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Use of video-based telehealth services using a mobile app for workers in underserved areas during the COVID-19 pandemic: A prospective observational study

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ABSTRACT

Background: The COVID-19 pandemic has limited face-to-face treatment, triggering a change in the structure of existing healthcare services. Unlike other groups, workers in underserved areas have relatively poor access to healthcare.

Objective: This study aimed to investigate the effects of video-based telehealth services using a mobile personal health record (PHR) app for vulnerable workers with metabolic risk factors.

Methods: A prospective observational study was conducted with 117 participants and 27 healthcare professionals for 16 weeks. Participants visited the research institution three times (at weeks 1, 8, and 16) and underwent health check-ups and used various features of the mobile PHR app. Healthcare professionals observed the participants's data using the monitoring system and performed appropriate interventions. The primary outcome measures were to evaluate the effects of services on changes in the participants' metabolic risk factors, and secondary outcome measures were to analyze changes in the participants' lifestyle and service satisfaction, and to observe service use through usage logs. One-way repeated measures ANOVA and Scheffé's test were performed to observe changes in participants' health status and lifestyle, and a paired *t*-test was performed to analyze changes in service satisfaction. Finally, in-depth interviews with healthcare professionals were performed using semi-structured questionnaires to understand service providers' perspectives after the end of the study.

Results: Systolic blood pressure ($F = 7.32$, $P < .001$), diastolic blood pressure ($F = 11.30$, $P < .001$), body weight ($F = 29.53$, $P < .001$), BMI ($F = 17.31$, $P < .001$), waist circumference ($F = 17.33$, $P < .001$), fasting blood glucose ($F = 5.11$, $P = .007$), and triglycerides ($F = 4.66$, $P = .01$) showed significant improvements with time points, whereas high-density lipoprotein cholesterol ($F = 3.35$, $P = .067$) did not. The dietary score ($F = 3.26$, $P = .04$) showed a significant improvement with time points, whereas physical activity ($F = 1.06$, $P = .34$) did not. In terms of service satisfaction, only lifestyle improvement ($P < .001$) showed a significant difference. COVID-19 has affected the performance of healthcare professionals, thereby changing the perspectives toward healthcare technology services.

Conclusions: We evaluated the effectiveness of video-based telehealth services supporting workers' health status and lifestyle interventions using healthcare technologies such as the mobile PHR app, tele-monitoring, and video teleconsultation. Our results indicate that as a complementary means, its utility can be expanded in the field of occupational safety and health to overcome the limitations of face-to-face treatment due to COVID-19 in the future.

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1. Introduction

1.1. Background

Metabolic syndrome refers to a state of having any three of the following health conditions: abdominal obesity, high blood pressure, impaired fasting blood glucose, high triglycerides, and low high-density lipoprotein (HDL) cholesterol due to chronic metabolic disorders [1]. The prevalence of metabolic syndrome in adults has been reported as 20 %–25 % in most countries [2,3], and 34 % in the United States [4]. The National Health and Nutrition Examination Survey found that rates of metabolic syndrome in Koreans have risen over 10 years, with a prevalence of 28.8 % in adults aged over 30 [5]. Metabolic syndrome is a risk factor for cardiovascular disease and diabetes; the risk of diabetes is five times higher and of cardiovascular disease is approximately 60 % higher than in healthy controls [6,7]. Cardiovascular disease has a high mortality rate [8], accounting for 37.2 % of occupational disease deaths. Managing metabolic syndrome is important for delaying or preventing chronic disease onset. Cardiovascular disease and diabetes can be prevented through early diagnosis of risk factors for metabolic syndrome and by improving lifestyle choices (eating habits, physical activity, smoking, drinking, etc.) [9]. Considering the difficulties in maintaining or improving lifestyle habits [10], mobile interventions can be more beneficial than traditional face-to-face counseling by regularly providing personalized health information [11]. Continuous and frequent interventions can improve physical activity, dietary changes, and weight loss [12]. The American Heart Association recommends lifestyle improvement using mHealth (a specific mobile application) as an effective intervention for cardiovascular disease [13]. Interventions using mHealth facilitate losing weight, increasing physical activity, smoking cessation, and reducing anxiety [14–18].

