Complex Interactive Multimodal Intervention Improve Personalized Stress Management Among Healthcare Workers in China: a controlled non-randomized study

Wenhua Liu, Quan Wang, Danli Zheng, Junhua Mei III, Jiajia Lu, Guohua Chen, Wei Wang, Fengfei Ding

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Abstract

Background: Healthcare is considered one of the most stressful occupations because multiple stressors exist in the workplace. Mobile stress management intervention is currently widely used in mental health intervention as an affordable and accessible approach. However, one of the major challenges in applying mobile intervention is the low interaction and engagement of participants, which hinders the optimal effects of mobile intervention, especially in self-guided mobile interventions where employees receive no human support during the intervention.

Objective: The present study aims to compare the effects of CIMI, a complex interactive multimodal intervention, on physiological and psychological stress measures in comparison to the self-guided mobile intervention.

Methods: We conducted a non-randomized, controlled study in two Chinese general hospitals. This study enrolled 245 healthcare workers who met the inclusion criteria for at least one of the three dimensions of the Depression, Anxiety, and Stress scale. All eligible participants were required to complete a questionnaire and wear a 24-hour Holter device to assess the physiological indicators of stress as indexed by heart rate variability at both baseline and post-intervention. During the program, participants in the CIMI group received a 12-week online intervention with the following four components: mobile stress management education, a web-based WeChat social network, tailored feedback, and a nurse coach, while the control group only received a self-guided intervention.

Results: After a 12-week intervention, the perceived stress, depression, anxiety, fatigue, sleepiness symptoms, and subjective happiness in the CIMI group improved more significantly than those in the self-guided group. Additionally, we found a reduction in HRV parameters in the control group rather than the CIMI group.

Conclusions: CIMI was an effective intervention for improving both psychological and physiological indicators of stress among distressed HCWs. The findings provide objective evidence for developing an effective and economically viable mobile stress management intervention with a minimum of human support, but further research is needed. Clinical Trial: ClinicalTrial.gov., NCT05239065; https://clinicaltrials.gov/ct2/show/NCT05239065.

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Complex Interactive Multimodal Intervention Improve Personalized Stress Management Among Healthcare Workers in China: a controlled non-randomized study

Abstract

Background: Healthcare workers (HCWs) frequently face multiple stressors at work, particularly those working night shifts. HCWs who have experienced distress may find it difficult to adopt stress management approaches, even if they are aware of the effects of stress and coping processes. Therefore, an individualized intervention may be required to assist distressed HCWs in bridging the "knowledge-practice" gap in stress management and effectively alleviating stress symptoms.

Objective: The main objective of this research was to compare the effects of A Complex Interactive Multimodal Intervention (CIMI) to self-guided stress management interventions on stress symptoms of distressed HCWs, as measured by physiological (heart rate variability), psychological (perceived stress, mental distress, and subjective happiness), and sleep (fatigue and sleepiness) disorder.

Methods: We conducted a non-randomized, controlled study in two Chinese general hospitals. The participants in this study were 245 healthcare workers who fulfilled at least one of the three dimensions of the Depression, Anxiety, and Stress scale. All eligible individuals were required to complete a questionnaire and wear a 24-hour Holter device to determine the physiological signs of stress as indexed by heart rate variability at both baseline and post-intervention. The CIMI group received a 12-week online intervention with four components: mobile stress management instruction, a web-based WeChat social network, personalized feedback, and a nurse coach, whereas the control group simply received a self-guided intervention.

Results: After a 12-week intervention, the Perceived Stress Scale (PSS) scores reduced significantly in the CIMI group (MD=–5.31; 95% CI=–6.26 to –4.37; P<0.001) after intervention as compared with the baseline levels, and the changes in PSS scores before and after interventions exhibited a significant difference between the CIMI and control groups (d=-0.64; MD=–4.03; 95% CI=–5.91 to –2.14; P<0.001), and the effect was medium. In terms of physiological measures, both the control group (MD=-9.56; 95% CI = -16.9 to -2.2; P=0.01) and the CIMI (MD =-8.45; 95% CI =-12.68 to -4.22; P<0.001) demonstrated a significant decrease in SDNN within the normal clinical range

(141±39), however, there were no significant differences between the two groups (d=0.03; MD=1.11; 95% CI=−7.38 to 9.59; P=0.80).

.**Conclusions:** CIMI was an effective intervention for improving sleep disorders, as well as parts of psychological stress measures in distressed HCWs. The findings provide objective evidence for developing a mobile stress management intervention that is adaptable and accessible to distressed HCWs, but its long-term effects should be investigated in future research.

Trial Registration: ClinicalTrial.gov., NCT05239065; https://clinicaltrials.gov/ct2/show/NCT05239065.

