Chat-based instant messaging support integrated with brief interventions for smoking cessation: a community-based, pragmatic, cluster-randomised controlled trial

Man Ping Wang, Tzu Tsun Luk*, Yongda Wu, William H Li, Derek Y Cheung, Antonio C Kwong, Vienna Lai, Sophia S Chan, Tai Hing Lam*

Summary

Background Mobile instant messaging apps offer a modern way to deliver personalised smoking cessation support through real-time, interactive messaging (chat). In this trial, we aimed to assess the effect of chat-based instant messaging support integrated with brief interventions on smoking cessation in a cohort of smokers proactively recruited from the community.

Methods In this two-arm, pragmatic, cluster-randomised controlled trial, we recruited participants aged 18 years or older who smoked at least one cigarette per day from 68 community sites in Hong Kong, China. Community sites were computer randomised (1:1) to the intervention group, in which participants received chat-based instant messaging support for 3 months, offers of referral to external smoking cessation services, and brief advice, or to the control group, in which participants received brief advice alone. The chat-based intervention included personalised behavioural support and promoted use of smoking cessation services. Masking of participants and the research team was not possible, but outcome assessors were masked to group assignment. The primary outcome was smoking abstinence validated by exhaled carbon monoxide concentrations lower than 4 parts per million and salivary cotinine concentrations lower than 10 ng/mL at 6 months after treatment initiation (3 months after the end of treatment). The primary analysis was by intention to treat and accounted for potential clustering effect by use of generalised estimating equation models. This trial is registered with ClinicalTrials.gov, number NCT03182790.

Findings Between June 18 and Sept 30, 2017, 1185 participants were randomly assigned to either the intervention (n=591) or control (n=594) groups. At the 6-month follow-up (77% of participants retained), the proportion of validated abstinence was significantly higher in the intervention group than in the control group (48 [8%] of 591 in intervention *vs* 30 [5%] of 594 in control group, unadjusted odds ratio 1·68, 95% CI 1·03–2·74; p=0·040). Engagement in the chat-based support in the intervention group was low (17%), but strongly predicted abstinence with or without use of external smoking cessation services.

Interpretation Chat-based instant messaging support integrated with brief cessation interventions increased smoking abstinence and could complement existing smoking cessation services.

Funding Hong Kong Council on Smoking and Health.

Lancet Digital Health 2019; 1: e183–92

Published Online July 31, 2019 http://dx.doi.org/10.1016/S2589-7500(19)30082-2

See Comment page e153

*Contributed equally

School of Nursing (M P Wang PhD, T T Luk BNurs, Y Wu BSc, W H Li PhD, D Y Cheung PhD, Prof S S Chan PhD) **and School of Public Health** (Prof T H Lam MD), **University of Hong Kong, Hong Kong SAR, China; and Hong Kong Council of Smoking and Health, Hong Kong SAR, China** (A C Kwong LLB, V Lai MPH)

Correspondence to: Dr Man Ping Wang, School of Nursing, University of Hong Kong, Pokfulam, Hong Kong SAR, China **mpwang@hku.hk**

Introduction

Advances in mobile technologies have provided a new avenue for mobile phone-based interventions (mHealth) for smoking cessation. Randomised trials have found mobile text messaging through short message service (SMS) to be effective for smoking cessation,[1,2] primarily by increasing perceived psychosocial support.[3] Whether more interactive and adaptive mHealth platforms, including smartphone apps and social networking tools, could further improve smoking cessation outcomes remains inconclusive.[4–6] Personalised, chat-based support provided in real time by counsellors is an emerging area in mental health care,[7] but no study has yet assessed its effect on smoking abstinence.

Mobile instant messaging apps (eg, WhatsApp, Facebook Messenger, and WeChat) are popular and inexpensive alternatives to SMS for interactive messaging. Our population-based survey[8] found that adults exposed to health information from instant messaging smoked less and were more physically active than those who were not exposed, suggesting that instant messaging might be a viable way of promoting preventive behaviours. Our pilot trial[9] found counsellor-moderated WhatsApp social groups to be effective in preventing relapse among individuals who had recently quit. Our formative qualitative study[10] of community smokers showed that mobile instant messaging is a feasible and acceptable platform for chat-based smoking cessation support.