Compared to the general public, workers are more exposed to risks due to bad lifestyle habits, such as stress caused by heavy work, lack of exercise, and frequent drinking [19]. Companies are increasingly interested in improving workers' health and welfare to improve their productivity and reduce direct or indirect costs [20–22]. Global companies, including Amazon [23], have provided workers with healthcare services by using technology. Unlike large-scale workplaces, small-scale workplaces with under 50 employees are disadvantaged and often do not receive systematic occupational health services [24,25]. About 81 % of accidents in Korea and 68 % of deaths from cardiovascular disease occur in workplaces with under 50 employees [8]. In Korea, such workplaces account for 98 % of all workplaces, and employ 50 % of all workers [8]. To fundamentally prevent occupational diseases and industrial accidents, small businesses need access to healthcare services. In 2011, the Republic of Korea established occupational health centers for workers in small-scale workplaces [26]. Occupational health centers are community institutions in Korea that provide services to prevent occupational diseases among workers in industrial parks (incorporating various industries, including manufacturing plants and factories). Currently, there are 23 centers in operation [27]. Each institution comprises healthcare professionals, such as occupational and environmental medicine specialists, occupational nurses, industrial hygiene safety engineers, physical therapists, and counseling psychologists, who provide comprehensive occupational health services, including those pertaining to occupational, cerebrovascular, and musculoskeletal disease prevention and job stress prevention. Similar to a workplace infirmary, all workers can visit their nearest center and use its services free of charge. After establishing a national infrastructure [28], operation of various healthcare services is being supported by using healthcare technology to manage workers' health, using the occupation health center systematically and efficiently.

Extant studies have mostly evaluated the effectiveness of healthcare services using mobile personal health record (PHR) apps [29–32], mHealth [33,34], and mobile telemedicine [35,36] through randomized controlled studies with outpatients. Workers have difficulty visiting medical institutions during working hours; workers at workplaces with under 50 employees are particularly overlooked by the medical system. Telemedicine can overcome these barriers. For example, workers can receive services from organizations through video teleconsultation at a convenient time and place [37]. Video teleconsultation showed comparable results to face-to-face treatment [38,39] and high satisfaction levels among patients and medical staff [39–42]. Recently, video teleconsultations have increased in number dramatically because of the COVID-19 pandemic [43]. The transition to video teleconsultation can make it easy to use healthcare services if the population in underserved areas has sufficient technology access and user experience [44]. Technology literacy and language capacity can determine the responsiveness [44] and interactive engagement [45,46] using mHealth. Developing a successful service requires identifying the influencing technological (mobile apps and wearable devices) and cultural (such as geography, gender, age, and education) factors. For example, Since the elderly are least likely to use telemedicine due to their low technical proficiency, healthcare software for telemedicine should be user-friendly [47].

To restrict the spread of COVID-19, social distancing has become essential [48]. Restrictions on visiting public places [49] and face-to-face treatment due to social distancing temporarily delayed access and delivery of existing healthcare services [50,51], greatly affecting workers in small-scale workplaces. Recently, companies have implemented work-from-home as a response to COVID-19. Work-from-home, although beneficial from economic and environmental standpoints [52,53] and suitable for unpredictable situations such as COVID-19 [54,55], poses occupational health risks, including weight gain, anxiety, sleep disturbances, and musculoskeletal problems [56]. There is a need to provide teleconsultation to workers to mitigate the negative impact of quarantine due to COVID-19. Many organizations have urgently built infrastructures to provide teleconsultation, and those that do not have the means to do so used other organizations' services (Telegram, FaceTime, Skype, etc.). Conversely, Occupational health centers have been operating video teleconsultation services for many years [28], and workers use mobile PHR apps [57,58] to manage their health information. We developed a video-based telehealth service using existing infrastructure and solutions (worker health management system and mobile PHR app) to expand workers' occupational health coverage. In particular, the mobile PHR app considers the user's perspective using the human-centered design (HCD) methodology and acquires data using various devices (*e.g.*, smartphone sensors, wearable bands, blood pressure monitors, blood glucose meters, and scales) and integrates these data with high-quality health information collected from various sources. This solves the inconvenience of having to manually input data [59] and improves data quality [60], which is a major challenges of PHR. In addition, the major barrier (participating in consultation based on meeting ID at the appointed time) to entry for elderly workers and healthcare professionals in the telemedicine process [61] is resolved by utilizing technologies such as Web-RTC, Single Sign-On, and Firebase to minimize difficulties in the process of creating and entering a video conference room.

1.2. Study objectives

This study evaluated the effectiveness of video-based telehealth services using a mobile PHR app for vulnerable workers with metabolic risk factors. The objectives were: (1) identify effects of the intervention on changes in workers' metabolic risk factors, (2) examine changes in workers' lifestyle and service satisfaction, (3) analyze workers' usage logs to observe service patterns, and (4) identify healthcare professionals' perceptions and impressions of the intervention.

