, $p < 0.05$).

4. Discussion

The current study attempted to evaluate an Omaha System based (OS-based) remote ergonomic intervention program to address the risk factors of work-related musculoskeletal disorders (WMSDs), particularly the postural stresses, among seasoned nurses (i.e., work tenure ≥3 years) from a variety of clinical departments during the pandemic of COVID-19. Each of the sampled departments has unique and rigorous routine operations. Therefore, as pointed out by previous studies [65], workplace intervention program, in general, should follow three steps, namely (1) the determination of the conceptual/theoretical framework, (2) the evidence-based program development, and (3) the evaluation and/or adjustment of the program. The current study, first, performed a thorough literature review of previous methods and then conducted structured interviews and consultations with internal and external experts and senior management to finalize the program specifics. In this study, the comparisons of workplace risk assessments at baseline and after the intervention revealed a trend of significant reduction of postural stress associated with the low back, neck, shoulder/arm, and hand/wrist among all IG participants. Omaha System, in general, may provide comprehensive guidance, systematically analyze the personalized needs of each nurse, and implement the targeted intervention procedures. After the intervention, participants' knowledge of workplace health and ergonomics and their daily behaviors were also routinely evaluated, which may help nourish a continuous improvement of workplace health climate. It has been generally agreed that the management involvement is a critical and essential attribute of a successful workplace intervention program, as suggested by Coskun Beyan et al. [66], where a multi-faceted program was administered, including ergonomic training sessions, assistance from auxiliary equipment, and a mandatory 10-min stretching exercise

Table 4
General data of study participants (n = 89).

Project	Category	Intervention group (46) n (%) /M(Q_{25},Q_{75})	Control group (43) n (%) /M(Q_{25},Q_{75})	Statistical value	*P value*
Gender					
	Man	14 (66.67)	7 (33.33)	2.470[a]	0.139
	Women	32 (47.06)	36 (52.84)		
Education level					
	Undergraduate	45 (51.14)	43 (48.86)	0.945[a]	0.331
	Postgraduate and above	1 (100.0)	0 (0)		
Physical exercise					
	Neither	16 (47.06)	18 (52.94)	2.506[a]	0.666
	Occasionally	16 (48.48)	17 (51.52)		
	2-3time/Month	2 (50.00)	2 (50.00)		
	1-2 time/Week	6 (75.00)	2 (25.00)		
	>2 time/Week	6 (60.00)	4 (40.00)		
Work time		8 (5.75 , 10.50)	8 (6.00 , 9.00)	1.046[b]	0.216

M(Q_{25},Q_{75}): M is the median. Q_{25}, Q_{75} represent the first and third quartiles, respectively. n(%):n is the frequency and the (%) is the percentage of events in the total.
a: The *P* value was obtained using a $\chi 2$; b: The *P* value was obtained using a nonparametric test; Significance at $P < 0.05$.

Table 5
Ergonomic load of nurses in the 2 groups before and after intervention (n = 89).

Group	Number	Before intervention				After intervention				Statistical value	*P value*
		Low load	Medium load	High load	Extremely high load	Low load	Medium load	High load	Extremely high load	–	–
Low back											
Intervention group	46	2	9	16	19	23	19	4	0	47.411	<0.001
Control group	43	1	7	17	18	9	15	10	9	14.124	0.003
Statistical value		0.330				3.962				–	–
P value		0.742				<0.001				–	–
Neck											
Intervention group	46	2	11	14	19	21	22	3	0	45.480	<0.001
Control group	43	0	8	8	27	8	10	9	16	11.667	0.007
Statistical value		1.943				2.285				–	–
P value		0.052				0.022				–	–
Shoulder/arm											
Intervention group	46	4	13	18	11	18	24	4	0	32.088	<0.001
Control group	43	2	10	15	16	14	13	10	6	14.937	0.002
Statistical value		1.365				2.130				–	–
P value		0.172				0.033				–	–
Hand/wrist											
Intervention group	46	7	21	15	3	17	23	6	0	10.649	0.009
Control group	43	4	15	17	7	11	16	12	4	4.979	0.173
Statistical value		1.768				4.745					
P value		0.077				<0.001					
Work rhythm											
Intervention group	46	4	42			5	41			–	1.000
Control group	43	0	43			4	39			–	0.116
Statistical value		3.915[a]				0.060[a]					
P value		0.117				0.806					
Work pressure											
Intervention group	46	3	22	21		3	27	16		1.262	0.571
Control group	43	0	21	22		1	22	20		1.068	0.829
Statistical value		0.802				1.270					
P value		0.422				0.204					