KEYWORDS

Multimodal intervention; stress management; healthcare workers; perceived stress, autonomic nervous system

Introduction

As a result of shift schedules, night shift healthcare employees face multiple workplace stressors, including insufficient rest periods, an increased risk of sleep deprivation, and mood changes [1-3]. Work-related stress has been shown to have a negative impact on employees' physical health, including a greater likelihood of developing hypertension, the advancement of cardiovascular diseases, and all-cause and coronary heart disease mortality as measured by heart rate variability (HRV) [4-7]. The link between work-related stress and psychological distress is also well established [8], and according to a recent meta-analysis, the prevalence of depression, anxiety, and stress symptoms among healthcare workers (HCWs) was 24.3%, 25.8%, and 45.0%, respectively, which was higher than in other occupational populations [9]. Furthermore, HCWs who are under stress at work are more likely to experience sleep problems such as fatigue and sleepiness [10], which can jeopardize their job performance and patient safety.

During the past decade, numerous workplace-based stress management programs have been conducted in high-income countries and achieved a desired effect in improving the mental health and stress symptoms of staff [11, 12]. However, the stress management interventions remained scarce in low- and middle-income country context [11]. On the one hand, due to the frequent conflict between increased medical service demand and limited healthcare resources, HCWs in these countries experienced a higher level of work-related stress than their counterparts [13]. On the other hand, limited medical resources made it difficult for distressed HCWs to seek professional help, and the current treatment gap for mental disorders in developing countries is estimated to be 72%-93%, with those from the poorest countries receiving less coverage [14]. Therefore, it is imperative to take effective measures to assist distressed HCWs in these countries in reducing their work-related stress so that they do not suffer.

For the time being, several stress management techniques, such as regular physical activity, deep breathing, and mindfulness, have been recommended for occupational populations at workplace [15-17]. Building new stress management habits, however, may be difficult for HCWs, especially those with distress symptoms. Based on the findings of a recent mixed-methods study, while the majority of HCWs were aware of some of the stress effects and stress management methods, almost half of them fail to adopt stress management behaviors [18]. Individuals suffering from distress symptoms such as anxiety and depression may experience loneliness, isolation, and stigma, which can lead to stress coping failure and increased stress responses [19]. Besides, the long-term distress symptoms may diminish their self-efficacy and perceived social support, hinder them to take advantage of stress management [20]. It appears that a "stress-distress" vicious circle exists, preventing HCWs from putting stress management knowledge into practice [21]. As a result, it is critical to assist distressed HCWs in closing the "knowing-doing" gap and benefiting from stress management.

Knowledge translation is defined as a process that occurs through social and environmental interactions, and underlines that knowledge exchange must happen in an interacting social situation [22]. Among different theoretical frameworks that applied in knowledge translation research, the most popular makes reference to social learning theory (SLT) [23]. SLT emphasizes three main elements associated with human behaviors: environmental factors, personal factors, and behavioral factors [24], and only when environmental and individual factors interact synergically toward sustainability, knowledge can translate to the desired behavioral changes [25-27]. In light of the theoretical foundation outlined above, creating an interactive intervention context may help HCWs reap the most benefit from stress management and alleviate stress symptoms [28].

Internet can be considered ideal for creating an interactive context in stress management intervention. First, by introducing social learning via the internet, stressed individuals may be able to change their attitudes toward the treatment, such as feeling alone, isolated, or stigmatized [29]. Second, the online peer interaction can provide a supporting environment where participants may find and provide practical advice, as well as received social connection which may be lack in their daily life [30]. Third, the use of a mobile health device would enable participants to self-monitor and receive feedback on their performance and tension reduction, which could be beneficial for enhancing their stress management skills [31]. Fourth, human support and guidance provided by coaching may potentially alter individuals' self-efficacy belief in stress management [32, 33]. Besides, the high percentage of internet users suggests that it has potential applications in working populations: according to the most recent official report, China's internet penetration rate has reached 73.0%, and there are more than 1.32 billion netizens in China, 99.7% of whom access the internet via smartphones [34]. Therefore, mobile stress management intervention may be a adaptable and accessible approach for distressed healthcare workers.

In response to the aforementioned findings, a complex interactive multimodal intervention (CIMI) for distressed HCWs was developed. The CIMI consisted of four components: (1) mobile stress management education, (2) a web-based social network provided by a WeChat group, (3) individualized practice feedback, and (4) personalized support and guidance provided by a nurse-coach.

Objectives

Our primary objective was to figure out whether CIMI is more effective than self-guided stress management in improving the stress symptoms of distressed HCWs, as measured by physiological (HRV indicators), psychological (perceived stress, mental distress, and subjective happiness), and sleep disorders (fatigue and sleepiness).

Methods

Study Design

The trial was a cluster-based, non-randomized, parallel controlled study conducted in two hospitals in Wuhan from August 11, 2021, to January 31, 2022. In order to prevent data contamination, we employed a non-randomized study design in the present study. Hospital A participants received the

CIMI intervention, while hospital B participants received the self-guided stress management intervention.