2. Methods

2.1. Study design

After receiving ethical approval (IRB No. 2021–05-016–001) from the Clinical Trial Review Committee of Kyungpook National University Hospital, we conducted a prospective observational study on video-based telehealth service using a mobile PHR app for workers who visited the occupational health center. For the study, 10 of the 23 centers that volunteered to participate by June 17, 2021, were selected as research institutes. Among the service providers working in the selected research institutions, 27 personnel who wanted to participate were selected as healthcare professionals (occupational and environmental medicine specialists, occupational nurses, physical therapists, and counseling psychologists).

Preliminary participants were recruited offline using posters from June 23 to July 9, 2021, based on the following criteria: (1) aged ≥ 19; (2) with one or more metabolic risk factors; (3) not taking drugs or receiving treatment for diseases such as high blood pressure and diabetes; and (4) able to use the mobile PHR app. Those who were informed about the background and purpose of this study and provided written consent were selected as the final participants. The estimated total sample size for the one-way repeated measures analysis of variance (ANOVA) using G-Power 3.15 was 116 (Cohen d = 0.15, alpha level = 0.05, desired power = 0.95, number of measurements = 3, correlation = 0.5). Considering a dropout rate of 20 %, we aimed to recruit 139 participants. Participants were provided with a user manual and taught to use the mobile PHR app to connect with healthcare professionals at the research institute.

This study was conducted for approximately 16 weeks from July 12 to October 27, 2021. Participants visited the occupational health center at least three times (at weeks 1, 8, and 16), and their body measurements, blood tests, and personalized healthcare counseling were conducted; subsequently, they undertook a survey. They also participated in the health promotion program operated by the research institution through the mobile PHR app and engaged in video teleconsultation over five times during the study. They were encouraged to use the different features of the mobile PHR app, and healthcare professionals used the monitoring system to observe the data and ensured appropriate interventions and teleconsultation. Moreover, they monitored and encouraged participants to continue study participation. After the completion of the study, in-depth interviews were conducted with the healthcare professionals. Workers and healthcare professionals participating in this study were given incentives for completing the study.

2.2. Intervention

Informed by previous studies [28,57,58], we developed and have supported a healthcare service for workers using healthcare technology. The mobile PHR app (Supplemental Material 1) can manage users' lifelogs and various health information (examination results, medical history, prescription history, etc.) in one place and provide personalized healthcare services through links with specific systems and platforms. For example, workers can collect test results and consultation records stored in national occupational health centers, add them to their PHR, and receive text-based counseling or video teleconsultation services from healthcare professionals. Personal information is encrypted and decrypted in the mobile PHR app by applying ARIA256 and SHA256, and user authentication and authorization are checked from the authentication server through OAuth 2.0.

The worker health management system is a standardized national system supporting the work of national occupational health centers and health zones and integrating data from scattered workplaces and workers. Institutions can systematically manage workers' test results, consultation records, and follow-up management data. A subsystem (Supplemental Material 2) monitors mobile PHR app users. Healthcare professionals can check the PHR of authorized workers and send advice or content necessary for health promotion. In addition, it is possible to provide feedback after checking the content of inquiries from workers or conducting video teleconsultation sessions by using web real-time communications (Web-RTC). This study utilized the mobile PHR and subsystem to provide participants with personalized healthcare counseling (interpretation of health information, cerebrovascular disease, musculoskeletal disease, job stress, and lifestyle) once a week through video or chatting.

2.3. Primary outcome measures

This study's primary outcome measures were changes in systolic and diastolic blood pressure, body weight, body mass index (BMI), waist circumference, fasting blood glucose, triglyceride, and HDL cholesterol levels at week 16. At weeks 1, 8, and 16, the health status of participants who visited the research institution was measured by a healthcare professional and recorded in the system. A blood pressure monitor (OMRON Co., Ltd.), body composition analyzer (InBody Co., Ltd.), blood glucose meter (SD Biosensor, Inc), and cholesterol meter (SD Biosensor, Inc) installed in the research institution were used for testing.

2.4. Secondary outcome measures

2.4.1. Lifestyle and service satisfaction

We used a structured questionnaire comprising 7 items about physical activity (frequency and amount of exercise per week) and 8 items about eating habits, to observe changes in participants' lifestyles over 16 weeks. Data were collected through a questionnaire of participants who visited the research institution every week (i.e., 1, 8, and 16). At weeks 8 and 16, five items were added to ask about service satisfaction. Each item was rated on a five-point Likert scale ranging from "strongly disagree" to "strongly agree" (Supplemental Material 3).

2.4.2. Usage data

We collected anonymous logs for participants for week 16 to analyze (1) the frequency and trend of logins and main features and (2) the proportion of use of PHR-related features.