Available models of treatment for tobacco dependence are mainly reactive and rely on a health-care practitioner to initiate treatment,[11] but novel approaches to engage less-motivated or hard-to-reach smokers have been increasingly studied.[12–14] In Hong Kong, only 31% of daily smokers have ever tried to quit and most current smokers (98%) never sought help from a smoking cessation service.[15] Existing brief intervention models, such as the five-step 5As

Research in context

Evidence before this study

We searched PubMed and Google Scholar for randomised trials of mobile health interventions for smoking cessation published in any language, from database inception to May 31, 2017, using the search terms "mobile phone", "smartphone", "mobile health", "mHealth", "smoking", and "tobacco". We identified a relevant Cochrane review of mobile phone-based interventions in general, three meta-analyses focusing on text-messaging support, a systematic review on smartphone apps, and a systematic review on social media (social networking sites). Few of the reviewed studies included biochemically confirmed abstinence as an outcome. A meta-analysis of six trials (n=7360) reported a moderate effect of mobile phone-based interventions (predominantly text messaging) on biochemically validated abstinence at 6 months, but with substantial heterogeneity. We did an in-depth review of these trials, and we found only two trials (n=6303) reporting a beneficial effect of text messaging on validated abstinence, which was assessed at the end of treatment. Whether the intervention effect could last after the end of treatment has remained uncertain. Nearly all trials included in the meta-analyses involved participants who were recruited by passive means in the community (eg, through advertisements) and were willing to quit within 30 days of randomisation. The findings might not be extrapolated to proactively recruited smokers and those without an interest in quitting at baseline. Evidence on smartphone apps and social media for smoking cessation was inconclusive because most trials were pilot in nature. We found no trial examining the effectiveness of mobile instant messaging for smoking cessation, which was reconfirmed by an updated electronic database search on Feb 28, 2019.

Added value of this study

Our trial showed that chat-based instant messaging support integrated with brief interventions was effective in increasing abstinence among smokers in the community. The proactive intervention model was able to reach a large proportion of smokers with low motivation to quit, in whom the intervention effect seemed to be stronger than in those with higher motivation to quit at baseline. Effective engagement in the chat-based intervention was low but strongly predicted biochemically validated abstinence with or without the use of external smoking cessation services.

Implications of all the available evidence

To our knowledge, we have provided the first robust evidence to support the use of chat-based instant messaging support as a new method for treatment of tobacco dependence. Future trials in different settings are warranted to ascertain the effectiveness of chat-based instant messaging support on quitting. Further improvements should optimise chat-based interventions and explore strategies to increase engagement. Our findings might be useful for providers of treatment of tobacco dependence and policy makers for improving the reach of smoking cessation support to community smokers.

(Ask, Advise, Assess, Assist, and Arrange), mainly target smokers in clinical settings.[11] We modified the 5As and developed a proactive recruitment and intervention model, AWARD (also with five steps: Ask, Warn, Advise, Refer, Do-it-again), delivered by lay counsellors for promoting quitting and uptake of smoking cessation services in smokers in community settings.[16–18] Hong Kong has extensive smartphone penetration (89% in 2017).[15] We developed a chat-based smoking cessation support programme delivered through instant messaging, which was designed to improve abstinence by providing theory-based behavioural support and increasing the use of smoking cessation services.[10] In this trial, we assessed the effect of chat-based instant messaging support, which was integrated with brief interventions from the AWARD model, on abstinence among proactively-recruited smokers from community sites in Hong Kong.

Methods

Study design and participants

For the **study protocol and Quit to Win campaign** see https://sctc.nursing.hku.hk/qtw2017

We did a two-arm, parallel, pragmatic, cluster-randomised, controlled trial nested within a Quit to Win (QTW) smoke-free community campaign, organised by the Hong Kong Council of Smoking and Health.[16–20] Details of the rationale and study protocol were reported elsewhere.[21] Ethical approval was granted by the University of Hong Kong and the Hospital Authority Hong Kong West Cluster Institutional Review Board (UW 17–246).

Participant recruitment took place in 68 community sites, such as shopping malls and housing estates and nearby areas, throughout all 18 districts in Hong Kong. Trained smoking cessation ambassadors, consisting mainly of university students, proactively approached smokers in the community sites, screened their eligibility, and invited them to participate in the trial. The ambassadors also collected written consent from participants at this stage. All smoking cessation ambassadors (48) attended a half-day training workshop, which included an overview of the research study and training in the delivery of baseline interventions, and completed a test of their knowledge, attitude, and practice before participant recruitment. A member of the research team oversaw the recruitment at each community site and provided support to the ambassadors as needed. Participants were Hong Kong residents aged 18 years or older who had smoked at least one cigarette daily in the preceding 3 months, verified by an exhaled carbon monoxide concentration of 4 parts per million (ppm) or higher; could communicate in Chinese; owned a smartphone with an instant messaging application installed; and intended to quit or reduce smoking, indicated by joining the QTW

campaign. Smokers who had a communication barrier (either physically or cognitively) or were participating in other smoking cessation programmes or services were excluded from participating in the trial.

