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A randomized controlled trial study using WhatsApp-delivered transtheoretical model–based intervention to promote healthy eating habits and anthropometric measurements for male firefighters

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ABSTRACT

Background: Fruit and vegetables (F&V) consumption is critical to preventing non-communicable diseases such as overweight and obesity. However, many people, including firefighters, focus on physical exercise to strengthen their physical fitness but ignore healthy eating, especially F&V consumption. The aim of this study was to investigate the association between a stage-matched health promotion program delivered through WhatsApp and the stage of change for F&V intake and its influence on anthropometric measurements.

Methods: Forty-eight firefighters were randomly assigned to either an intervention (health promotion pamphlet and stage-matched teaching materials through WhatsApp) or active control (health promotion pamphlet) group. Twenty-three were assigned to the intervention group and 25 to the active control group.

Results: Significant differences ($P < 0.05$) were found within the group comparison at the stage of change. More than 60 and 44 percent of firefighters in intervention and active control groups, repectively, were promoted to the "Action" and "Maintenance" stages 6 months after the completion of the intervention. The mixed-effects model results indicated a significant interaction between the two groups across the three time points with regard to the number of fruits consumed ($P = 0.0022$). This observation suggests that the intervention had a varying effect on the number of fruits ingested over time compared to the control group. Significant differences in body weight, body mass indexes, and waist circumference were observed within both groups ($P < 0.05$).

Conclusions: Stage-matched interventions based on the transtheoretical model delivered through WhatsApp successfully promoted F&V consumption and improved anthropometric measurements among firefighters.

Introduction

Firefighters are crucial in maintaining public safety and protecting lives and property. However, there is a growing concern regarding the prevalent issue of overweight and obesity within the firefighting community [1]. This global health crisis affects individuals across various professions, including firefighters [2]. The nature of their work puts them at a heightened risk of weight gain, with long and irregular shifts, as well as high stress levels, often leading to a reliance on calorie-dense, low-fiber fast-food choices [3,4]. The need for quick and easily accessible meals during emergencies further compounds the challenge of maintaining a nutritious diet. [5]. The elevated rates of overweight and obesity among firefighters are closely linked to their inadequate intake of fruit and vegetables (F&V), crucial for weight management [6] and overall well-being [7]. Poor dietary choices, especially the lack of sufficient F&V, significantly contribute to the burden of weight control [8]. Excessive weight and obesity, coupled with a deficiency in F&V consumption, increase the likelihood of developing cardiovascular diseases, such as sudden cardiac death among firefighters [1,9]. In 2020, on-duty fatalities related to sudden cardiac death accounted for the largest portion of United States firefighter deaths, making up approximately 47% of the total [10]. Therefore, promoting healthy eating and boosting F&V consumption are essential steps in reducing firefighters' risk of cardiovascular diseases.

List of abbreviations: BMI, Body mass indexes; BW, Body weight; F&V, Fruit and vegetables; TTM, Transtheoretical model; WC, Waist circumferences

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Firefighters face demanding work that necessitates immediate responses to emergency calls, always remaining on-call to swiftly attend fire incidents or other emergencies. Recent statistics indicate a troubling trend, with fire calls increasing by 3.8% from 34,775 to 36,103, and incident calls surging by 15.4%, surpassing 4000 calls [11]. Given the unique challenges firefighters encounter, such as the unpredictability of callouts, the development of a flexible health promotion program is crucial. This program should provide essential healthy eating information to firefighters in real-time, accessible regardless of their location or availability. The flexibility of WhatsApp allows firefighters to receive this information at their convenience, even during breaks or downtime between calls. Studies have shown that utilizing WhatsApp can help increase F&V consumption among various populations [12–14]. Firefighters typically work in a shift pattern of 24 hours on duty followed by 48 hours off duty [15]. During their 24-hour shifts, firefighters maintain, clean, and organize equipment while fostering companionship through shared meals and teamwork [16]. Research has uncovered evidence indicating that high workloads and long working hours hinder the development of healthy eating habits, contributing to excessive weight gain [17]. Several studies have found that health-promotion programs focusing on F&V could increase F&V intake ($P < 0.05$) [18], decrease body weight (BW) gain ($P < 0.05$) [18], and reduce waist circumferences (WC) ($P < 0.05$) [19]. Firefighters often eat quickly due to meal interruptions caused by emergency calls [20], which can contribute to weight gain as rapid eating reduces awareness of food quantities consumed. This can lead to overeating beyond satiety levels [20]. Establishing a health promotion program with adaptable distribution methods is essential to encourage firefighters to adopt healthy eating habits, as their well-being is crucial for public health. Previous studies have shown an increase in F&V consumption after a short intervention period [21]. However, the longer-term effect of this intervention among firefighters has not yet been identified. It is necessary to explore the sustainability of changes in firefighters' F&V eating habits over time.