2.5. Data collection

To evaluate the effectiveness of the video-based telehealth service, we collected body measurements, blood tests, and survey data from participants at the research institute, who measured their health status three times (at weeks 1, 8, and 16) using the test equipment according to the established protocol. The in-depth interviews with 27 healthcare professionals used semi-structured questionnaires and lasted 40–50 min; additional interviews were conducted as required. The content was transcribed after obtaining the professionals' consent and analyzed for service evaluation. The questions were as follows:

- How has COVID-19 affected occupational health services for workers?
- From a healthcare professional's viewpoint, what do you think of telehealth services in response to COVID-19?
- What are the relative advantages of video-based telehealth using the mobile PHR app over existing healthcare services?
- What were workers' reactions to the video-based telehealth service using the mobile PHR app?

2.6. Data analysis

Frequency analysis was performed to analyze participants' general characteristics. One-way repeated measures ANOVA and Scheffé's test were performed to observe changes in participants' health status and lifestyle at weeks 1, 8, and 16. A paired *t*-test was performed to analyze changes in participants' service satisfaction at weeks 8 and 16. $P<.05$ was considered statistically significant. Analyses were performed using IBM SPSS Statistics ver. 25.0 (IBM Corp, Armonk, NY, USA).

To analyze qualitative data, summative content analysis was used. After reviewing the transcribed interview content, we extracted meaningful statements and analyzed the frequency of specific words and content, tendencies, and keywords to understand healthcare professionals' thoughts. The derived results and interpretations were reviewed by three healthcare professionals who participated in the in-depth interview to receive feedback on whether the meanings match.

3. Results

3.1. Participants

Among the 164 workers who wished to participate, 162 met the inclusion criteria. This study started with 151 participants – 11 refused to participate and 24 dropped out. From the 127 participants who completed the study, we excluded 7 with missing health status values and 3 with answers inappropriate for analysis (insincere responses or did not meet the study purpose). Fig. 1 shows a flowchart of the study process.

Table 1 summarizes the workers' general characteristics. Most workers were women and over 50, followed by those in their 40 s and 30 s. The most common duration of employment was 1–4 years, and 60.6 % (71/117) were employed in workplaces with under 50 employees. Clerical and service-based businesses were more common than production and technical businesses.

3.2. Clinical outcomes

We performed one-way repeated measures ANOVA and Scheffé's test to confirm changes in participants' health status across the time points (Table 2). Systolic blood pressure ($F = 7.32$, $P < .001$), diastolic blood pressure ($F = 11.30$, $P < .001$), body weight ($F = 29.53$, $P < .001$), BMI ($F = 17.31$, $P < .001$), and waist circumference ($F = 17.33$, $P < .001$) all showed significant differences over the study period. Post hoc analysis revealed significant differences in systolic and diastolic blood pressure only after weeks 8 and 16, and body weight, BMI, and waist circumference showed significant differences not only after but also between weeks 8 and 16.

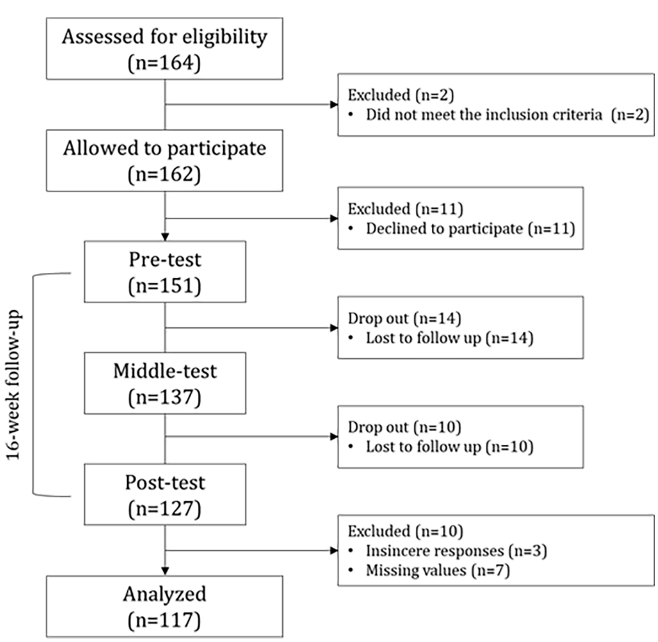

Fig. 1. Flow chart of the study process.

Table 1
Participants' characteristics (N = 117).