Recruitment and Participants

All participants were recruited between August 11, 2021 and January 31, 2022. HCWs were eligible to participate if they (1) worked the night shift in hospital A or hospital B, (2) did not plan to leave their current position within the next 6 months, (3) did not have any serious clinical diagnoses that affected stress levels or follow-up quality (i.e., abnormal cardiac rhythm, heart disease including coronary artery disease, angina, and arrhythmia, cardiac pacemaker, stroke, panic attack, and cognitive impairment), and (4) had at least one sign of psychological distress measured by Depression, Anxiety, and Stress Scale (DASS-21) (i.e., the subscale of depression, anxiety, and stress was above 10 points, 7 points and 11 points) [35]. HCWs are excluded if they (1) were unwilling to complete the 3-month follow-up or (2) were unable to do exercise because of fractures or limb abnormalities, etc.

Although we intended to recruit participants with a good gender and age balance, the Coronavirus pandemic caused numerous difficulties during the recruiting process. As a result, the current study was unable to maintain a balanced age and gender distribution. In total, 661 participants completed the pre-screening questionnaires, and 245 of them were eligible for enrollment based on the inclusion and exclusion criteria. Participants from hospital-A (n=179) were assigned to the intervention group, and participants from hospital-B (n=66) to the control group. Five participants from the intervention group and eight from the control group dropped out of the study during the three-month study period due to personal reasons (**Fig. 1**). According to **Table 1**, 208 (84.9%) of the 245 participants were women, with a mean age of 33.7. In regard to educational background, 57 (23.3%) persons obtained graduate degrees. There were 85 doctors (23.7%) or other healthcare professionals and 160 nurses (65.3%) in terms of position. In respect to age, marital status, education, weekly working hours, and health status, the CIMI and control groups are comparable. In comparison to the control group, the CIMI group had a higher proportion of females (87.7% vs. 77.3%, p=0.043), worked for more than ten years (54.8% vs. 34.9%, p=0.006), and nurses (68.2% vs. 57.6%, $p = 0.003$).

Table 1 Baseline characteristics of the participants

Variables	Total (n = 245)	Intervention (n = 179)	Control (n = 66)	p value
Age, years[§†] Mean(SD)	33.7(0.3)	33.6(0.4)	33.9(0.7	0.67

		)		
≤35	165(67.3)	120(67.0)	45(68.2)	0.87
>35	80(32.7)	59(33.0)	21(31.8)	
Gender[†]				
Female	208(84.9)	157(87.7)	51(77.3)	0.04
Male	37(15.1)	22(12.3)	15(22.7)	
Marital status[†]				
Unmarried	70(28.6)	52(29.1)	18(27.3)	0.79
Married	175(71.4)	127(71)	48(72.7)	
Educational level[†]				
≤Undergraduate	188(76.7)	143(79.9)	45(68.2)	0.054
≥Postgraduate	57(23.3)	36(20.1)	21(31.8)	
Working experience, y[§]				
<10	124(50.6)	81(45.3)	43(65.2)	0.006
≥10	121(49.4)	98(54.8)	23(34.9)	
Role[†]				
Nurse	160(65.3)	122(68.2)	38(57.6)	
Physician	58(23.7)	33(18.4)	25(37.9)	0.003
Other healthcare workers	27(11)	24(13.4)	3(4.6)	
Weekly working hours[†]				
≤ 40	126(51.4)	91(50.8)	35(53)	0.76
> 40	119(48.6)	88(49.2)	31(47)	
Health status[†]				
Bad	54(22)	38(21.2)	16(24.2)	0.47
So-so	167(68.2)	121(67.6)	46(69.7)	
Good	24(9.8)	20(11.2)	4(6.1)	
Diagnosed disease[†]				
No	193(78.8)	141(78.8)	52(78.8)	0.998
Yes	52(21.2)	38(21.2)	14(21.2)	

Note: [†]Categorical variables; [§]continuous variables.

Power Calculation

The primary outcomes in our study are Perceived Stress Scale (PSS) scores and HRV measurements. As reported in a previous research [36], the PSS score decreased by 1.5 points after intervention in the control group. We hypothesized that PSS score in the CIMI group would decrease by an additional 2 points compared to the control group. Therefore, at least 60 participants per group was required to detect a difference between the two groups with 85% power, accounting for a 20% dropout rate and a significance level of 0.025.

Similarly, based on HRV indicators, the SDNN of the HRV indicator decreased by 5 ms^2 in the control group after intervention [37]. We assumed that the CIMI group will experience a greater reduction in SDNN by 2 ms^2 compared to the control group. Therefore, a minimum of 200 participants per group was required to detect a difference between the two groups with 85% power,

accounting for a 20% dropout rate and a significance level of 0.025. Therefore, we planned to recruit 200 participants in each group to ensure the detection of differences in both PSS and SDNN between the two groups.

However, the recruitment process was impeded due to the COVID-19 pressures, and we eventually enrolled 245 people who satisfied our inclusion criteria. Hence, the power calculation in the current study was determined via a post hoc analysis. According to our study, PSS scores fell by 1.28 points in the control group and 5.31 points in the CIMl group between the baseline and three months after the intervention, respectively. Therefore, taking into account a 2-sided significance level of 0.05, the sample sizes of 179 in the intervention group and of 66 in the control group would have more than 95% power to detect the significant difference between the two groups.