A systematic review [22] emphasizes that integrating behavioral theory is crucial for the effectiveness of dietary mobile phone health application interventions. The transtheoretical model (TTM) stands out as a robust framework for promoting healthy eating habits among various populations [23,24], including firefighters [25]. Stage-matched interventions have demonstrated greater effectiveness compared to non-tailored interventions in promoting health behavior change, as supported by findings from a meta-analysis [26]. Despite this, there is a lack of stage-matched healthy eating interventions specifically designed for firefighters. The TTM comprises five stages of change, including precontemplation, contemplation, preparation, action, and maintenance [27]. This study focuses on evaluating the potential long-term impact of a TTM stage-matched intervention delivered via WhatsApp on firefighters' consumption of F&V, BW, body mass indexes (BMI), and WC.

Methods

Study design and setting

This present study used a randomized controlled trial feasibility design. Firefighters were allocated randomly into two parallel arms of 8-week intervention (health promotion pamphlet and stage-matched teaching materials through WhatsApp) versus 8-week active control (health promotion pamphlets). The nursing laboratories in one university were used for measurements. The university's Human Subjects Ethics Sub-committee approved the study. All participants signed the written informed consent at the beginning of the study.

Participants

Forty-eight eligible male firefighters agreed to participate in this study. All of them met all the inclusion criteria, including 1) being aged 18 years or older; 2) currently working as firefighters, working on a "24 hours on, 48 hours off" shift; and 3) being owners of smartphones with internet access. If firefighters had participated in any health promotion program within the previous 6 months, they would be excluded.

Recruitment, randomization, and blinding

Recruitment of participants was using convenience and snowball sampling methods by sending the poster to 1) interested firefighters through WhatsApp directly and 2) the Hong Kong Fire Services Department Staff General Association and relied on those interested firefighters to promote this study to their peers and the recruitment period was from September 2018 to May 2019. An information sheet, which included study aims, procedures, and duration, was sent to those interested firefighters. For sample size estimation of a feasibility study, no clear definition is established [28]. The possible sufficient sample size was 10 to 15 in group [29]. In total, 36 participants were the target sample size, and 17% as an attrition rate [30,31].

Forty-eight male firefighters who volunteered for the study provided written consent and completed a baseline questionnaire. An independent and experienced information technology expert was blinded to the intervention allocation and responsible for conducting the randomization. A total of 48 firefighters were allocated randomly into either intervention (n = 23) or active control (n = 25) groups. Random numbers were generated by a computer, with odd numbers designated for the active control group and even numbers for the intervention group. To prevent cross-contamination, firefighters from the same fire station were assigned to either the intervention or active control group. Participants were unaware of their group assignment and were instructed not to share any received information with their colleagues. The overview of the study is shown in Figure 1.

Intervention and active control groups

Participants in the intervention and active control groups completed the questionnaires at baseline (T_0). The teaching materials and pamphlets were designed based on the Promoting Healthy Lifestyles: Alternative Models' Effects [32], Centre for Food Safety [33], and Department of Health in Hong Kong [34]. Out of the 10 sessions, four sessions would be dedicated to designing a healthy eating intervention tailored for Hong Kong firefighters. The teaching materials and pamphlets covered four key areas: 1) explaining the reasons for healthy eating; 2) highlighting the benefits of consuming fruits and vegetables; 3) exploring various cooking methods for fruits and vegetables; and 4) providing practical advice on incorporating enough fruits and vegetables when dining out and during festive seasons. The teaching materials were delivered via WhatsApp according to the participants' baseline TTM stage of change, while the pamphlets were distributed to all participants based on their respective stages at the baseline. Dividing the stages of change at the "Action" stage serves as a dividing point, categorizing them into two stages: Stage 1 and Stage 2. Stage 1 encompasses the stages of "Pre-contemplation," "Contemplation," and "Preparation," whereas Stage 2 includes the "Action" and "Maintenance" stages. In the context of the stages of change, progress entails participants advancing from one stage to the next, like moving from Precontemplation to the Preparation stage. When participants are unchanged, they maintain their position in the current stage of change. Regression