Characteristic		n (%)
Gender		
	Male	48 (41.0)
	Female	69 (59.0)
Age (years)		
	20–29	8 (6.8)
	30–39	24 (20.5)
	40–49	33 (28.2)
	≥50	52 (44.4)
Marital status		
	Single	24 (20.5)
	Married	91 (77.8)
	Divorced or separated	2 (1.7)
Education		
	Elementary school	3 (2.6)
	Middle school	6 (5.1)
	High school	25 (21.4)
	College	67 (57.3)
	Graduate school	16 (13.7)
Duration of employment in the workplace (years)		
	> 1	15 (12.8)
	1–4	47 (40.2)
	5–9	24 (20.5)
	≥10	31 (26.5)
Number of employees in the workplace		
	>5	18 (15.4)
	5–9	15 (12.8)
	10–29	26 (22.2)
	30–49	12 (10.3)
	50–99	10 (8.5)
	≥100	36 (30.8)
Type of business		
	Production	4 (3.4)
	Clerical	58 (49.6)
	Service-based	25 (21.4)
	Technical	12 (10.3)
	Other	18 (15.4)

Fasting blood glucose ($F = 5.11$, $P = .007$) and triglycerides ($F = 4.66$, $P = .01$) showed significant differences with time, whereas HDL cholesterol ($F = 3.35$, $P = .067$) did not. Post hoc analysis revealed a significant difference in triglyceride levels only after week 8, and a significant difference in fasting blood glucose only after week 16.

3.3. Lifestyle

We performed one-way repeated measures ANOVA and Scheffé's test to confirm changes in participants' lifestyle across the time points (Table 3). Physical activity for the week before the survey was calculated using the International Physical Activity Questionnaire (IPAQ) [62], and the dietary score for the past week was calculated based on whether the 8 items were practiced (Supplemental Material 4). The dietary score ($F = 3.26$, $P = .04$) showed a significant difference with time, whereas physical activity ($F = 1.06$, $P = .34$) did not. Post hoc analysis of dietary scores showed significant differences only after week 16.

3.4. Service satisfaction

Table 4 summarizes paired *t-test* results regarding differences in service satisfaction between weeks 8 and 16. The mean score for all variables at week 16 was higher than that at week 8. Lifestyle improvement ($P < .001$) showed a significant difference, but other variables did not.

3.5. Usage logs

We classified the collected usage logs according to the main categories (Health record, Center service, Video teleconsultation, and Login)

Table 2
Differences in participants' metabolic risk factors by time point (N = 117).

Variable	Week 1, mean (SD)	Week 8, mean (SD)	Week 16, mean (SD)	*F* value	*P* value	Scheffé
Systolic blood pressure	122.01 (12.67)	119.18 (13.36)	118.49 (10.48)	7.32	<0.001	c < a b < a
Diastolic blood pressure	77.55 (10.32)	75.24 (11.27)	73.56 (8.88)	11.30	<0.001	c < a b < a
Body weight	67.04 (12.40)	66.35 (12.65)	65.90 (12.75)	29.53	<0.001	c < a b < a b < c
BMI	24.85 (3.45)	24.52 (3.46)	24.31 (3.67)	17.31	<0.001	c < a b < a b < c
Waist Circumference	85.40 (9.42)	84.92 (9.84)	84.16 (10.09)	17.33	<0.001	c < a b < a b < c
Fasting blood glucose	119.30 (31.67)	114.05 (27.48)	111.54 (30.11)	5.11	0.007	c < a
Triglyceride	182.61 (93.40)	173.93 (84.47)	172.83 (82.50)	4.66	0.01	b < a
HDL cholesterol	49.08 (15.04)	51.03 (15.54)	51.96 (14.23)	3.35	0.067	–

a: week 1.
b: week 8.
c: week 16.

Table 3
Differences in participants' lifestyle by time point (N = 117).

Variable	Week 1, mean (SD)	Week 8, mean (SD)	Week 16, mean (SD)	*F* value	*P* value	Scheffé
Dietary score	4.88 (1.95)	5.06 (1.90)	5.21 (1.85)	3.26	0.04	a < c
Physical activity	2234.69 (2320.95)	2041.11 (2101.41)	2292.67 (2068.43)	1.06	0.34	–

a: week 1.
b: week 8.
c: week 16.

Table 4
Differences in participants' service satisfaction by time point (N = 117).

Variable	Week 8, mean (SD)	Week 16, mean (SD)	*t*	*P* value
Total satisfaction	4.36 (0.70)	4.47 (0.58)	−1.55	0.12
Lifestyle improvement	4.21 (0.69)	4.50 (0.55)	−4.05	<0.001
Easy to understand	4.31 (0.65)	4.39 (0.52)	−1.31	0.19
Service interest	4.39 (0.61)	4.47 (0.52)	−1.26	0.21
Recommend to coworkers	4.43 (0.60)	4.49 (0.50)	−1.15	0.25

to observe the service usage status; subsequently, unique values (deduplication of hours, minutes, and seconds per day) were counted weekly for each participant (Fig. 2). Login frequency showed an overall downward trend, decreasing by 27.7 %. Usage increased briefly at certain time points (weeks 4, 8, 12, and 16), and usage was relatively low during the Thanksgiving holiday (week 11). The log related to PHR showed the highest step count, followed by blood pressure, medical check-ups, and body weight (Fig. 3).

