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Effects of a blended face-to-face and eHealth lifestyle intervention on physical activity, diet, and health outcomes in Hong Kong community-dwelling older adults: a randomized controlled trial

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Abstract

Background The effectiveness of a blended approach integrating face-to-face and eHealth interventions for promoting positive lifestyle behaviours in older adults has not been systematically tested. This study aimed to assess the feasibility and effectiveness of such interventions in improving health behaviours and outcomes among older adults in Hong Kong.

Methods A 10-week, single-blind, randomized controlled trial recruited 132 eligible older adults. Participants were assigned to three groups: (1) a blended intervention group: two sessions per week for ten weeks with one for physical activity and one for diet (fruit and vegetable intake; meat, fish, egg and alternatives intake) and two web-based sessions; (2) a face-to-face intervention group: same content and intensity like the blended group but as face-to-face sessions; and (3) a control group receiving biweekly telephone calls. Data on lifestyle behaviours and health outcomes (physical fitness, depression, loneliness, health-related quality of life) were collected at baseline (T1), 10 weeks post-test (T2), and a 3-month follow-up (T3). All data were analyzed using IBM SPSS 29.0. Descriptive statistics were used to describe the feasibility. The generalized linear mixed models were used to evaluate the effects of the intervention.

Results The study demonstrated high feasibility with > 90% adherence, > 88% session attendance, and an acceptability score of 4.7/5. The blended intervention outperformed the face-to-face and control conditions for both diet behaviours at T2 and T3, with a Cohen's d effect size ranging from 0.77 to 1.18 ($p < 0.05$). It also showed a significant effect on physical activity compared to controls at T3 (Cohen's $d = 0.21$, $p < 0.05$). Both intervention groups

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improved in lower body strength, agility and dynamic balance, and health-related quality of life compared to control at T3 ($p < 0.05$).

Conclusions This study provides empirical evidence for the feasibility and superiority of blended interventions to promote dietary habits among Hong Kong older adults. Future research applying rigorous study design, identifying effective strategies promoting physical activity, and exploring psychological mechanisms of health behaviour changes is warranted to enhance the efficacy of lifestyle interventions among older adults.

Trial registration This study was retrospectively registered on the ISRCTN (ISRCTN32329348).

Keywords Physical activity, Diet, Health outcomes, Older adults, Blended intervention, eHealth, Face-to-face

Introduction

Background

Non-communicable diseases (NCDs) are the leading cause of death worldwide [1]. Older adults are a vulnerable group living with NCDs, such as cancer, diabetes, obesity, and cardiovascular ailments [2, 3]. Evidence shows that NCDs are strongly associated with unhealthy lifestyle behaviours, including insufficient physical activity (PA), insufficient fruit and vegetable intake (FVI), consumption of food high in saturated fat and trans fat, and a poor diet [4, 5]. Therefore, a healthy lifestyle is essential for preventing and managing NCDs and promoting physical and mental health in older adults [6]. In Hong Kong, the Population Health Survey 2020-22 indicated that 33.5% of older adults (≥65 years old) exhibited insufficient PA [7]. Besides, 98.0% of older adults in Hong Kong consume an average of fewer than five portions of fruits and vegetables per day, which was recommended by the World Health Organization (WHO) [8]. Regarding meat consumption, 62.8% of Hong Kong older adults indicated the frequency of meat intake (e.g., beef, pork, and lamb) is less than once per day, while older adults were recommended 5–6 taels (189.0–226.8 g) of meat, fish, egg and alternatives intake (MFEAI) per day, recommended by Department of Health in Hong Kong [9]. Engaging in multiple risk behaviours can lead to adverse health effects [10]. Implementing healthy lifestyle interventions among older adults is crucial and impactful in averting adverse effects on individual health, medical systems, and healthcare costs [11].

The health interventions were delivered in various formats, with face-to-face and eHealth being the most commonly utilized methods. Face-to-face interventions enable intervention providers to deliver individualized-tailored interventions and foster interactive communication [12]. Empirical evidence supports the efficacy of face-to-face interventions in promoting health behaviours, such as PA and dietary [13, 14]. It also identified several limitations. For instance, counselors may need to allocate more attention to participants, which could be labour-intensive. Additionally, physical interaction necessitates more commuting time, making it more time-consuming and less cost-effective [15].

With the increasing prevalence of Internet usage, digital technology presents new opportunities to support multiple health behaviour interventions among the general public, including the older population [16, 17]. A burgeoning area of research has shifted towards integrating eHealth technologies to facilitate more individualized, cost-effective, and manageable interventions for changing multiple health behaviours [18–20]. The global trend of population ageing results in a rising demand for long-term healthcare and escalating costs for public health [21]. In this context, eHealth has emerged as a solution for promoting various health behaviours [22]. Moreover, the high dropout rate presents a significant challenge in any eHealth intervention program, as a considerable proportion of participants discontinue engagement with the program during the intervention period [17]. Seceding the program prematurely significantly diminishes the maximum benefits participants can derive from health interventions and undermines the achievement of the program's ultimate goals [16]. According to a government report, while many older adults in Hong Kong have Internet access, they face challenges using smartphones. Many perceive eHealth as complex and not user-friendly. The difficulty is partly due to their introduction to technology later in life, as they lacked access to digital education in their youth, which hampers their ability to adapt to rapidly changing mobile functions [23]. Consequently, older adults may struggle with stand-alone eHealth interventions. Nevertheless, eHealth can serve as an effective complement to traditional face-to-face interventions.

In recent years, a health treatment format known as blended intervention combines both face-to-face and eHealth interventions into one integrated treatment [24, 25]. It is considered an innovative approach to delivering health treatment designed to address the shortcomings of stand-alone interventions [25]. The blended intervention has been widely implemented among individuals with mental disorders, as well as populations experiencing overweight/obesity and individuals with various diseases, including adults with familial hypercholesterolemia, hypertension, and type 2 diabetes [26]. A recent review and meta-analysis have demonstrated

that the face-to-face and eHealth blended interventions yield preliminary success in increasing total physical activity levels and enhancing diet quality among adults, compared with the control group (e.g., usual care, face-to-face sessions) [26]. However, limited research has explored whether blended interventions are more effective than stand-alone face-to-face intervention, and target the older population.