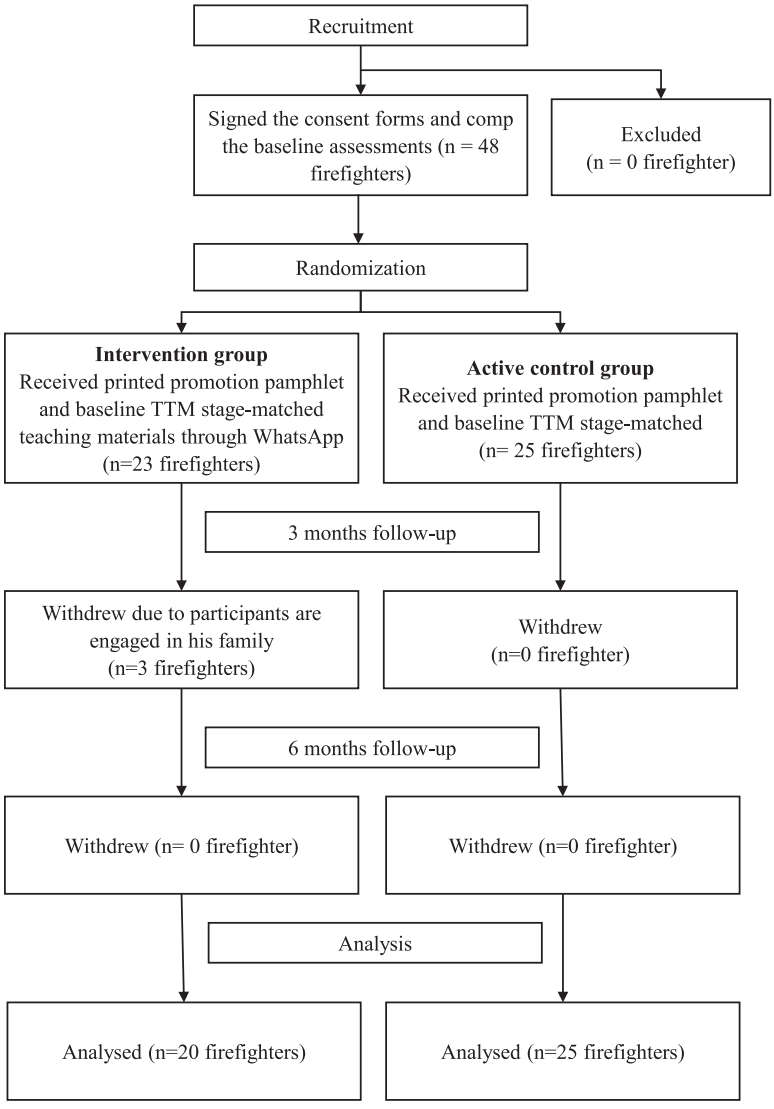

Fig. 1. Flow chart of the study.

indicates a step back in the stages of change, where participants revert to previous stages, for example, moving from the Action stage back to the Precontemplation stage.

Details of the development of the questionnaire, teaching material, and pamphlets were reported elsewhere [5]. A panel is composed of six experts, including three registered nurses, two nutritionists, and one dietitian, and they were invited to review the pamphlet, teaching material, and questionnaires. The pamphlet's fidelity and the questionnaires' validity were determined in the study protocol [5]. The stage of change of intervention participants was assessed at baseline, and the corresponding teaching materials, according to their stage of change status, were distributed to them every 2 weeks through WhatsApp. The study protocol has described the intervention in detail [5].

Reliability of anthropometric data collection

A registered nurse carried out the anthropometric measurement alongside the researcher. The intra-class correlation coefficients between the nurse-measured and researcher-measured values were 0.98 for BW, 0.96 for body height, 0.98 for BMI, and 0.98 for WC.

Data collection

All participants were required to complete the questionnaires, including the F&V consumption at baseline (T_0), 3 months after the completion of the 8-week intervention (T_1), and 6 months after the completion of the intervention (T_2). The study protocol stated that one out of five statements assessed the participant's stage of change at baseline [5].