Procedure

First, a screening questionnaire about demographic characteristics (age, gender, martial status, educational level, working experience, role, working hours), health status, diagnosed disease, and the DASS-21 was sent to the potential participants. After screening, all eligible participants were required to complete a detailed baseline questionnaire and wear a 24-hour Holter device to assess the physiological indicators of stress as indexed by HRV. The day of HRV recording was selected as at least 48 hours after a night shift to ensure enough rest prior to recording. Furthermore, a sport wristband and corresponding use method were given to each participant, and participants were also asked to upload their exercise data from their wristbands to a research APP on a daily basis. The research APP only acted as a recording application which tracked daily information related to exercise, such as daily exercise time, consumed calories, step counts, instead of providing any interaction between participants and researchers. In addition, a printed brochure was distributed to both the CIMI and control groups to teach them how to use three types of stress management techniques (i.e., regular physical activity, deep breathing, and mindfulness) (**Supplementary File 1**).

During the 12-week intervention, the CIMI group were required to complete a weekly online questionnaire which contained four sections: daily life stressors, stress management practices, psychological symptoms, and sleep quantity and quality (**Supplementary File 2**). The questionnaire was sent to each participant's mailbox, and the nurse coach was responsible for checking and ensuring the completion of the questionnaire, as well as reminding participants if they were unable to complete it within three days of receiving it. To keep contact between researchers and participants to

a minimum, the control group only needed to complete the online questionnaire biweekly. All questionnaire data was collected using the Research Electronic Data Capture (REDCap) platform.

Intervention

Participants in the CIMI group received a 12-week online intervention with the following four components: mobile stress management education, a web-based WeChat social network, tailored feedback, and a nurse-coach.

Mobile stress management education

Participants in the CIMI group were invited to join the Wechat group anonymously. A professional nurse coach delivered the evidence-based course about stress through a WeChat group every weekend for 12 weeks. In addition, three evidence-based SMS (physical activity, deep breathing, and mindfulness) were introduced during every course, and to ensure participants practiced those SMS appropriately, each participant received a package of instructional videos to guide them through the practices' techniques.

Web-based WeChat social network

During each course through the WeChat group, a 30-minute online discussion session was scheduled. During the discussion, participants were invited to answer several questions about stress management and encouraged to share their photos or videos that recorded their SMS practice over the past week.

Tailored feedback

The weekly and monthly summary reports on the stress symptoms and SMS performance were sent to the participants through email. The summary reports were developed by the research group based on the uploaded research APP data from the wristbands and the weekly questionnaires completed by the participants.

Nurse coach

The nurse coach would help participants whenever needed to: (1) ensure their proper use of portable devices and continuous participation in the program; (2) evaluate their practice performance and

identify possible barriers to practicing SMS and further give specific instructions; and (3) support HCWs and encourage them to practice SMS continuously during the intervention.

Control group

The control group received the same wristband and research app, as well as instructions to ensure that they used the wristbands correctly. Participants in the control group were asked to fill out a brief online questionnaire every two weeks and upload their exercise data from the wristbands daily, but they would not receive the four components of intervention mentioned above.

Outcomes

Primary outcome

Perceived stress

PSS-14 is a globally used 14-item scale that has been translated and validated in the Chinese population to measure the level of perceived stress [38]. The PSS-14 used a five-point Likert scale, and each item was scored from 0 to 4. The total score ranges from 0 to 56, with higher total scores indicating a higher level of stress [39]. The Cronbach alpha was 0.835, demonstrating that the PSS-14 was a reliable instrument to measure the participants' perceived stress in this study.

Heart rate variability

HRV is a common tool for assessing autonomic nervous system (ANS) function, and it reflects the balance of the cardiovascular system controlled by the sympathetic and parasympathetic nerves of the ANS [40]. The research and clinical device (DMS300-4, Diagnostic Monitoring Software, NV, USA) had an internal sampling rate of 4,096 Hz, and the R-peaks were automatically detected with a precision of < 1 ms. In the present study, the standard deviation of all normal NN intervals (SDNN), which is the most frequently employed time domain measure of HRV, was used to assess physiological measures of stress [41, 42]. The power spectrum of heart rate variability was calculated by fast Fourier transform (FFT) and expressed by ms^2 power spectrum density [41]. To avoid signal quality issues from biological (ectopic beats, arrhythmia, etc.) or technological (movement, signal interference, etc.) sources, all ECG files were manually edited for detection by trained biomedical analysts. Values with differences greater than 20% were considered artifacts, and the interpolation of degree zero was used for the artifact.