To the best of our knowledge, no research has explored the effectiveness of blended interventions in promoting PA and diet among community-dwelling older adults in Hong Kong. Therefore, it is imperative to contribute evidence to evaluate the effects of blended interventions within the Hong Kong context and to develop new treatments that can effectively promote healthy lifestyles among older adults in Hong Kong.

The objectives of this study were to evaluate the feasibility and effectiveness of the blended intervention program among older adults. The hypothesis was that participants in the blended intervention group would improve PA, diet behaviours (fruit and vegetable intake [FVI] and meat, fish, egg, and alternatives intake [MFEAI]), adherence to multiple behaviour guidelines, physical fitness, mental health outcomes (depression and loneliness), and health-related quality of life (HRQoL), compared to a traditional face-to-face group and a control group.

Method

Study design, procedure, and participants

The current study was a single-blinded, randomized controlled trial (RCT). The target population was Hong Kong community-dwelling older adults. Participants were recruited and randomly assigned into one of three groups with a 1:1:1 allocation ratio: a blended face-to-face and eHealth intervention group (IG-1), a stand-alone face-to-face intervention group (IG-2), and a control group (CG). In addition, participants were asked to finish the assessments at pre-test (T1), post-test (T2), and three-month follow-up tests after intervention completion (T3) in the senior centres or nearby sports venues. The study flow is presented in Fig. 1. Outcome assessors are blinded from the assignment results to the intervention. They were informed only about when, where, and for whom they would collect outcome data and were unaware of an assigned intervention for participants. This study was conducted and reported following the CONSORT 2010 Statement [27] and has been retrospectively registered on the ISRCTN (Registration ID: ISRCTN32329348). The protocol was already published [28].

From 1 March 2023 until 1 April 2023, participants were recruited from two Senior Centers in Hong Kong. The e-poster and video were designed by the researchers and advertised by the staff in the Senior Centers. The participants should: [1] be aged 65 years and above; [2] own a smartphone and have access to the Internet; [3] pass the Physical Activity Readiness Questionnaire (PAR-Q); [4] have sufficient reading and listening skills in Cantonese; and [5] at least one health behaviour (PA, FVI, MFEAI) fails to meet the recommended health guideline. Exclusion criteria included: [1] under special situations that seriously affected their diet (e.g., oral allergy syndrome) and mobility (e.g., physical disability); [2] participating in other ongoing projects related to PA and diet intervention.

After finishing all the registration and eligible screening, they received the study consent forms. Then, all the participants were randomly allocated to one of three groups, including IG-1, IG-2, and CG. Randomization was conducted using Excel software. In particular, all eligible participants were assigned a unique identification number (e.g., from 1 to 132). Then, a random number between 0 and 1 was generated for each participant by entering the formula "= RAND ()" next to their assigned ID using Excel software. The random numbers generated were sorted in ascending order, which determined the randomization sequence of the participants. Subsequently, based on a 1:1:1 allocation ratio, the first one-third of participants were assigned to the IG-1, the middle one-third to the IG-2, and the final one-third to the CG. This randomization process was conducted independently by a research team member who would not be involved in the intervention implementation and data collection.

The sample size was calculated using G*Power 3.1 software. For achieving a medium effect size (Cohen's f 0.26) on PA and diet based on a previous similar blended study among adults [29], with a statistical power (1-β) of 0.8 and an alpha of 0.05 [30], a total of 91 participants is required for the three groups (IG-1, IG-2, and CG). Considering the dropout rate of approximately 20%, a total of $N = 114$ participants is required to enable a robust evaluation.

Intervention

The intervention has been described in greater detail in our previously published protocol [28]. According to previous blended intervention studies on promoting PA and diet among young adults, a 6-week blended intervention indicated significant improvement in diet outcomes [31], and an 8-week blended intervention indicated significant improvement in PA level [32]. Considering that older adults may need more time to improve their PA and diet from blended intervention as well as the feasibility of program implementation in older adults, the minimum intervention period of 10 weeks was adopted in this study. The brief descriptions of the intervention are as follows.