Statistical analysis

A descriptive analysis was performed on the participants' demographic characteristics. Continuous variables, including age and years of working experience, were presented as mean and standard deviation. Multiple imputation methods were used to impute missing data for participants (n = 3, 6% of samples) who did not complete the postintervention and were missing any other data. The missing values were imputed using the fully conditional

specification method with five imputed datasets created. The imputation model included stages of change, BMI, BW, WC, and F&V consumption. Assumptions of missing at random were applied during the imputation process, ensuring the validity of the imputed data. Additionally, sensitivity analyses were performed to evaluate the reliability and consistency of the imputation results. The between-group comparison of the stages of change, BMI, BW, and WC at three-time points (baseline, T_1, and T_2) was assessed with the Kruskal-Wallis test. The Wilcoxon sign-ranked test was used to assess within-group comparison for BMI, BW, and WC, while stages of change were analyzed by the Friedman test. To evaluate the effect of the intervention on the outcomes of interest, we employed generalized linear mixed-effects models. The models included time of measurement (baseline, T_1, and T_2), group assignment (intervention or active control), and their interaction as fixed effects. A P value of less than 0.05 was considered significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 26.0, Armonk, NY: IBM Corp. Intention-to-treat analyses were performed in this study.

Results

Participants' characteristics

Most firefighters (91.7%, n = 44) participating in the study were frontline firefighters, responsible for many physically demanding tasks, such as firefighting, emergency, and rescue work. At baseline, no significant difference was found in the participants' characteristics, including age and working experience, between the intervention and active control groups (Table 1).

Table 1
Baseline characteristics of the participants (N = 48)

Characteristics	Total (N = 48)	Intervention (n = 23)	Active control (n = 25)	P
Age (y)				0.114
Mean	34.7	32.5	36.6	
SD	9.5	9.1	9.6	
Working experience (y)				0.260
Mean	11.1	9.3	12.8	
SD	9.7	9.1	10.1	
Fruits consumption (number/d)				0.395
Mean	1.8	1.8	1.9	
SD	0.5	0.4	0.5	
Vegetables consumption (bowl/d)				0.080
Mean	1.9	2.0	1.7	
SD	0.6	0.6	0.6	
BMI				0.710
Mean	24.2	23.9	24.5	
SD	2.5	2.2	2.7	
BW				0.302
Mean	73.9	72.3	75.3	
SD	8.3	6.9	9.3	
WC				0.207
Mean	85.4	84.0	86.7	
SD	6.3	5.3	6.9	
Stage of change	n (%)	n (%)	n (%)	0.620
Stage 1	35 (72.9)	16 (69.6)	19 (76.0)	
Stage 2	13 (27.1)	7 (30.4)	6 (24.0)	

Stages of change

In both the intervention and active control groups, the proportions of participants in Stage 2 have increased. A significant difference ($P < 0.001$) was noted between three time points in both the intervention and active control groups, with the proportion increasing from 7 (30.4%) to 21 (91.3%) in the intervention group, with the proportion rising from 6 (24%) to 17 (68%) in the active control group (Figs. 2 and 3). However, no significant difference ($P > 0.05$) was identified between groups. Figures 4 and 5 compare the percentage of changes between "T_0–T_1" and "T_0–T_2" in the intervention and active control groups. The changes were not statistically significant in the group comparison, while $P < 0.05$ within-group comparison in the intervention and active control groups, respectively.

Number of fruits and bowls of vegetables consumed per day by the participants in the progressed stage of change

In the progressed stage of change, 17 firefighters (75.0%) in the intervention group and 16 firefighters (64.0%) in the active control group increased their consumption of F&V. Specifically, 12 firefighters (70.6%) in the intervention group and 12 firefighters (75.0%) in the active control group increased their overall fruit intake. The mean number of fruits consumed in the intervention group (T_0: 1.8 ± 0.5, T_1: 1.9 ± 0.5; T_2: 2.7 ± 0.5) and in the active control group (T_0: 1.8 ± 0.6; T_1: 1.8 ± 0.4, T_2: 2.1 ± 0.5) were increased from T_0 to T_2. Notably, a significant difference was observed between the two groups regarding the number of fruits consumed at T_1 (P = 0.026) and T_2 (P = 0.011) (Fig. 6). Additionally, a significant difference in the number of bowls of vegetables consumed was identified (P = 0.003) at T_2 (Fig. 7 and Table 2).