Secondary outcomes

Mental distress

DASS-21 is a well-developed instrument used in the Chinese population for assessing the negative emotions of individuals in the past week [43]. The 21-item scale can be clustered into 3 subscales, and each subscale is rated on a 4-point Likert scale. The sum score of each subscale is multiplied by two and ranges from 0 to 42, with a higher score representing greater emotional health. The Cronbach alpha was 0.877, 0.872, and 0.805 for the depression subscale, anxiety subscale, and stress subscale, respectively, indicating excellent reliability for this scale in measuring emotional health in this study.

Subjective happiness

The subjective happiness scale (SHS) was used to assess the global subjective happiness of participants. SHS consists of 4 items, and each item is rated on a 7-point Likert scale ranging from 1 to 7. Responses on this scale were summed and divided by 4, with higher scores indicating more happiness. The SHS has been utilized and validated in Chinese adults [44]. The Cronbach alpha was 0.683 for SHS, demonstrating the reliability of this scale is acceptable in this study.

Fatigue symptoms

The fatigue assessment scale (FAS) is a widely used fatigue measure that includes 10 items rated on a 5-point Likert scale. This scale has been tested extensively on healthcare workers and demonstrated to have reliability and validity for measuring fatigue and to be free of gender bias [45]. The Cronbach alpha for FAS was 0.883, indicating that the internal reliability of this scale was quite satisfactory in this study.

Sleepiness

The Epworth sleepiness scale (ESS) is a useful tool for evaluating daytime sleepiness in both the general population and shift workers [46]. This scale consists of 8 items, and each item is rated on a 4-point Likert scale. The Cronbach alpha for the ESS was 0.768, confirming that this scale is reliable to measure sleepiness in this study.

Statistical analysis

The analysis was conducted according to the intent-to-treat principle. Continuous variables were described by mean (standard deviation), median (interquartile range), and categorical variables were represented by frequency (percentage). Baseline characteristics were compared between groups using the 2-sample t test for normally distributed continuous variables, nonparametric Wilcoxon rank sum tests for non-normally distributed variables, and the Chi-Quest test for categorical variables. A linear mixed-effects regression model with random intercepts was fitted for each primary and secondary outcome. A two-way interaction between the groups (control vs. intervention) and time (baseline vs. post-intervention) was modeled using restricted maximum likelihood with the Kenward-Roger denominator degrees of freedom. As proposed by the JBI's checklist for quasi-experimental studies (non-randomized experimental studies), the disparities between participants in compared groups pose a risk to the internal validity of a study investigating causal linkages. Furthermore, as indicated by two publications published in JMIR[reference], the authors also emphasized the significance of managing confounding variables to guarantee the comparability of the intervention and control groups. Therefore, in our statistical analysis approach, we included the age, sex, marital status, education level, working experience, occupation, weekly working hours, health status, and diagnosed disease as covariates in each model , to guarantee that the impact size can be fully attributed to our intervention and not influenced by other factors.

A post-hoc exploratory subgroup analysis was performed to detect the influence of age, sex, marital status, education level, working experience, occupation, and weekly working hours through adding the three-way interaction including group, time point, and subgroup variable into the model, respectively. The adjusted mean difference with 95% CI (confidence intervals) from baseline to post-intervention for the CIMI group and the control group separately, and the between-group adjusted mean difference with 95% CI from baseline to post-intervention were obtained from the linear mixed-effects regression. We used Cohen's d as the standardized effect size, which is considered small (0.2), medium (0.5), or large (0.8), and the Cohen's d was calculated with the between group adjusted mean difference divided by the standard deviations at baseline. The missing values of the outcomes were handled in the mixed-effects models. All analyses were performed by the Stata 15.1 software (StataCorp LLC) at a two-sided α level of 0.05.

Ethical Considerations

The study was approved by the Institutional Review Board of Tongji Medical College, Huazhong University of Science and Technology (IRB#2021S141). Before participating in the study, all participants provided informed consent in writing. All study data were deidentified to ensure participants' privacy and confidentiality. A complimentary cardiovascular assessment for a close relative was given to research participants who completed the program, while no monetary rewards were offered.

Results

Primary outcome

As shown in **Table 2**, the PSS scores,reduced significantly in the CIMI group (MD=–5.31; 95% CI=–6.26 to –4.37; P<0.001) after intervention as compared with the baseline levels, while the PSS scores of the control group remained largely unaltered (MD=–1.28; 95% CI=–2.91 to 0.34; P=0.12). The changes in PSS scores before and after interventions exhibited a significant difference between the CIMI and control groups (d=-0.64; MD=–4.03; 95% CI=–5.91 to –2.14; P<0.001), and the effect was medium.

In terms of physiological measures, both the control group (MD=-9.56; 95% CI = -16.9 to -2.2; P=0.01) and the CIMI (MD =-8.45; 95% CI =-12.68 to -4.22; P<0.001) demonstrated a significant decrease in SDNN within the normal clinical range (141±39). In terms of the changes, there were no significant differences between the two groups (d=0.03; MD=1.11; 95% CI=–7.38 to 9.59; P=0.80).