The P value was obtained using a $\chi 2$; Significance at $P < 0.05$.

at workplace required by the management. In addition, in the current study, five initial participants were lost during the follow-up. It may be attributed to the program intensity and the potential disturbance to their daily schedule and personal life. However, most participants finished this remote program designed to minimally impact participants personal life (i.e., to perform more exercise at work). It should be noted that other factors, such as organizational climate, and psychosocial factors, may also contribute to the program compliance. For example, some studies have suggested the importance of self-efficacy during the management of low back pain [67].

The current intervention program was developed to address ten common nursing operations that may pose postural stress or other ergonomic issues, such as excessive trunk flexion during intravenous therapy and manual patient handling [68]. During their daily nursing operations, nurses were reminded to use both hands to carry and/or support weights, use appropriate body mechanics for performing forceful exertions, avoid static postures, etc., and exercising good ergonomic principles. In addition, nurses were encouraged to use assistive tools and equipment (e.g., transfer sheet) to facilitate patient transferring/handling. When manual patient handling was unavoidable, they were instructed to adjust the bed height (i.e., about 80 cm) and apply the newly learned knowledge of ergonomics and body mechanics to minimize the load on their upper body and low back [69]. During routine operations (e.g., scrubbing the bed), nurses were reminded to organize the items and place more frequently used ones close to their elbow height to avoid awkward postures, such as bending over and kneeling. In general, with the organizational support from the co-workers and the management, employees are more likely to develop awareness for WMSDs and sustain continuous participation in workplace intervention programs. Unfortunately, improved awareness for WMSDs does not necessarily result in less body pain or discomfort, as some

Table 6
Bad back and neck postures of nurses in the 2 groups before and after intervention (n = 89).

Group	Nurmber	Before intervention				After intervention				Statistical value	*P value*
		Upright	Lean forward slightly	Lean forward sharply	Head backward	Upright	Lean forward slightly	Lean forward sharply	Head backward		
The position of back at work											
Intervention group	46	3	28	15		13	33	0		21.660	<0.001
Control group	43	4	31	8		2	28	13		1.980	0.392
Statistical value		2.343				21.400					
P value		0.318				<0.001					
The position of neck at work											
Intervention group	46	1	20	24	1	9	22	15	0	9.593	0.011
Control group	43	2	18	22	1	0	22	20	1	2.372	0.476
Statistical value		0.763				11.382					
P value		0.933				0.005					

Back posotion: Upright:0°-10°, Lean forward slightly:20°-60°, Lean forward sharply: >60°.
Neck posotion: Upright:0°-10°, Lean forward slightly:10°-20°, Lean forward sharply: >20°.
The P value was obtained using a $\chi 2$; Significance at $P < 0.05$.

Table 7
Awkward postures of nurses in the 2 groups before and after intervention (n = 89).