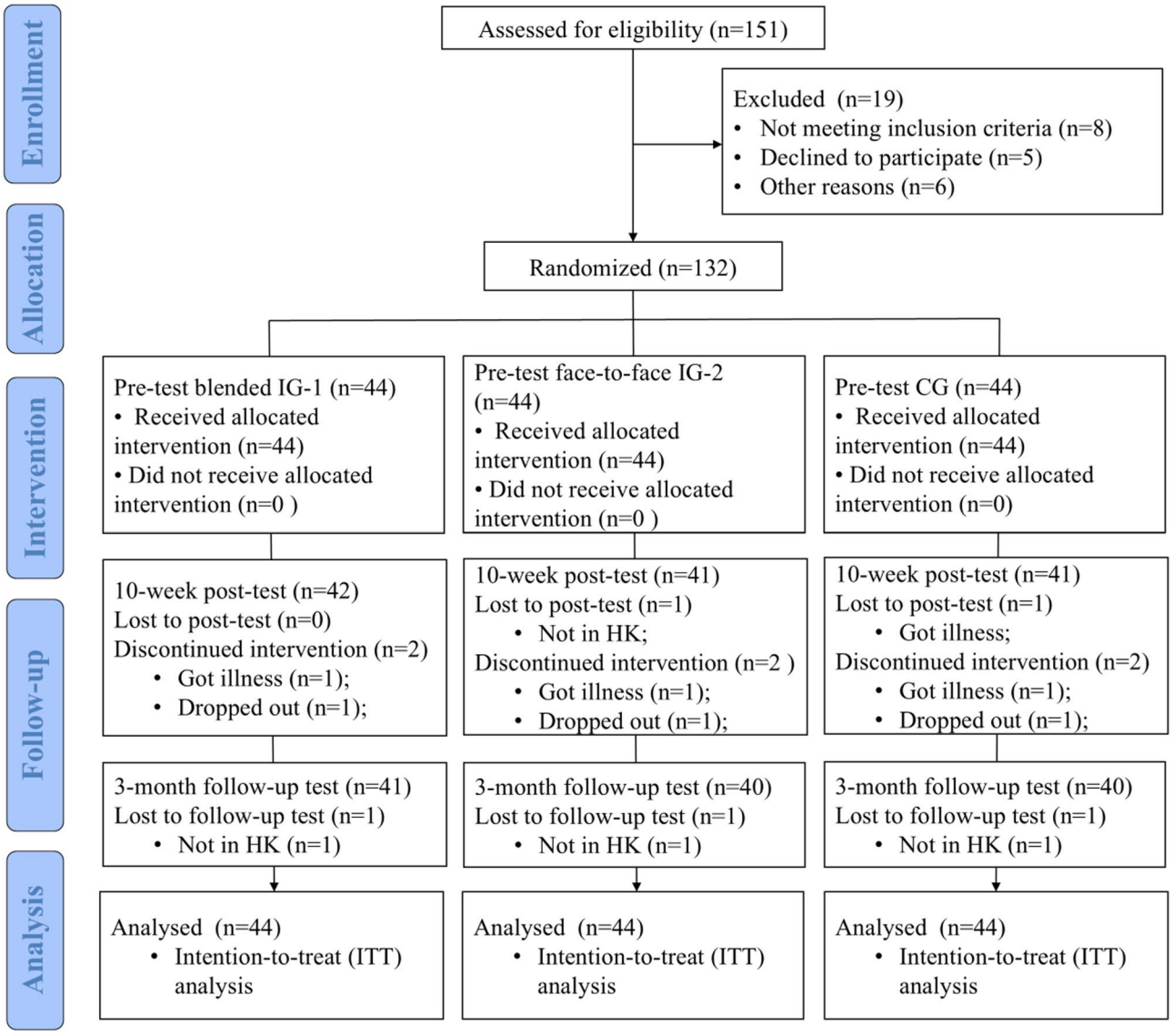

Fig. 1 Study flow CONSORT diagram

Face-to-face intervention group

The participants in the face-to-face intervention group engaged in two 60-minute sessions per week, including one session for PA at the sports venue and one for diet at the neighbourhood senior centre [33] for ten weeks. Each PA session consisted of two parts: health education on PA and health (10 min) and physical exercise (50 min). Each session included a warm-up exercise (5 min), a main exercise (40 min), and a cool-down exercise (5 min). The main activity consisted of diverse components such as aerobic training, resistance training, balance training, and mindfulness meditation training. If the participants had questions, feedback was given during the PA courses. Each PA session was delivered by a PA coach with the assistance of two to four research assistants to ensure safety and feasibility.

Each diet session consisted of two parts: health education on a diet (30 min) and nutrition counselling (30 min). The education topics, such as dietary fibre, cholesterol, fruits and vegetables, and red and white meat, were developed based on suggestions from a nutritionist. The nutrition counselling included a 15-minute group discussion with 3–4 participants in one group to design daily dishes and 15 min of dish sharing. Personalized nutritional advice was offered by the nutritionist accordingly. Each diet session was delivered by a nutritionist with the assistance of one research helper.

Blended intervention group

Participants in the blended group engaged in two types of intervention activities, including (1) attending two 60-minute sessions per week for ten weeks: one session

focused on PA at the gym and the other on dietary education at the neighbourhood senior centre, same as that applied to the face-to-face group; (2) attending two supplementary behavioural change promotion eHealth intervention courses per week for ten weeks: one online session for PA and one online session for diet.

A mobile-based website, namely Perfect Diet and Exercise, was established to facilitate the eHealth intervention. Participants accessed the eHealth website through the web link provided by researchers. The website's homepage included the PA module and the diet (FVI and MFEAI) module. Each module consisted of two sections. (i) Sect. 1 comprised a theory-based (Health Action Process Approach; HAPA)) [34] 10-week intervention courses targeting social-cognitive predictors of PA/diet (FVI and MFEAI). In alignment with HAPA, various behaviour change techniques (BCTs) were employed as integral intervention components to facilitate behavioural modification (see Table S1) [34]. Participants were required to access this section once a week and they can sequentially enter the weekly course after completing the previous weekly course. Each online course for PA and diet can be finished in about 15 min respectively. (ii) Sect. 2 was a data repository platform collecting former exercise and diet records. Participants can access their files at any time throughout the 10-week intervention period, including behaviour records of PA/diet, action planning of PA/diet, coping planning of PA/diet, and "my diary" about PA/diet behaviours.

To ensure participants can engage in eHealth intervention efficiently, participants' online courses learning PA and diet in the first two weeks were guided by a research assistant and student helpers and conducted immediately after participants completed the face-to-face sessions for PA (at the sports venue) and for diet (at the neighbourhood senior centre). Sequentially, participants were asked to complete online courses independently in the following eight weeks.

Control group

The participants in the control group received a biweekly telephone call. Each call lasted about 5 min. The participants were given special attention by asking several health-related questions, such as "Has your physical activity changed in the last two weeks?", "If it changed, what are the reasons for the increase or decrease?" "Have you changed your diet in the last two weeks?" "What has changed? What are the reasons for the increase or decrease if it changed?".

Measures

Feasibility was evaluated using several indicators, including (1) adherence rate (% of completing three assessments). The criterion was set as 70.0% [35]; (2) attendance rate (% of scheduled sessions attended by participants). The criterion was set as 70% [36]; (3) acceptability of the intervention program was assessed by a 10-item self-reported questionnaire in a blended intervention group [37]. Answers were given a 5-point Likert scale ranging from strongly disagree "1" to strongly agree "5".

The waist-worn accelerometer was used to objectively assess PA (wGT3X+, ActiGraph Inc, Pensacola, FL, USA). To evaluate the Fruit and Vegetable Intake (FVI) and Meat, Fish, Egg and Alternatives Intake (MFEAI) over the past seven days, participants were instructed to complete a diet record booklet. They recorded the number of portions of fruit, vegetables, and fruit and vegetable juice consumed each day. A detailed description of measuring PA, FVI and MFEAI by using reliable and valid measuring tools can be found in our published protocol [28].