Secondary outcome

From baseline to post-intervention, the depression score of the CIMI group decreased by 3.53 points more than that of the control group (95%CI=-5.57 to -1.48, P=0.001, d=-0.48), and the stress score decreased by 4.25 points more than that of the control group (95%CI =-6.46 to -2.03, P<0.001, d=-0.64). Nevertheless, the anxiety score increased significantly in the control group (95% CI=1.97 to 5.59, P<0.001), whereas that did not change significantly in the CIMI group (95% CI=-0.85 to 1.26, P=0.70). As compared with the control group, the CIMI group had statistically significant decreases in fatigue symptoms (MD: -2.48, 95%CI: -4.07 to -0.89, P=0.002, d=-0.47) and daytime sleepiness (MD: -1.31, 95%CI: -2.39 to -0.24, P=0.02, d=-0.35), in addition to a significant increase in subjective happiness (MD: 0.38, 95%CI: 0.14 to 0.63, P=0.002, d=0.47), before and after the intervention (**Table 2**). Overall, the CIMI group had a medium effect on improving depression, stress, fatigue, and promoting subjective happiness, a small effect on improving sleepiness.

Table 2 Estimations of adjusted mean differences and effect sizes for stress indicators (linear mixed model)

	Control group				Intervention group				Between group		
	Baseline (M±SD)	Post-intervention (M±SD)	Change from baseline, Adjusted MD (95% CI)[a]	P value	Baseline (M±SD)	Post-intervention (M±SD)	Change from baseline, Adjusted MD(95% CI)[a]	P value	Change from baseline, Adjusted MD (95% CI)[b]	P value	Cohen's d (95% CI)
Physiological indicators											
SDNN[ʃ]	156.7(35.2)	145.7(34.6)	-9.56(-16.9 to -2.22)	0.01	156.8(32.5)	147(32.6)	-8.45(-12.68 to -4.22)	<0.001	1.11(-7.38 to 9.59)	0.80	0.03(-0.25 to 0.32)
Psychological indicators											
PSS	30.7(7.0)	29.2(5.5)	-1.28(-2.91 to 0.34)	0.12	31.6(6.3)	26.4(6.3)	-5.31(-6.26 to -4.37)	<0.001	-4.03(-5.91 to -2.14)	<0.001	-0.64(-0.93 to -0.36)
DASS-D	11.4(5.7)	10.3(6.2)	-0.97(-2.74 to 0.79)	0.28	13.3(8.0)	8.8(6.8)	-4.5(-5.52 to -3.47)	<0.001	-3.53(-5.57 to -1.48)	0.001	-0.48(-0.77 to -0.19)
DASS-A	10.9(5.6)	14.6(6.6)	3.78(1.97 to 5.59)	<0.001	13.2(6.3)	13.4(6.8)	0.21(-0.85 to 1.26)	0.70	-3.57(-5.67 to -1.47)	0.001	-0.60(-0.88 to -0.31)
DASS-S	16.3(6.4)	10.2(6.3)	-6.09(-8.0 to -4.17)	<0.001	19.6(6.8)	9.3(5.9)	-10.33(-11.45 to -9.22)	<0.001	-4.25(-6.46 to -2.03)	<0.001	-0.64(-0.93 to -0.36)
SHS	3.7(0.7)	4(0.8)	0.26(0.05 to 0.47)	0.02	3.7(0.9)	4.3(1)	0.64(0.52 to 0.76)	<0.000	0.38(0.14 to 0.63)	0.002	0.47 (0.18

											to 0.75)
				1							

Sleep indicators

ESS	7.6(3.2)	7.9(4.3)	0.5(-0.43 to 1.42)	0.29	8.7(3.9)	7.8(4)	-0.81(-1.35 to -0.28)	0.003	-1.31(-2.39 to -0.24)	0.02	-0.35(-0.64 to -0.07)
FAS	29.3(4.8)	27(4.8)	-2.04(-3.42 to -0.67)	0.004	30.8(5.6)	26.3(6.3)	-4.52(-5.32 to -3.72)	<0.0001	-2.48(-4.07 to -0.89)	0.002	-0.47(-0.75 to -0.18)

Note: M: Mean; SD: Standard Deviation; MD: Mean Difference; PSS: Perceived Stress Scale; DASS: Depression, Anxiety, and Stress Scale; ESS: Epworth Sleepiness Scale; FAS: Fatigue Assessment Scale; SHS: Subjective Happiness Scale: SDNN: Standard Deviation of Normal-to-Normal Interval; RMSSD: Mean Squared Differences of successive Normal-to-Normal intervals; HF: High Frequency; LF: Low Frequency; TP: total spectral power.

[a] Change from baseline to post-intervention for intervention group and control group respectively.

[b] Mean difference of change from baseline to post-intervention between intervention group and control group.

[f] The normal clinical range of SDNN was 141±39.