3.6. In-depth interviews

The 27 healthcare professionals interviewed had provided personalized healthcare counseling to participants for 16 weeks. We wanted to compare the experience of existing occupational health services with that of using healthcare technologies in response to COVID-19, to confirm the perspectives of service providers engaged in occupational health. Similar content was integrated into a single category (Table 5).

4. Discussion

4.1. Principal results

This 16-week study confirmed significant improvements in the primary and secondary outcomes. Except for HDL cholesterol, metabolic risk factors showed significant improvements. Many longitudinal and randomized controlled trials demonstrate that interventions using mHealth can reduce the risk of metabolic syndrome through lifestyle improvement [63], and some studies have reported a positive relationship between PHR and reduced metabolic syndrome risk [64,65]. PHR allows users to systematically collect, process, store, and share their health information with others, such as family members or medical personnel [60]. They can easily access their medical records, prescription drug information, hospital test results, and health promotion information [66]. These characteristics encourage users to be interested in their health management.

4.2. Comparison with prior work

Although the participants, study periods, content provided by the app, and intervention method in this study differed from those in previous studies, changes in participants' behavior improved their health status, which was consistent with existing studies [63]. Senecal et al.'s [67] 1-year retrospective cohort study showed that digital health interventions in workplace health promotion programs were associated with systolic, diastolic, and weight improvements. A similar 1-year RCT by Mattila et al. [68] showed that workplace interventions using personal health technology techniques were associated with improvements in weight, body fat, and waist circumference. However, relatively short-term lifestyle changes did not affect HDL cholesterol levels, which is known to be difficult to reduce [69].

Dietary score showed significant improvements across time points, but amount of physical activity did not. Several studies confirm that mHealth services effectively change behaviors related to physical activity and eating habits [70]. Kelly et al. [71] found that dietary intervention through telemedicine improved dietary quality, fruit and vegetable intake, and sodium intake. According to a *meta*-analysis of cohort studies [72,73], metabolic risk factors decrease with increasing physical activity. This study did not show sustained increases in participants' physical activity, presumably influenced by COVID-19. Similar to this trend, IPAQ scores in this study decreased at week 8 and increased again at week 16. Evidation Health [74] reports that physical activity across the United States declined by approximately 39

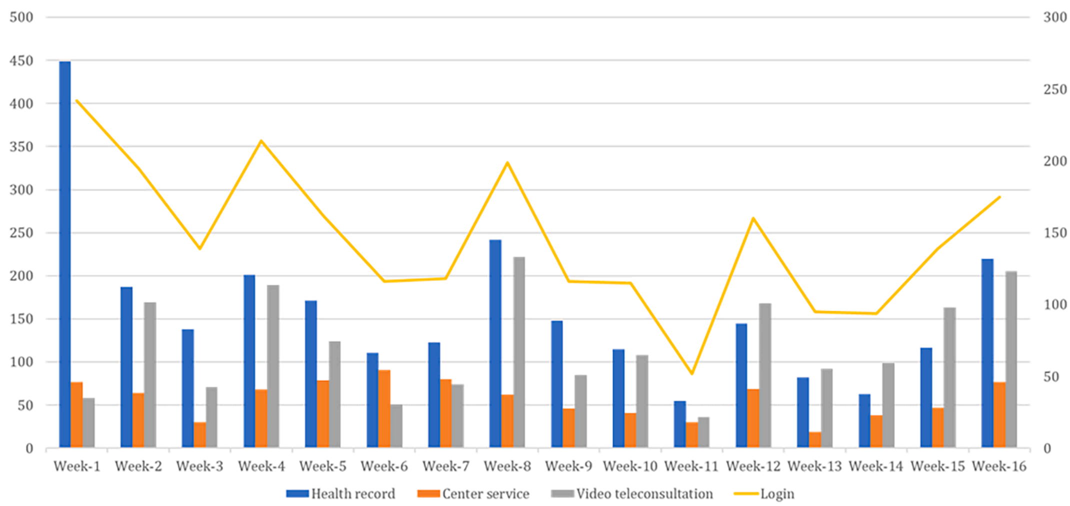

Fig. 2. Frequency of participants using mobile PHR app during the study based on usage logs.