In terms of adherence to multiple behaviour recommendations (two and three out of PA, FVI, and MFEAI), meeting less than two of three behaviour guidelines was coded as "0", while meeting two or three behaviour guidelines was coded as "1". The recommended health guideline of PA is that MVPA ≥ 150 min/week [38]. The recommended health guideline for FVI is that FVI should be ≥ 5 portions/day [39]. The recommended health guideline of MFEAI is 5–6 taels/day (equal to 189.0–226.8 g/day) [40].

The Senior Fitness Test Manual was applied to assess the physical fitness of participants [41]. The physical fitness testing includes measurements of muscular strength (lower and upper body), aerobic endurance, flexibility (lower and upper body), agility and dynamic balance, and body mass index (BMI). Mental health outcomes consist of the Geriatric Depression Scale 15-item (GDS-15) - Cantonese Version, which was used to assess depression among participants [42, 43], and the Chinese translation of the 6-item De Jong Gierveld Loneliness Scale, which was applied to assessing loneliness [44]. The Hong Kong brief version of the World Health Organization's Quality of Life questionnaire (WHOQOL-BREF [HK]) was employed to assess the Health-Related Quality of Life (HRQoL) [45]. A detailed description of measuring physical fitness, depression, loneliness, and HRQoL by using reliable and valid measuring tools can be found in our published protocol [28].

The sociodemographic encompassed gender, age, marital status, educational level, professional status, household income, and history of chronic diseases. Sociodemographic data was exclusively gathered at the baseline data collection (T1). All other outcomes were assessed at T1 (baseline pre-test), T2 (10-week post-test), and T3 (follow-up test).

Assessors were trained before each test to ensure all the assessments would go smoothly. There were mock tests

and brief training for all the assessors. The researcher supervised all the mock tests. Any mistakes found during the briefing were corrected. Regarding blood sample collection, the assessors got professional guidance and training. The detailed practical manual was disseminated to all the assessors, including all the outcomes.

Data analysis

All data was analyzed by SPSS 29.0. The intention-to-treat principle (ITT) was used for all analyses. All variables were checked for missing values. Missing Completely at Random (MCAR) test was used to recognize missing values in the data by employing Little's test; the p-value was insignificant ($p > 0.05$), indicating that random reasons caused the existence of missing values. As it belonged to MCAR, the expectation-maximization (EM) method was adopted to impute the missing data within each measurement point in time [46]. For the missing data from the dropouts, the values were imputed with the last observed data [47–49].

Independent samples included continuous and categorical variables. The normality of data distribution was assessed using kurtosis and skewness statistics. For data that was non-normal distribution, a logarithmic transformation was applied before conducting descriptive statistics. Descriptive statistics (e.g., mean, standard deviation, number, and percentage) were used to describe the feasibility indicators and baseline characteristics. The F-tests and Chi-square analysis were used to compare the baseline characteristics at T1 across three groups. The Statistical significance was established at the 5% level (two-tailed).

A series of generalized linear mixed models (GLMM) were applied to evaluate the intervention effects on dependent variables (regression coefficient, B; determining odds ratio, OR), including behaviours (PA, FVI, and MFEAI), adherence to single health behaviour guideline (PA, FVI, and MFEAI) and multiple health behaviour guidelines (meet two or three health behaviour guidelines), physical fitness, mental health outcomes (depression and loneliness), and HRQoL with time (T1, T2, and T3), groups (IG-1, IG-2, and CG), and their interaction as fixed effects, with individuals as random effects. Where there were significant differences across groups at baseline, the variables were treated as covariates (potential confounders) in the subsequent analyses.

Following the evaluation of the effects of the intervention on behaviours, post-hoc tests were performed using the least significant difference (LSD) method. According to Cohen (1988), Cohen's $d = 0.2$, 0.5, and 0.8 represent small, medium, and large effects, respectively [50].

Results

Feasibility

At T1, data were collected from 132 older adults, with 124 completing data collection at T2 and 121 completing data collection at T3. Within the IG-1 and CG, 40 out of 44 older adults (90.9%) adhered to the health program by T3. In the IG-2, 41 out of 44 older adults (93.2%) adhered to the health program by T3. The adherence rate from T1 to T3 was 91.7% (121/132), more than 70%.

Regarding attendance rates for face-to-face and eHealth sessions, participants in IG-1 attended an average of 88.9% of PA face-to-face sessions and over 90.0% of diet face-to-face sessions. The majority of participants (88.6%, 39/44) in IG-1 finished all eHealth PA and diet sessions. Participants in IG-2 attended an average of 91.4% of PA face-to-face sessions and 90.2% of diet face-to-face sessions. Overall, participants engaged in an average of 90.1% of all face-to-face sessions, exceeding the predetermined threshold of 70%.

In terms of the acceptability of the intervention program, results indicated that the participants of the blended intervention group were satisfied with the health programs, achieving a mean score of 4.7 out of 5.0. In particular, the average score was 4.8 out of 5 for the following items: whether this project increased their understanding of health behaviours (item 3) and the overall evaluation of this health project (item 10). The average score was 4.7 out of 5 for the following items: whether this project enhanced their health behaviours (item 1), whether this project motivated them to maintain health behaviours (item 2), professionalism (item 7) of the information and advice provided on health behaviours, the arrangement of the implementation (item 8), and the rigour and responsibility of the implementation (item 9). Regarding whether this project had a great impact on their life (item 4), the usefulness (item 5), and comprehensibility (item 6) of the information and advice provided on health behaviours, the average score was 4.6 out of 5.

Sample characteristics

A total of 151 older adults finished the registration, and 19 participants were excluded, including 8 people who did not meet the inclusion criteria, 5 people who declined to participate, and 6 people who dropped out because of other reasons. All eligible 132 older adults were randomly assigned to one of the three groups, with 44 participants in each group.