Subgroup analysis

Subgroup analyses of the PSS score were conducted based on the age, sex, marital status, education levels, working experience, occupation, and weekly working hours of the participants. As shown in **Fig. 2**, the effect sizes between the CIMI group and the control group were statistically better in males than females, better in doctors than nurses, and higher in postgraduate degree participants than bachelor degree participants (interaction p values for sex=0.004, p values for occupation=0.005, and p values for education=0.005). And there was no statistically significant difference in the effect sizes between the CIMI group and the control group by age, marital status, working experience, or weekly working hours subgroups (interaction p values were 0.92, 0.71, 0.22, and 0.09, respectively).

Discussion

The current study found that, with the exception of anxiety symptoms, most psychological markers significantly improved more in the CIMI group following a 12-week intervention than in the self-guided group. When it came to alleviating sleep disorders, CIMI was more effective in reducing fatigue and sleepiness. Regarding physiological indications, heart rate variability decreased in both groups but stayed within the range that is considered clinically normal. Overall, the CIMI was found to be effective for improving psychological indicators and sleep symptoms in HCWs, but not in physiological stress indicators.

To the best of our knowledge, despite the fact that numerous stress management interventions have been implemented in workplaces, none of them have been specifically designed for distressed HCWs. As previously stated, developing stress management behaviors would be difficult for HCWs with distress symptoms even if they were aware of the effects of stress and coping strategies. Hence, we developed a complex interactive multimodal intervention based on knowledge translation theory

[22] and social learning theory [24] to bridge the "knowing-doing" gap in stress management among distressed HCWs. The CIMI specifically created an interactive context with the goal of changing the HCWs' negative attitudes and skills through mobile stress management education, a web-based WeChat social network, tailored feedback, and a nurse-coach. The current study compared the effects of the CIMI and self-guided groups on stress symptoms using physiological, psychological, and sleep disorders.

In terms of physiological indicators of stress, SDNN is a common HRV metric that represents the NN standard deviation. SDNN may drop significantly in disorders such as myocardial infarction, indicating collisions with HRV. Under physiological settings, SDNN swings within a particular range, with a normal SDNN of 141 ± 39 ms^2 [37, 44, 45]. Both the intervention and control groups showed isotropic changes in SDNN before and after intervention. There was no statistical difference between the two groups. This suggests that CIMI is primarily concerned with improving subjective markers.

In aspects of psychological stress measures, CIMI was significantly more effective in improving depression and stress symptoms and elevating the subjective happiness of HCWs. However, we found that the anxiety symptoms in the control group exaggerated significantly from baseline to post-intervention, while there were no significant changes in anxiety symptoms in the intervention group. That means, the effect of CIMI on alleviating anxiety was still unclear. Furthermore, we found that the CIMI helped improve daytime sleepiness and fatigue symptoms significantly. In a word, the CIMI was found to be significantly more effective than the control group in improving both psychological and sleep indicators of stress, as well as parts of psychological stress measures. Although previous research found that human support was more effective than self-guided mobile interventions, the majority of studies did not directly compare self-guided and human support e-therapy [47]. Therefore, the

current study provided objective evidence of the effect of CIMI, a novel human

support intervention, on alleviating stress symptoms among distressed HCWs.

To explore if our intervention effects varied between participants with different

demographic characteristics, we further performed a subgroup analysis. We found that

educational level, gender, and occupation may all influence treatment effects of the

CIMI. Participants with postgraduate degrees benefited from the intervention more

than those with graduate degrees. This finding was consistent with previous research,

which found that highly educated participants were more likely to engage in health-

promoting behaviors and use interventions more effectively [48, 49]. This could be

explained by the fact that those with higher educational levels also tend to have higher

socioeconomic status, allowing them to better protect themselves from the risk of

poor mental health [50]. Thus, future research should consider how to assist

participants with lower educational levels in making better use of interventions.

Besides, we found that men benefited more from the interventions than women, which

was in consistent with prior studies. This may be explained by the fact that women are

more likely to assume more family duties, thus they are less likely to have spare time

to practice the recommended stress management techniques [51]. Hence, future

research should consider how to help female HCWs to get support from families so

that they can spend enough time on stress management. Interestingly, we discovered

that occupation influenced treatment effects, with physicians benefiting from

interventions more than nurses. The findings were similar to those of Yildirim et al.,

who identified that physicians exercised more than nurses and had a higher quality of

life. [52]. Given that nurses face more barriers to adopting health-promoting

behaviors and have higher levels of work stress [53], future interventions may need to

target this population in order to successfully manage their stress.

Overall, the current study found that CIMI was more effective than self-guided stress

management in distressed HCWs. The design's uniqueness stems from the

combination of multiple interventions and target populations. Integration of all

elements into a computerized program allowing interactive crosstalk with participants could be a future CIMI modification [54, 55]. It would save labor while also increasing the acceptance of interventions among distressed occupational populations.