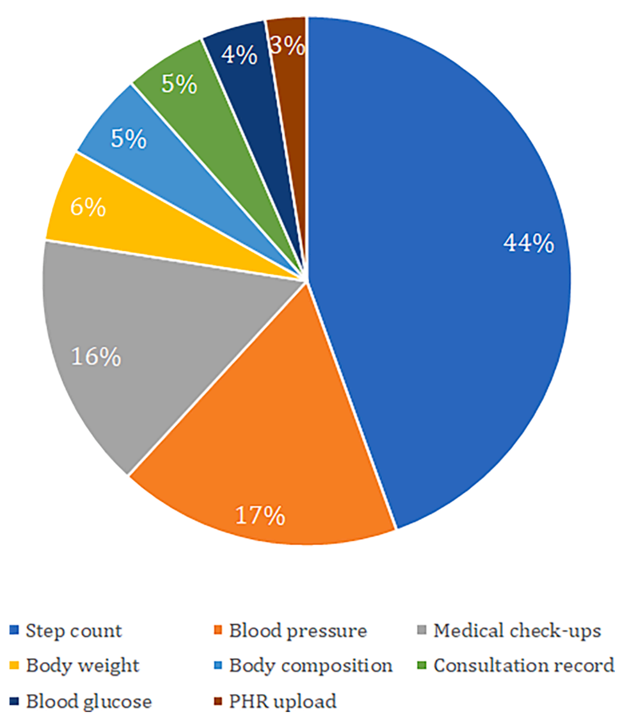

Fig. 3. Proportion of usage log related to the personal health record.

% because of COVID-19.

The trend of using the video-based telehealth service in this study exceeded the average participation period of 3–5 weeks reported in other mobile app industries [75,76], and showed a declining trend with high fluctuations, which differed from previous studies [33,68]. User adoption of the new service peaked in the first few weeks and then declined steeply as content was consumed. Although it was a trial period, it was judged that interventions (push alarm, content sending, and video teleconsultation) through the mobile PHR app affected participants' continuous use.

Interviews confirmed the impact of COVID-19 on occupational health providers. Most occupational health centers have consequently reduced the number of workers visiting or have restricted workplace visits. Currently, most medical and healthcare institutions are experiencing difficulties with operating restrictions [77], and face-to-face contact between healthcare professionals and patients is minimized to restrict the spread of the virus [78]. Similar to physicians' concerns about telemedicine [79], many healthcare professionals previously had doubts about non-face-to-face healthcare. However, telemedicine has showed the need for prompt service provision in medical emergencies [80] and maintenance of continuity of healthcare [81,82]. Occupational health service using the mobile PHR app greatly helped with counseling for prevention of cerebrovascular disease, musculoskeletal disease, and job stress prevention. Job stress affects approximately 28 % of all workers [83], and stress is reported to affect 80 % of work-related injuries and 40 % of turnover [84]. Kim et al. [85] found that an intervention using mobile video counseling significantly reduced workers' stress. Ekpanyaskul and Padungtod [56] confirmed that among work-from-home workers, musculoskeletal problems such as back pain (36.3 %) and neck and shoulder pain (40.9 %) were more frequent. Video-based telehealth services are judged to be an appropriate way to relieve workers' musculoskeletal problems and job stress during the COVID-19 pandemic.

4.3. Strengths and limitations

In terms of occupational safety and health, few researchers have focused on workers. This study is meaningful because it used mobile video teleconsultation as well as existing intervention methods in a limited face-to-face counseling situation due to COVID-19. However, it has several limitations:

- This study was not an RCT. Randomization was not possible because this study, as a national project, aimed to investigate effects of video-based telehealth service on vulnerable workers with metabolic risk factors using data from 10 occupational health centers.
- This study was a prospective observational study over a short period, and the clinical evidence for the effectiveness of the evaluated services is low. To obtain more objective evidence, RCTs or bias-adjusted inequality-controlled studies with large sample sizes and long-term studies should be performed.
- This study used only 10 of 23 occupational health centers nationwide. To obtain more generalized results, it is necessary to investigate a larger sample of occupational health centers nationwide.
- This study conducted in-depth interviews with professionals engaged in public occupational health. As the tasks they perform differ from the those performed by professionals in companies or medical institutions, the perspectives of service providers could change depending on characteristics of the personnel (career, field type, institution type, experience in healthcare technology, etc.).

Table 5
Summary of in-depth interviews with healthcare professionals (N = 27).