Number of fruits and bowels of vegetables consumption

In addition to the progressed stage of change results, the mixed-effects model results revealed a significant interaction regarding daily fruit consumption across the three-time points between the two groups (P = 0.0022). This indicates that the intervention had a differential effect on daily fruit consumption over time compared to the active control group. However, no significant interaction was identified for vegetable consumption ($P > 0.05$) between the two groups.

Anthropometric measurements

Furthermore, when the anthropometric measurements were compared across three-time points (baseline, T_1, and T_2) in both groups, the mean WC decreased within the normal range of <90 cm. The mean BMI was slightly reduced, remaining in the "overweight" category. Asian males with BMIs equal to or greater than 23 and 25 are categorized as overweight or obese [35]. No statistically significant differences were found in BW, BMI, or WC between groups. In contrast, a significant difference ($P < 0.05$) was detected in BW, BMI, and WC within intervention and active control groups (Table 3). The intervention demonstrated effect sizes of 0.15 for BW, 0.15 for BMI, and 0.16 for WC.

Discussion

This study illustrates that the WhatsApp-delivered TTM-based stage-matched intervention was successful in boosting F&V consumption among firefighters, with lasting effects on fruit intake between T_1 and T_2, as well as vegetable intake at T_2. The proportion of the Action/Maintenance stage in the intervention group has increased dramatically from 30.4% at baseline to 91.3% at 6 months after intervention, and those in the active control group at the Action/Maintenance stage changed from 24.0% at T_0 to 68.0% at 6 months after intervention. A study found that individualized stage-matched intervention had remarkedly influenced the

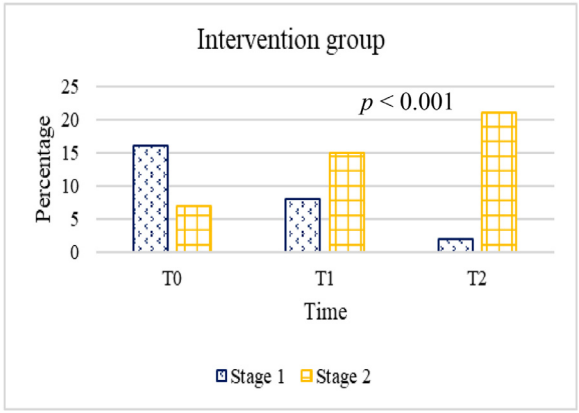

Fig. 2. Percentage of Stage 1 and Stage 2 comparison in the intervention group.

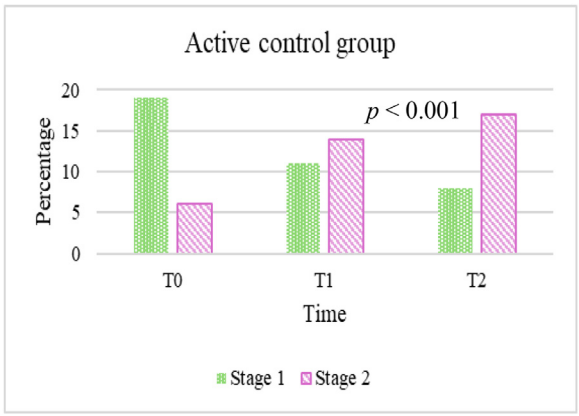

Fig. 3. Percentage of Stage 1 and Stage 2 comparison in the active control group.

progression of healthy eating from the Precontemplation/Contemplation/Preparation stage (Stage 1) to the Action/Maintenance stage (Stage 2) [36], which is similar to this study's finding that 45% of participants in the intervention group progressed from the preaction stage to the postaction stage. One potential reason is the specific stage-matched intervention tailored to each intervention

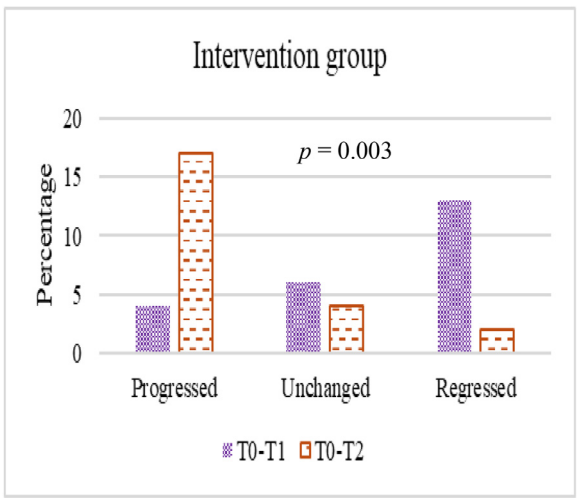

Fig. 4. Comparison of the percentage of change between "T0–T1" and "T0–T2" in the intervention group.