Group	Number	Before intervention		After intervention		Statistical value	*P value*
		No	Yes	No	Yes		
Keep turning your head for a long time							
Intervention group	46	31	15	31	15	0.000	1.000
Control group	43	23	20	26	17	0.427	0.514
Statistical value		2.343		0.463			
P value		0.318		0.516			
Turn around often							
Intervention group	46	5	41	14	32	5.373	0.02
Control group	43	3	40	2	41	–	1.000
Statistical value		0.412		10.020			
P value		0.715		0.002			
Turn around while bending over							
Intervention group	46	13	33	30	16	12.619	<0.001
Control group	43	10	33	10	33	0.000	1.000
Statistical value		0.291		15.815			
P value		0.635		<0.001			
The trunk often repeats the same movement							
Intervention group	46	16	30	26	20	4.381	0.036
Control group	43	13	30	14	29	0.054	0.816
Statistical value		0.209		5.158			
P value		0.659		0.033			
Keep the back in the same posture for a long time							
Intervention group	46	11	35	22	24	5.718	0.017
Control group	43	5	38	14	29	5.472	0.019
Statistical value		2.275		2.151			
P value		0.171		0.142			
Stay bent over for a long time							
Intervention group	46	12	34	26	20	8.788	0.003
Control group	43	13	30	7	36	2.345	0.126
Statistical value		0.189		15.427			
P value		0.814		<0.001			
Maintain a turned posture for a long time							
Intervention group	46	26	20	36	10	4.946	0.026
Control group	43	21	22	22	21	0.047	0.829
Statistical value		0.527		7.190			
P value		0.527		0.008			
Keep the neck in the same posture for a long time							
Intervention group	46	11	35	16	30	1.311	0.252
Control group	43	6	37	10	33	1.229	0.268
Statistical value		1.427		1.428			
P value		0.286		0.253			
Keep your head down for a long time							
Intervention group	46	11	35	18	28	2.467	0.116
Control group	43	8	35	10	33	0.281	0.596
Statistical value		0.373		2.579			
P value		0.611		0.107			

Often: > 5 time/min; long time: >60s.
The *P* value was obtained using a $\chi 2$; Significance at $P < 0.05$.

studies have found no significant correlation between the two [70]. Additionally, the current study found no significant difference in work rhythm and work-related mental pressure between the IG and CG participants, which may be explained by the relatively short intervention time and the vast disturbance of the work schedule due to the COVID-19 pandemic.

Awkward postures at work have been identified as a major risk factor of work-related musculoskeletal disorders (WMSDs), such as extensive trunk flexion, neck flexion, and twisting [71]. During the current 6-week intervention program, IG participants were educated about the potential risk associated with awkward postures (i.e., both static and dynamic). They were also given instructions on how to achieve good postures when performing a variety of nursing operations and other daily activities. For example, picking up items from the floor in a seated position should be avoided to minimize trunk flexion and twisting. Previous studies have suggested that programs designed to improve workforce awareness of awkward postures may be more effective than the ones designed to improve pain symptoms [72,73]. In this study, the current IG participants reported significant reduction of workplace awkward postures. It may be explained by the fact that the current program included exercises for specific body parts, especially the comprehensive core muscle exercises, which may help improve an individual's ability to control postures [74]. However, it should be noted that some awkward postures persisted despite the relatively good program compliance, such as prolonged head twisting. This may be partially explained by the fact that some routine nursing operations and/or protocols are cumbersome and time-consuming, such as retention catheterization and central venous catheterization. Therefore, future research should consider developing ergonomic intervention measures targeting specific nursing operations, which should be a collective effort from all stakeholders (e.g., management, education, and practitioners).

Limitations of this study include the following, (1) nurses were recruited from tertiary hospitals, and thus the results might not be directly applicable in other environments, such as secondary hospitals and nursing homes (2) questionnaires used in this study (i.e., both QEC-derived and postural stress). may be subjective. Unfortunately, while the blinding approach was not implemented, the results may be subjected to bias. Future research should consider using objective methodology, such as surface electromyography (EMG) and goniometers to evaluate the postural stress or other ergonomic risk factors. (3) due to limited manpower and financial resources, deep project-based intervention (e.g., workstation design) was not included in this study.

5. Conclusion

In summary, the current OS-based remote ergonomic intervention program has promising effect, protecting clinical nurses from workplace postural stress. It may also provide valuable references regarding the form, the content, and the timing of the remote intervention for other WMSDs among nurses. Future research should also explore the possibility of developing various remote intervention programs with respect to a wide spectrum of cultural backgrounds, socio-economic status, and international underpinnings.

Author contributions

Tian Suzhai: Validation, Supervision, Project administration. Zhang Tianqiao: Writing – original draft, Supervision, Investigation, Data curation. Tian Ye: Data curation. Yin Yanliang: Investigation, Data curation. Sun Weige: Software, Formal analysis. Tang Limei: Project administration, Methodology. Tang Ruoliang: Writing – review & editing, Methodology. Tian Yichao: Investigation. Gong Shuhui: Methodology

Data availability statement

The data are available from the corresponding author on reasonable request.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24514.

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