Category	Content
Impact of occupational health services for workers due to COVID-19	*The number of workers visiting occupational health centers has decreased (approximately 50 % less than before COVID-19). As face-to-face counseling was limited, the need for telehealth was felt.* [Healthcare professional 3]
	Most of the work to check the health status of workers by visiting the workplace or reviewing the work environment at the workplace was delayed or canceled in most cases. [Healthcare professional 2]
	The number of healthcare professionals visiting the workplace has been minimized, and the employer has asked for a certificate of vaccination or identification for each professional person. Teleconsultations are increasingly being requested at workplaces. [Healthcare professional 13]
	Many offline health promotion programs (e.g., lifestyle improvements, exercise) were terminated. Instead, the proportion of counseling by phone or mobile PHR app has increased. [Healthcare professional 18]
Awareness of telehealth services due to COVID-19	*Compared to before COVID-19, many tasks that were accomplished by working face-to-face have now shifted online. Things I was not used to before, I am used to now. I think that more telehealth services will be needed in the future.* [Healthcare professional 9]
	I had a negative perception before conducting this study However, when I saw workers with high satisfaction, I thought positively about the telehealth service. For example, multiple video teleconsultations created a rapport with workers, which played a significant role in providing personalized healthcare counseling when visiting. [Healthcare professional 14]
	Many healthcare professionals have doubts about the effectiveness of telehealth services. However, in practice, the perception changed through counseling workers who had difficulty going to the hospital after being vaccinated against COVID-19. [Healthcare professional 16]
	Before COVID-19, I had never heard of telemedicine, tele-monitoring, etc., in the field of occupational safety and health. It is considered effective for workers to access telehealth through smartphones while working. For example, it is considered appropriate for lifestyle improvement (e.g., smoking, exercise, diet) that requires continuous intervention or urgent situations (e.g., pain). [Healthcare professional 24]
Relative advantages of video-based telehealth service	*Ability to consult the healthcare professionals more frequently than face-to-face consultations. Even if workers do not visit the occupational health center, they can consult with healthcare professionals at any time and place using the mobile PHR app. Healthcare professionals can monitor the health information of workers in the workplace without having to visit the workplace in a remote location.* [Healthcare professional 23]
	Video counseling can form a closer relationship with workers faster than phone counseling. For example, after healthcare professionals identify a worker's pain area and show a joint model, they conduct consultation sessions. Consultation on the prevention of musculoskeletal disorders, or a worker's facial expression and emotional mood are of great help in counseling on job stress. [Healthcare professional 11]
	Tele-monitoring and intervention for workers who visited the occupational health centers were considered effective in terms of follow-up management. Workers can check health information or counseling information measured by the occupational health center through the mobile PHR app and receive interventions necessary to improve their lifestyles from healthcare professionals. [Healthcare professional 24]
Workers' response to video-based telehealth service	*It was difficult at first, but it was confirmed that the usability of video teleconsultation using the mobile PHR app gradually increased. For example, it was used by workers during spare time (e.g., delivery by a courier or traveling by car).* [Healthcare professional 16]
	Video teleconsultation was more positive than phone consultation, and workers were surprised and embarrassed at first. As they gradually became accustomed to it, the workers revealed their inner thoughts that they did not reveal earlier during the face-to-face visits or phone consultations. [Healthcare professional 8]
	Through personalized healthcare counseling, I gathered more healthcare knowledge than I was aware of earlier (e.g., fruits can increase sugar levels). Based on this, one can manage lifestyle and health conditions. [Healthcare professional 25]

- This study did not conduct a pre-post evaluation of healthcare professionals. It is necessary to add a survey on healthcare professionals to the introduction and expansion of telemedicine in the Republic of Korea after COVID-19.
- This study did not use an implementation science approach. To improve the quality and effectiveness of video-based telehealth services in the field of occupational safety and health, a mixed quantitative-quantitative design is needed to identify influencing factors at multiple levels, including not only workers and healthcare professionals, but also organizations and the policy environment.

4.4. Conclusions

The video-based telehealth service had positive effects on workers' metabolic risk factors, lifestyle, and service satisfaction. Interventions such as tele-monitoring and video teleconsultation using mobile PHR apps are appropriate for workers with poor access to healthcare during the COVID-19 pandemic. More studies are needed to demonstrate the effectiveness of interventions and if the services can be generalized. While companies and employers need to implement telehealth services for employees increasingly working from home, occupational health providers need to positively review their services using healthcare technology responding to the changes in the working environment. Therefore, future research should conduct a case-control study on workers' physical and mental health (stress, anxiety, and depression) to confirm the clinical effectiveness of in-company services.

Summary Table

What was already known on this topic	• Metabolic syndrome is a risk factor for cardiovascular disease and diabetes. • Workers in underserved areas have relatively poor access to healthcare. • The COVID-19 pandemic has limited face-to-face treatment, making it even more difficult for workers to receive healthcare services.
What this study added to our knowledge	• Video-based telehealth service with a PHR app positively impacted workers' metabolic risk factors and lifestyle. • Workers were satisfied with the services they received. • Video-based telehealth services may be a useful method for workers to receive services and avoid metabolic syndrome.

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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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijmedinf.2022.104844.

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