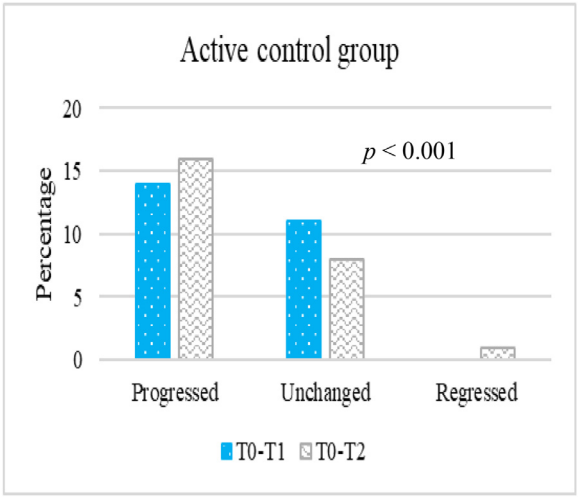

Fig. 5. Comparison of the percentage of change between "T0–T1" and "T0–T2" in the active control group.

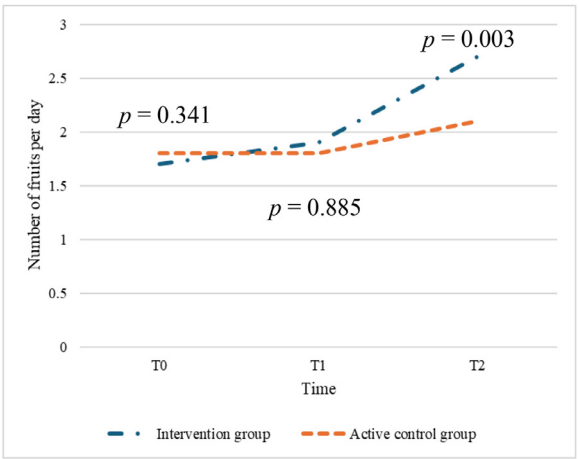

Fig. 6. Between groups comparison of number of fruits consumed per day by the participants in the progressed stage of change.

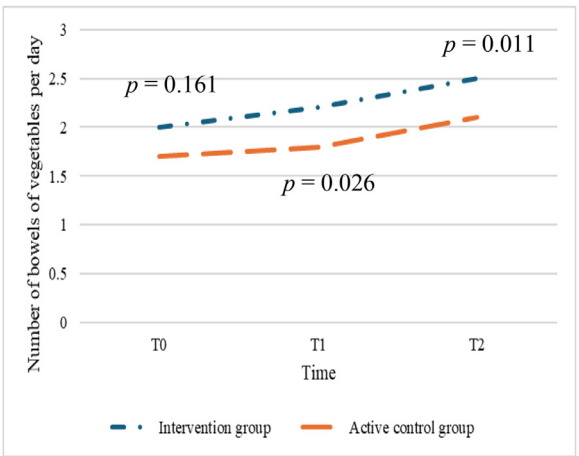

Fig. 7. Between groups comparison of number of bowels of vegetables consumed per day by the participants in the progressed stage of change.

Table 2
Number of fruits and bowels of vegetables consumed per day by the participants in the progressed stage of change at T_2

	Total (N = 33)	Intervention (n = 17)	Active control (n = 16)	P
Fruits consumption (number/d)				0.003
Mean	2.7	2.7	2.1	
SD	0.5	0.5	0.5	
Vegetables consumption (bowl/d)				0.011
Mean	2.4	2.5	2.1	
SD	0.6	0.5	0.4	

group participant, which may increase their relevance and motivation to increase their consumption of F&V [37]. More than 60% of participants in the intervention group were promoted from Stage 1 to Stage 2 between baseline and 6 months after the intervention, as well as around 45% of participants in the active control group were promoted to the postaction stage. These results illustrated that the participants in both groups could be motivated to change their eating habits over a period of time.