Of the 132 participants who finished the baseline data collection (See Table 1), the age range was from 65 to 80 years ($M = 72.5$ years, $SD = 3.92$). The majority of the participants (81.1%, 107/132) were female. Less than half (47.0%) of participants were married. The majority (82.6%) of the participants had at least one child. Over

Table 1 Baseline characteristics of participants randomized to the blended, face-to-face, and control groups

Variables	IG-1 (*N* = 44)	IG-2 (*N* = 44)	CG (*N* = 44)	Total (*N* = 132)	F/χ^2	*p*
Age (years) *Mean (SD)*	72 (4.06)	73.07 (3.95)	72.3 (3.77)	72.5 (3.92)	0.87	0.422
Gender*N (%)*					0.69	0.708
Male	8 (18.2)	7 (15.9)	10 (22.7)	25 (18.9)		
Female	36 (81.8)	37 (84.1)	34 (77.3)	107 (81.1)		
Marital status*N (%)*					3.36	0.499
Single	11 (25.0)	8 (18.2)	5 (11.4)	24 (54.6)		
Married	19 (43.2)	19 (43.2)	24 (54.5)	62 (40.9)		
Divorced/Widowed	14 (31.8)	17 (38.6)	15 (34.1)	46 (4.5)		
Whether have children*N (%)*					1.37	0.504
No	10 (22.7)	7 (15.9)	6 (13.6)	23 (17.4)		
Yes	34 (77.3)	37 (84.1)	38 (86.4)	109 (82.6)		
Educational level*N (%)*					8.68	0.070
Below middle school	18 (40.9)	22 (50.0)	13 (29.5)	53 (40.2)		
Middle school	23 (52.3)	17 (38.6)	20 (45.5)	60 (45.4)		
Above middle school	3 (6.8)	5 (11.4)	11 (25.0)	19 (14.4)		
Professional status*N (%)*					5.93	0.204
Employed	1 (2.3)	1 (2.3)	1 (2.3)	3 (2.3)		
Retired	42 (95.4)	38 (86.4)	35 (79.5)	115 (87.1)		
Unemployed	1 (2.3)	5 (11.4)	8 (18.2)	14 (10.6)		
Household income*N (%)*					10.17	**0.006****
< 10,000 HKD	38 (86.4)	40 (90.9)	29 (65.9)	107 (81.1)		
≥ 10,000 HKD	6 (13.6)	4 (9.1)	15 (34.1)	25 (18.9)		
History of chronic diseases*N (%)*					2.65	0.266
Yes	29 (65.9)	22 (50.0)	23 (52.3)	74 (56.1)		
No	15 (34.1)	22 (50.0)	21 (47.7)	58 (43.9)		
Number of guidelines met*N (%)*					3.94	0.414
None	12 (27.3)	14 (31.8)	19 (43.2)	45 (34.1)		
One of three	23 (52.3)	24 (54.6)	21 (47.7)	68 (51.5)		
Two of three	9 (20.4)	6 (13.6)	4 (9.1)	19 (14.4)		
Behaviours*Mean (SD)*						
MVPA (minutes/week)	186.68 (1.09)	190.62 (1.39)	156.04 (128.05)	177.78 (1.26)	0.99	0.373
FVI (portions/day)	4.05 (1.20)	4.04 (1.20)	3.94 (1.29)	3.87 (0.01)	0.25	0.781
MFEAI (taels/day)	4.64 (1.36)	3.98 (1.33)	4.38 (1.66)	4.33 (1.47)	2.26	0.108

Note. IG-1, a blended face-to-face and eHealth intervention group, IG-2. Stand-alone face-to-face intervention group. MVPA = moderate-to-vigorous physical activity (mins/week); FVI = fruit and vegetable intake (portions/day); MFEAI = meat, fish, egg, and alternatives intake (taels/day); PA Guideline = moderate-to-vigorous physical activity (MVPA) ≥ 150 min/week; FVI Guideline = fruit and vegetable intake (FVI) ≥ 5 portions/day; MFEAI Guideline = meat, fish, egg, and alternatives intake 5–6 taels/day

85% of participants were retired. Over 80% (107/132) of participants reported they had less than 10,000 HKD income per month. Over half (56.1%) of the participants said they were suffering from one chronic disease (such as diabetes and hypertension).

There were 34.1% (45/132) of participants who met neither the PA nor the diet (FVI and MFEAI) guidelines. 51.5% (68/132) of participants met only one of three health guidelines, and only 14.4% of participants met two of three health guidelines.

There were no significant differences across the three groups at baseline concerning demographics, behaviours, adherence to health guidelines, physical health outcomes, mental health outcomes, and health-related quality of life, except household income ($\chi^2 = 10.17$, $p = 0.006$).

Evaluation of time and treatment on PA, FVI, MFEAI and adherence to multiple behaviour guidelines

Table 2 presents the findings of the evaluation of intervention effects on weekly MVPA, daily FVI, daily MFEAI, and adherence to multiple behaviour guidelines. In terms of MVPA behaviour, no significant time and group interaction effect was found ($F_{4,384} = 1.45$; $p > 0.05$). In addition, participants in the blended group conducted significantly more MVPA per week compared with those in the control group at T3, with a small effect size ($p < 0.05$, Cohen's $d = 0.21$).