Limitations

This study has several limitations that should be mentioned. First, the controlled, non-randomized design may bias estimates of treatment effects and cause the uncertainty of our findings. As a result, future studies can consider using randomized controlled trials to investigate our findings. Second, because of the Coronavirus pandemic, we failed to balance gender and age balance during our recruitment process. To avoid any bias caused by demographic characteristics, Cohen's d effect was calculated by dividing the between-group adjusted mean difference by the standard deviations at baseline in the present study. Third, since our study only tested the effectiveness of CIMI over a three-month period, it was unclear how long its effects would last. As a result, more research into the long-term effects of human assistance intervention is needed. Last but not least, we recognized that we might not have been able to detect the significant effect of the CIMI on improving HRV measures since we hadn't been sure that our sample size complied with the requirements for HRV indicators. Therefore, we recommended that future studies examine the influence of CIMI on HRV markers using a larger sample size.

Conclusions

In the current study, we discovered that CIMI was effective at alleviating stress symptoms in distressed HCWs. The current study's findings may provide objective evidence for the development of an effective mobile stress management intervention for distressed HCWs. Given that the current study was a non-randomized controlled trial that lasted three months among distressed HCWs, future research may consider investigating the long-term effects of CIMI using a randomized controlled trial design.

Data Availability

The data supporting the findings of the study are accessible from the corresponding author upon reasonable request.

Conflict of Interests

All authors state that there is no conflict of interest.

Authors Contributions

WW, FFD, WHL, QW, and DLZ oversaw the study's design and paper preparation. WW, FFD, JHM, JJL, and GHC helped develop the study protocol and manage the study. FFD, WHL, QW, and DLZ oversee data science integration. All authors read and approved the final manuscript.

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Supplementary Files

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URL: http://asset.jmir.pub/assets/5e08b77ae13de330fa4ba8a01dc4ec30.docx

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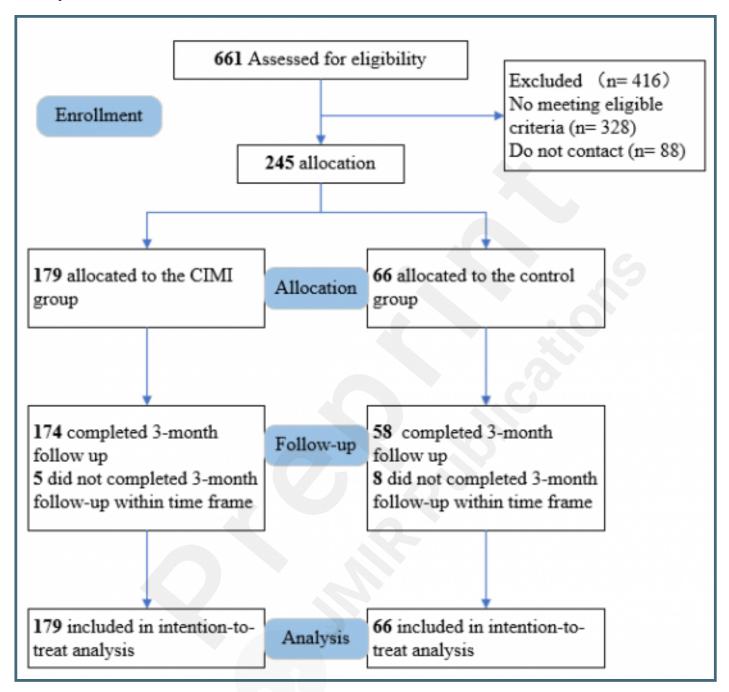URL: http://asset.jmir.pub/assets/e6982bc526c0117effd7f7522cc4c2b8.docx

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Figures

Participants flow.

661 Assessed for eligibility

Enrollment

Excluded （n= 416)
No meeting eligible
criteria (n= 328)
Do not contact (n= 88)

245 allocation

179 allocated to the CIMI group   Allocation   66 allocated to the control group

174 completed 3-month follow up
5 did not completed 3-month follow-up within time frame   Follow-up   58 completed 3-month follow up
8 did not completed 3-month follow-up within time frame

179 included in intention-to-treat analysis   Analysis   66 included in intention-to-treat analysis

Subgroup analysis to detect the influence of demographic factors on treatment effects.

Subgroup	MD(95%CI)		P value
Age, y			
≤35	-3.97(-6.26 to -1.68)		0.923
>35	-4.17(-7.51 to -0.83)		
Sex			
Male	-9.64(-13.8 to -5.47)		0.004
Female	-2.65(-4.76 to -0.54)		
Marital status			
Married	-3.79(-5.99 to -1.58)		0.71
Unmarried	-4.58(-8.14 to -1.02)		
Educational level			
≤Undergraduate	-2.62(-4.83 to -0.4)		0.005
≥Postgraduate	-8.49(-11.9 to -5.08)		
Occupation			
Nurse	-2.13(-4.53 to 0.26)		0.009
Physician	-7.71(-11.15 to -4.28)		
Working experience, y			
<10	-5.42(-7.83 to -3.02)		0.215
≥10	-2.94(-6.04 to 0.15)		
Weekly working hours			
≤40h	-2.52(-5.1 to 0.07)		0.094
>40h	-5.73(-8.45 to -3.01)		

MD(95%CI)

CIMI better   Control better