In terms of the progressed stage of changes among intervention participants, a more significant enhancement in the daily fruit consumption was observed compared to active control participants at 6 months after the intervention (T_2). On the other hand, a number of bowls of vegetable intake began to show significant improvement 3 months after the intervention (T_1) and continued through T_2. It showed that a WhatsApp-delivered TTM stage-matched intervention effectively motivates the participants to change their eating habits by increasing F&V consumption. This positive result of using TTM stage-matched to promote healthy eating, including F&V, matches those investigated in earlier studies [21,38]. The results of this study can be treated as evidence to support the feasibility of changing the eating habits among firefighters. It can be illustrated that TTM-based stage-matched intervention positively impacts the participants in their stages of change on F&V intake, which is similar to the TTM-based study on the increase in the stage of change about F&V intake [39]. Our study revealed a significant increase in the daily number of fruits consumption at T_2, alongside an increase in number of bowls of vegetables at T_1, with this shift persisting throughout T_2. This finding suggests that our WhatsApp-based healthy eating program had a more substantial influence on boosting vegetable intake 3 months after the intervention, while also promoting increased fruit consumption 6 months after intervention. A study suggested that perceived access to F&V can drive consumption, with effects becoming noticeable after 4 months [40]. Our findings demonstrate a rise in number of bowls of vegetables in 3 months, highlighting how providing detailed information during specific stages of our WhatsApp intervention can effectively enhance vegetable consumption [41]. An interesting finding from the study was the notable increase in number of fruits consumed per day by firefighters from both groups 6 months after the intervention. Intervention participants consumed an average of 2.7 ± 0.5 fruits, compared to the average of 2.1 ± 0.5 fruits among active control participants. A study indicates that personal, social, and environmental factors play a crucial role in shaping fruit consumption behavior. For instance, the fruit-eating habits of a friend who does not consume fruits can distinctly impact an individual's own dietary choices [42]. This positive change may be attributed to firefighters taking individual accountability for acquiring and preparing their own fruits, aligning with another study that identified a significant difference in F&V consumption between groups after receiving a TTM-based intervention [24]. These findings provide evidence that the health promotion program focusing on F&V is viable.

Significant differences in the number of fruits consumed were noted across three-time points between two groups within the progressed stage of change participants. The fruits were not provided in the firefighters' meals, which were prepared by the chef of the fire station [43]. Firefighters need to prepare the fruit by themselves. It can be illustrated that the increase in the consumption of fruits could be related to the health promotion program from this study. It is also consistent with the results of the study in Australia [44]. There were no significant differences in the number of vegetables between groups; however, significant differences were found within the group comparison. In this study, the intervention group demonstrated a higher consumption of vegetables compared to the active control group, showing a more favorable trend in the desired direction, which is aligned with the findings of another study [45]. Communal meals are customary at the fire station, with the chef preparing a set quantity of vegetables for all firefighters during each meal [46]. Nevertheless, this approach might not supply sufficient vegetables to meet the recommended intake for all firefighters [47]. Moreover, there is a cultural inclination among the Chinese to emphasize generous yet unnecessary acts of food sharing, like encouraging others to consume more [48]. The results supported that the effect of the intervention by firefighters might increase their vegetable intake not only at three working days per week and their resting days.

Following the intervention, the intervention participants (−1.7 ± 4.3 kg) showed a greater reduction in BW across three-time points compared with the active control group participants (−0.6 ± 1.7 kg). The variance in working experience could potentially explain these results. Dobson et al. [3] noted that younger firefighters demonstrated a higher interest in

Table 3
Anthropometric measurements between groups and within groups at each time point

Anthropometric measurements	T_0	T_1	T_2	P within group
Body weight (kg), mean (SD)				
Intervention (n = 23)	72.33 (6.87)	71.44 (5.02)	70.63 (4.95)	0.006
Active control (n = 25)	75.25 (9.31)	75.66 (9.40)	74.69 (8.99)	0.014
P between group	0.302	0.119	0.157	
Body Mass Index (kg/m^2), mean (SD)				
Intervention (n = 23)	23.94 (2.18)	23.98 (1.82)	23.53 (1.64)	0.004
Active control (n = 25)	24.49 (2.73)	24.62 (2.73)	24.30 (2.68)	0.006
P between group	0.710	0.464	0.695	
Waist circumference (cm), mean (SD)				
Intervention (n = 23)	84.00 (5.27)	84.00 (4.38)	82.70 (4.43)	0.030
Active control (n = 25)	86.74 (6.91)	86.62 (7.12)	84.50 (6.87)	0.002
P between group	0.207	0.287	0.541	