In terms of FVI, a significant time and group interaction effect was found ($F_{4,384} = 7.4$, $p < 0.001$). Participants in the blended intervention group consumed significantly more fruit and vegetables per day compared with those in face-to-face and control conditions at T2 and T3 (all

Table 2 Results of the generalized linear mixed models with MVPA, FVI, MFEAI, and adherence to multiple behaviour guidelines at post-test and follow-up test as outcome measures (N = 132)

Time and Group	MVPA			FVI			MFEAI			Adherence to multiple behaviour guidelines	
	Value	p	Cohen'sd	Value	p	Cohen'sd	Value	p	Cohen'sd	Value	p
Type III test, ***F*** Time * Group	1.45	0.218	N/A	7.40***	< 0.001	N/A	5.52***	< 0.001	N/A	0.74	0.563
Group	2.43	0.089	N/A	7.87***	< 0.001	N/A	13.18***	< 0.001	N/A	10.98***	< 0.001
Time	2.03	0.132	N/A	20.31***	< 0.001	N/A	17.95***	< 0.001	N/A	9.84***	< 0.001
Post-test (T2), mean difference										**OR**	
Blended vs. Control	27.67	0.337	0.37	1.07***	< 0.001	0.91	1.41***	< 0.001	1.04	1.81	0.457
F2F vs. Control	-17.23	0.550	0.11	0.01	0.965	0.07	0.30	0.378	0.06	0.56	0.499
Blended vs. F2F	44.91	0.120	0.23	1.06***	< 0.001	0.91	1.11***	< 0.001	1.16	3.22	0.120
Follow-up test (T3), mean difference										**OR**	
Blended vs. Control	60.68*	0.049	0.21	0.94***	< 0.001	0.82	0.99**	0.001	0.77	1.74	0.493
F2F vs. Control	28.72	0.350	0.38	-0.15	0.527	0.07	0.07	0.819	0.20	1.11	0.899
Blended vs. F2F	31.96	0.298	0.15	1.10***	< 0.001	1.00	0.92**	0.002	1.18	1.56	0.544

Note: MVPA = moderate-to-vigorous physical activity (mins/week); FVI = fruit and vegetable intake (portions/day); MFEAI = meat, fish, egg, and alternatives intake (taels/day); Adherence to multiple behaviour guidelines: meeting less than two of three behaviour guidelines (for PA, FVI and MFEAI) was coded as 0 while meeting two or three behaviour guidelines was coded as 1. OR = Odd Ratio; F2F = face-to-face

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

$p < 0.001$), with large effect sizes (Cohen's $d = 0.82\text{-}1.00$). In particular, after the 10-week intervention (T2), the blended group ate more portions of fruit and vegetables per day than the face-to-face group ($p < 0.001$, Cohen's $d = 0.91$) and control group ($p < 0.001$, Cohen's $d = 0.91$). After the 3-month follow-up (T3), the blended group reported more fruit and vegetable intake per day than the face-to-face group ($p < 0.001$, Cohen's $d = 1$) and control group ($p < 0.001$, Cohen's $d = 0.82$). The results also indicated that the face-to-face and control groups did not differ significantly from each other in FVI at T2 and T3 ($p > 0.05$).

In terms of MFEAI, a significant time and group interaction effect was found ($F_{4,384}$ = 5.52, $p < 0.001$). Participants in the blended intervention group consumed significantly more MFEA per day compared with those in face-to-face and control conditions at T2 and T3 (all $p < 0.01$), with large effect sizes (Cohen's $d = 0.77–1.18$). In particular, after the 10-week intervention (T2), the blended group ate more MFEA per day than the face-to-face group ($p < 0.001$, Cohen's $d = 1.16$) and control group ($p < 0.001$, Cohen's $d = 1.04$). After the 3-month follow-up (T3), the blended group reported more MFEA consumption per day than the face-to-face group ($p < 0.001$, Cohen's $d = 1.18$) and the control group ($p < 0.001$, Cohen's $d = 0.77$). The results also indicated that the face-to-face and control groups did not differ significantly from each other in MFEA at T2 and T3 ($p > 0.05$).

To further explore the extent to which kind of intervention predicted adherence to the multiple behaviour guidelines at T2 and T3, the GLMM with binary logistic regression model was conducted. The findings indicated no significant between-group difference at T2 and T3 among three groups ($p = 0.457–0.899$).

Evaluation of time and treatment on health outcomes

Table 3 presents the findings of the evaluation of intervention effects on physical fitness. Significant time and group interaction effects were found on lower body strength ($F_{4,384}$ = 9.64, $p < 0.001$) and agility and dynamic balance ($F_{4,384}$ = 4.95, $p < 0.001$). In terms of lower body strength, participants in the blended group showed a significant decline in lower body strength compared with those in the control group at T2 (mean difference = -0.61, $p < 0.01$), with a large effect size (Cohen's d = 1.05). Then, participants in the blended group showed significantly better lower body strength compared with those in the control group at T3 ($p < 0.01$), with small effect sizes (Cohen's $d = 0.02$). In addition, participants in the face-to-face group showed significant improvement in lower body strength compared with those in the control group at T2 ($p < 0.01$, Cohen's $d = 1.00$) and T3 ($p < 0.001$, Cohen's $d = 1.18$). No significant differences were found between the two intervention groups at T2 and T3. In

Table 3 Results of the generalized linear mixed models with 7 items of physical fitness at post-test and follow-up test as outcome measures ($N = 132$)

Time and Group	Item 1		Item 2		Item 3		Item 4		Item 5		Item 6		Item 7	
Time * Group	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***
	0.72	0.581	9.64***	0.000	1.05	0.380	0.75	0.557	1.50	0.201	0.47	0.759	4.95***	0.001
Group	0.18	0.835	14.11***	0.000	4.07*	0.018	2.61	0.075	1.74	0.177	0.53	0.591	1.92	0.148
Time	8.82***	0.000	23.01***	0.000	3.22*	0.041	8.97***	0.000	3.20*	0.042	9.27***	0.000	17.58***	< 0.001
Post-test (T2)	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**
Blended vs. Control	0.01	0.03	-0.61**	1.05	-0.90	0.62	2.66	0.35	2.91	0.48	-1.94	0.09	-0.66*	0.40
F2F vs. Control	-0.20	0.13	0.67***	1.00	2.59	0.70	0.77	0.21	2.74	0.23	0.22	0.01	-0.28	0.10
Blended vs. F2F	0.21	0.08	-1.29	0.10	-3.49	0.13	1.89	0.11	0.16	0.19	-2.16	0.10	-0.38	0.25
Follow-up (T3)	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**
Blended vs. Control	-0.17	0.02	3.69***	0.02	-1.26	1.25	5.04	0.53	2.39	0.52	-0.78	0.19	-1.08***	0.74
F2F vs. Control	-0.33	0.09	1.80***	1.18	2.56	0.74	6.78	0.53	3.07*	0.26	1.28	0.10	-0.78**	0.44
Blended vs. F2F	0.16	0.09	1.90	0.46	-3.82*	0.05	-1.74	0.22	-0.68	0.15	-2.06	0.11	-0.31	0.31

Note: Item 1 = BMI (body weight/(body height)^2), Item 2 = 30-second Chair Stand Test (times), Lower body strength; Item 3 = 30-second Arm Curl Test (times), Upper body strength; Item 4 = 2-minute Step Test (times), Aerobic endurance; Item 5 = Chair Sit-and-Reach Test (cm), Lower body flexibility; Item 6 = Back Scratch Test (cm), Upper body flexibility, Item 7 = 8-Foot Up-and-Go Test (second), Agility and dynamic balance; MD = mean difference (T2 - T1) or (T3 – T1); ES = effect size of Cohen's *d*; F2F = face-to-face

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

terms of agility and dynamic balance, participants in the blended intervention showed more improvement in agility and dynamic balance compared with the control group at T2 ($p < 0.01$, Cohen's $d = 0.40$) and T3 ($p < 0.001$, Cohen's $d = 0.74$). Participants in the face-to-face group also indicated more improvement in agility and dynamic balance compared with the control group at T3 ($p < 0.01$, Cohen's $d = 0.44$).

Table 4 presents the findings of the evaluation of intervention effects on mental health outcomes (depression and loneliness) and health-related quality of life (HRQoL). The results reveal that there was no significant mental health status change over time between the three groups at T2 and T3 ($p > 0.05$, Cohen's $d = 0.05–0.62$). A significant time and group interaction effect was found on HRQoL ($F_{4,384}$ = 2.90, $p = 0.022$). The participants receiving the blended ($p < 0.05$, Cohen's $d = 0.18$) and face-to-face ($p < 0.01$, Cohen's $d = 0.15$) intervention reported significant improvement in HRQoL compared with the control group at T3.

Discussion

Principal findings

In the present study, a 10-week blended face-to-face and eHealth intervention was developed to improve PA, diet behaviour, and health outcomes (agility and dynamic balance, and quality of life) among community-dwelling older adults in Hong Kong. The main purpose of this study was to examine the feasibility and effectiveness of the intervention, including comparing the effects on PA, dietary behaviour (FVI and MFEAI), adherence to PA and a healthy diet (FVI and MFEAI), and health outcomes between three groups (blended intervention group, face-to-face intervention group, and control group).

Notably, participants in this study were heavily engaged in both blended and stand-alone face-to-face intervention groups with high adherence rates (> 90%) and high sessions of face-to-face and eHealth attendance rates (> 88%). In addition, participants reported higher mean scores (4.7 out of 5) on the program acceptability. The results support the feasibility of the intervention.

The finding regarding MVPA was consistent with the findings of a previous meta-analysis indicating no significant difference between the blended and control groups [26]. One possible reason for this is that more than half of the participants in the blended and face-to-face intervention groups had already met the recommendations for MVPA at baseline (IG-1: 186.7 min/week, IG-2: 190.6 min/week). In this study, the recommendation used regarding PA was at least 150 min of MVPA per week. If participants feel that they are already sufficiently active, interventions aimed at increasing their PA levels may be marginalized or ignored [29]. Future research should also focus on optimizing the combination of face-to-face and

Table 4 Results of the generalized linear mixed models with depression, loneliness and HRQoL at post-test and follow-up test as outcome measures ($N = 132$)

Time and Group	Depression		Loneliness		HRQoL	
	F	***p***	***F***	***p***	***F***	***p***
Time * Group	1.49	0.203	0.85	0.496	2.90*	0.022
Group	3.42*	0.034	0.22	0.806	0.61	0.544
Time	8.28***	0.000	4.92**	0.008	3.81*	0.023
Post-test (T2)	**MD**	**ES**	**MD**	**ES**	**MD**	**ES**
Blended vs. Control	-0.53	0.48	-0.40	0.22	0.19	0.13
F2F vs. Control	-0.11	0.17	-0.34	0.02	0.12	0.16
Blended vs. F2F	-0.42	0.62	-0.05	0.19	0.07	0.28
Follow-up test (T3)						
Blended vs. Control	-0.50	0.43	-0.23	0.10	0.21*	0.18
F2F vs. Control	-1.24	0.20	-0.53	0.14	0.30**	0.15
Blended vs. F2F	0.74	0.24	0.30	0.05	-0.09	0.02

Note: MD = mean difference (T2 - T1) or (T3 – T1); ES = effect size of Cohen's *d*; F2F = face-to-face

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

eHealth interventions. For instance, it is essential to identify which behaviour change techniques (BCTs) are more effective in face-to-face settings and which are better suited to eHealth platforms, and then explore the optimal integration of these methods. Additionally, examining how blended interventions influence behaviour change through various mechanisms—such as the roles of social support, feedback, and incentives—can contribute to the development of the most effective strategies for promoting sustained behaviour change.

Significant effects of the intervention on dietary behaviour (FVI and MFEAI) were identified, which were consistent with the findings of previous studies [51, 52]. The blended group indicated significantly more improvement in diet behaviours than the face-to-face and control group, while a previous meta-analysis indicated no significant difference in the effects on FVI between the blended intervention group and the control group [26]. Previous reviews have suggested that it is crucial to have accurate and helpful knowledge about a healthy diet to enable people to make appropriate choices to consume a healthy diet [53]. The results of this study indicated that education may not be enough to improve dietary behaviour, as no significant difference was found between the face-to-face intervention group and the control group. eHealth interventions are effective at promoting healthy dietary behaviours among older adults [19]. The application of eHealth technologies in health promotion and primary prevention among older adults has been investigated. eHealth technology has been utilized in various health promotion programs among older adults, offering alternatives to traditional face-to-face interactions for monitoring and improving their health [54, 55]. The findings of the present study support the effectiveness of eHealth as a supplementary intervention to traditional face-to-face interventions in improving the dietary behaviours of older adults.