health and fitness than their more experienced counterparts. Upon reviewing our data, it became evident that the mean working experience of the intervention participants was lower than that of the active control group. This finding aligns with research indicating that less experienced firefighters exhibit greater awareness of their fitness than older ones [3]. Moreover, age appears to be another influential factor affecting the changes in BW among participants in both groups. The mean age of the intervention participants was lower than that of the active control group. A study has shown that younger adults are more driven by appearance and social influence compared to older adults [49]. This could explain why participants in the intervention group found it easier to achieve weight loss than those in the active control group in this study. After 6 months of the intervention, participants in both groups experienced a reduction in BMI, with significant differences observed within each group. This further solidified the confirmation that increasing F&V intake can lead to reductions in BW and BMI [50]. This effect may be attributed to the higher intake of F&V by both groups, as these foods are rich in fiber and promote a feeling of fullness [51]. A previous study has also supported the association between increased F&V consumption and favorable changes in BW and BMI [18]. The WC of participants in both groups decreased notably. This outcome is consistent with a previous study indicating a marked reduction in WC after a dietary intervention [52]. The composition of F&V may contribute to this effect by being resistant to digestion and absorption in the gastrointestinal tract, thereby aiding in weight management [53], and potentially diminishing visceral fat stores and reducing WC [54]. Therefore, the definite stage-matched intervention used in this study was an applicable intervention designed to motivate behavioral changes.

In our study, firefighters from the same fire station were assigned to either the intervention or active control group, with all participants reminded not to share study-related information with their colleagues. Hong Kong comprises 138 fire stations distributed across 15 divisions under four commands [55]. However, due to the confined geographical area of fire stations in Hong Kong, eliminating contamination poses a challenge. However, the proximity of fire stations in Hong Kong may lead to potential contamination issues [56]. To address this concern, Allan and her colleagues suggested that a minimum of eight clusters for a parallel-arm cluster randomized trial should be implemented to uphold a *P* value below 0.05 using a randomization-based test [57]. Therefore, it is imperative to collaborate with the Fire Service Department to enhance the study's statistical power and efficiency. Another strategy involves adjusting the sample size calculation, where the inflation to accommodate contamination is often significantly lower than the design effect, which could be considered for future studies [56].

Strengths and limitations

Using WhatsApp for the intervention was a strength of our study. There are two limitations to this study. Firstly, the risk of bias may occur due to the same researcher delivering the study intervention and collecting the data. The self-reported nature of the F&V intake data may pose a risk of overestimation or underestimation, which is a limitation of this study. Future studies should aim for a double-blind design and use photos to solve the limitation of poor recall. However, the validity and reliability of the validated questionnaires have been used to collect self-reported data in this study to reduce this limitation. This would improve the quality of the trial and provide more accurate information on participants' F&V intake.

Conclusions

Significant differences were observed across three-time points, either in the intervention or active control groups, concerning the stage of change. Specifically, when assessing progress in the stage of change, there was a statistically significant variance in the number of vegetable bowls consumed. The results of the mixed-effects model indicated a notable interaction related to daily fruit consumption over the three-time points between the two groups. In terms of within-group comparisons, significant variances were identified in BW, BMI, and WC. Our findings indicate that implementing a health promotion program for F&V intake using WhatsApp and stage-matched interventions based on the TTM yielded long-term positive outcomes. The program effectively promoted F&V consumption, especially fruit intake, and showed promising results regarding anthropometric outcomes among firefighters. These findings highlight the potential of utilizing WhatsApp and tailored interventions based on TTM to enhance healthy eating behaviors. Further research initiatives can partner with the Fire Service Department to deploy interventions on a broader scope, thereby boosting statistical robustness and effectiveness. This collaboration would involve recalibrating sample size calculations to better tackle contamination issues.

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Ethical statement and informed consent

This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethics Committee of the Hong Kong Polytechnic University (HSEARS20180527001). Written informed consent was obtained from all subjects.

Declaration of competing interests

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 article.`

CRediT authorship contribution statement

Winnie Wing Man Ng: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Formal analysis, Conceptualization. **Kin Cheung:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Maria Shuk Yu Hung:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Conceptualization. **Ki Lui:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis.

Data availability

The data from this study can be obtained upon reasonable request directly from the corresponding author. However, it is important to note that the data are not publicly available as they are subject to privacy and ethical restrictions.

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