No time-by-group interaction effect was found for adhering to multiple health behaviour guidelines. Further studies are needed to provide convincing support on the effectiveness of blended intervention in promoting multiple health behaviours among older adults. Limited blended intervention studies reported significant improvements in multiple health behaviours (PA and diet) [51, 52]. The majority of the findings from prior blended interventions indicate that only a single health behaviour was promoted [29, 56–60]. Previous studies only reported whether behaviours were improved but did not explore whether health behaviours reached health standards. Accordingly, the current study adds to the evidence by closing this gap.

Compared with the control group, significant effects in the two intervention groups were observed for lower body strength as well as agility and dynamic balance at

the follow-up test, implying physical exercise sessions in the intervention groups may play an important role in producing sustained benefits on certain physical fitness. Participants in the blended group showed a significant decline in lower body strength compared with those in the control group at the post-test. This unexpected result may be explained by potential factors such as the unwell health status of some participants in the blended group during the post-test. Further study to closely monitor participants' health status at the measurement time point should be warranted. No significant effect was found for BMI, which is inconsistent with the findings of a previous meta-analysis [26]. Previous blended interventions showed significant effectiveness in reducing BMI in the obese population [61–64]. One meta-analysis indicated that a nutritional intervention combined with exercise (resistance training) had no additional effects on physical fitness among older adults than the diet-alone intervention [65]. The frequency of the PA sessions and the duration of the intervention in this study might lead to no significant effect on the between-group differences in physical fitness tests. Engaging in MPA or resistance-based PA once or twice a week has been shown to help maintain good physical fitness among healthy older adults [66]. For optimal effects, 30–45 min of multimodal exercise combined with moderate-to-high-intensity progressive resistance training and functional balance and mobility training is recommended at least twice a week to promote the physical fitness of older adults [67]. Moreover, the majority of interventions that aimed at enhancing the physical function of older adults by combining PA and diet lasted 12 weeks [68]. The findings of the current study indicate that short-term and low-frequency PA interventions can also enhance the agility and dynamic balance of older adults. Future studies should evaluate the optimal intensity and duration of the intervention to promote physical fitness among older adults.

Previous systematic reviews have demonstrated that blended interventions are effective treatments for people with mental disorders [25]. The current study demonstrate no significant impact on mental health outcomes. One possible reason is that the participants in this study already had good mental health status at the baseline assessment, such that a large improvement or change in mental health outcomes was not observed due to a roof effect. Such findings were consistent with the previous blended intervention studies targeting adults without mental health problems [52, 63].

The significant effect of the interventions on HRQoL was inconsistent with the findings of previous blended intervention studies [52, 69]. The findings of the current study indicated that the blended intervention and the traditional face-to-face intervention had significantly more residual effects on improving HRQoL than the control condition among older adults. Consistent participation in PA and a healthy diet have been found to improve HRQoL, implying that such a healthy lifestyle might have a beneficial influence on both physical and mental health, which in turn enhances HRQoL [70–72]. More studies should be conducted to provide evidence.

Limitations and future directions

This study had some limitations that should be noted to give suggestions for improvements in future studies. First, despite best efforts to recruit a diverse sample of participants, there was an overrepresentation of those with low household income and female participants. In the future, the advertisement could aim to also better address individuals from high household income groups and men. Second, even though the food booklet gave a detailed demonstration about how to count fruit and vegetable portions and taels of meat, fish, egg, and alternative consumption, the subjective self-reported data might have led to a bias. In the future, more reliable nutrition behaviour measures could be collected such as sensory-based technology. Finally, self-reported questionnaires were used to assess FVI, MFEAI, mental health variables, and HRQoL. Due to the inherent subjectivity of self-reported measures, the influence of personal subjective factors cannot be ruled out.

The present study demonstrated that the blended intervention was more effective in promoting physical activity (PA) and a healthy diet compared to both the stand-alone face-to-face intervention and the control condition. However, whether the blended intervention is superior to a stand-alone eHealth intervention remains unclear and warrants further investigation. Employing multi-group designs (blended group, stand-alone face-to-face group, stand-alone eHealth group, control group) could enable researchers to identify the most effective intervention modalities for promoting lifestyle behaviours among older adults. Given the increasing prevalence of smartphones and internet access, the feasibility and effectiveness of eHealth interventions as a novel strategy for health improvement in older populations should be further explored. Individualized feedback, facilitated by emerging technologies such as artificial intelligence (AI) and machine learning, offers the potential to enhance eHealth interventions through the dynamic adaptation of content and strategies.

Conclusions

This research supports the feasibility of conducting the face-to-face and eHealth blended intervention among Hong Kong community-dwelling older adults. Furthermore, this innovative blended lifestyle intervention had a significant effect in improving diet behaviours, agility

and dynamic balance, as well as the quality of life of older adults, but only descriptively on physical activity. To the best of our knowledge, this is the first study to examine the effectiveness of a blended intervention in improving lifestyle behaviours compared to face-to-face intervention and control conditions among older adults. The theoretical and empirical evidence from this study can guide researchers, healthcare centres, clinicians, and policymakers in their efforts to improve PA, dietary behaviour, and health outcomes among older adults.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Conceptualization, Y.D., M.Y., L.W., S.L., S.Z., and L.C.; methodology, Y.D., and M.Y.; software, M.Y.; validation, Y.D.; formal analysis, M.Y.; investigation, M.Y., Y.W., S.C., and Y.D.; resources, Y.D., M.Y., and W.L.; data curation, M.Y., Y.W., S.C.; writing—original draft preparation, M.Y.; writing—review and editing, M.Y., and Y.D., and S.L.; visualization, M.Y.; supervision, Y.D. All authors have read and agreed to the published version of the manuscript.

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Data availability
The datasets generated during the present study are not publicly available, owing to the risk of disclosure or deduction of private individual information, but they are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
All procedures performed in studies involving human participants were done so following the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study protocol was approved by the Research Ethics Committee of Hong Kong Baptist University (REC/21–22/0485) and was registered on the ISRCTN, ISRCTN32329348. All the participants completed the written informed consent form before the study's commencement.

Consent for publication
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Competing interests
The authors declare no competing interests.

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