Randomisation and masking

We randomly assigned the 68 community sites (1:1) to the intervention or control group, with random permuted blocks of two, four, and six to yield a similar number of clusters in both study groups. The characteristic (type of land use) of the clusters was balanced in both study groups (appendix p 1). Because smokers tended to gather at smoking hotspots where ashtrays were available, participants recruited within the same community site received the same intervention to avoid potential risk of treatment contamination and the practical difficulty of doing individual randomisation on site. The random allocation sequence was computer-generated by a non-investigator who had no other involvement in the study. Masking of participants and the research team was not possible because of the nature of the intervention, but the participants were not informed of the treatment provided in the other group. Outcome assessors and statistical analysts were masked to the participants' allocation to the trial group.

Procedures

Participants in the intervention and control groups received brief face-to-face smoking cessation advice by the smoking cessation ambassadors at baseline. The ambassadors first initiated conversations with smokers by asking about their smoking behaviours (the Ask step) and then invited the smokers to test for exhaled carbon monoxide concentrations. The test results were shown to the smokers to warn about the risks of continued smoking (the Warn step). The ambassadors then advised the smokers to quit or reduce smoking as soon as possible by joining the QTW contest (the Advise step). All eligible smokers willing to participate signed a written consent form, completed a baseline questionnaire, and received a 12-page self-help booklet. Participants in the control group received only brief smoking cessation advice (the Ask, Warn, and Advise steps) at baseline.

Following the AWARD model, participants allocated to the intervention group additionally received information about the smoking cessation services in Hong Kong from an information card and were offered referral to a smoking cessation service (the Refer step). The contact details of participants who agreed to be referred were then sent to the service providers of their choice for further treatment for tobacco dependence. Details of the treatments offered by these service providers are available in the appendix (p 1).

Participants in the intervention group also received chat-based cessation support delivered through an instant messaging app (WhatsApp) for 3 months from baseline. Details of the design and content of the chat-based intervention have been described elsewhere.[10,21] Briefly, a smoking cessation counsellor interacted with a participant in real time and provided personalised, theory-based cessation support. The acceptance and commitment therapy (ACT) is a counselling model focusing on increasing psychological capacity to accept unpleasant experiences while committing to value-guided behavioural change.[22] Guided by ACT, the counsellor helped participants to identify values (eg, family health) that could strengthen their commitment to quit or reduce smoking and helped them to overcome urges to smoke by using metaphors and mindfulness exercises. The counsellor also delivered behavioural change techniques that promote adjuvant activities to aid smoking cessation.[23] Specifically, the counsellors encouraged the use of a smoking cessation service and offered referral for participants who had refused referral at baseline (the Do-it-again step). On the basis of the need and progress indicated by the participants during the chat conversation, other behavioural change techniques (eg, setting graded tasks, eliciting and answering questions, and assessing withdrawal symptoms) were also used to support quitting. Although participants could send a message anytime, the counsellor could only respond during office hours (0930–1830) on working days, because of resource constraints.

See Online for appendix

To initiate and facilitate interactions between participants and counsellors in WhatsApp, 19 push messages were sent to participants on a tapering schedule (from twice per week in the first month to once weekly in the third month). These messages covered generic information about the benefits of quitting, strategies to manage urges to smoke, smoking cessation services, and reminders to participate in the telephone follow-up at 1, 2, and 3 months. A reminder to participate in the 6-month telephone follow-up was also sent at 26 weeks. Participants in the control group also received a reminder to participate in the telephone follow-up at each timepoint by SMS. Regular messages alone were not found to be effective in increasing abstinence in our previous QTW trial.[19]

The counsellors who delivered the chat-based intervention were research staff with at least 1 year of experience in smoking cessation research, supervised by an MSc-level psychotherapist trained in ACT and by a research nurse (TTL). The counsellors met at least once weekly to discuss the caseloads. The instant messaging dialogues were recorded and checked to ensure intervention fidelity. Apart from the baseline questionnaire completed during recruitment, all participants received telephone follow-up calls at 1, 2, 3, and 6 months after baseline. The follow-up assessments included current smoking status, quitting behaviours, use of smoking cessation services, and other outcomes.

Outcomes

The primary outcome was smoking abstinence in the preceding 7 days at 6 months after treatment initiation

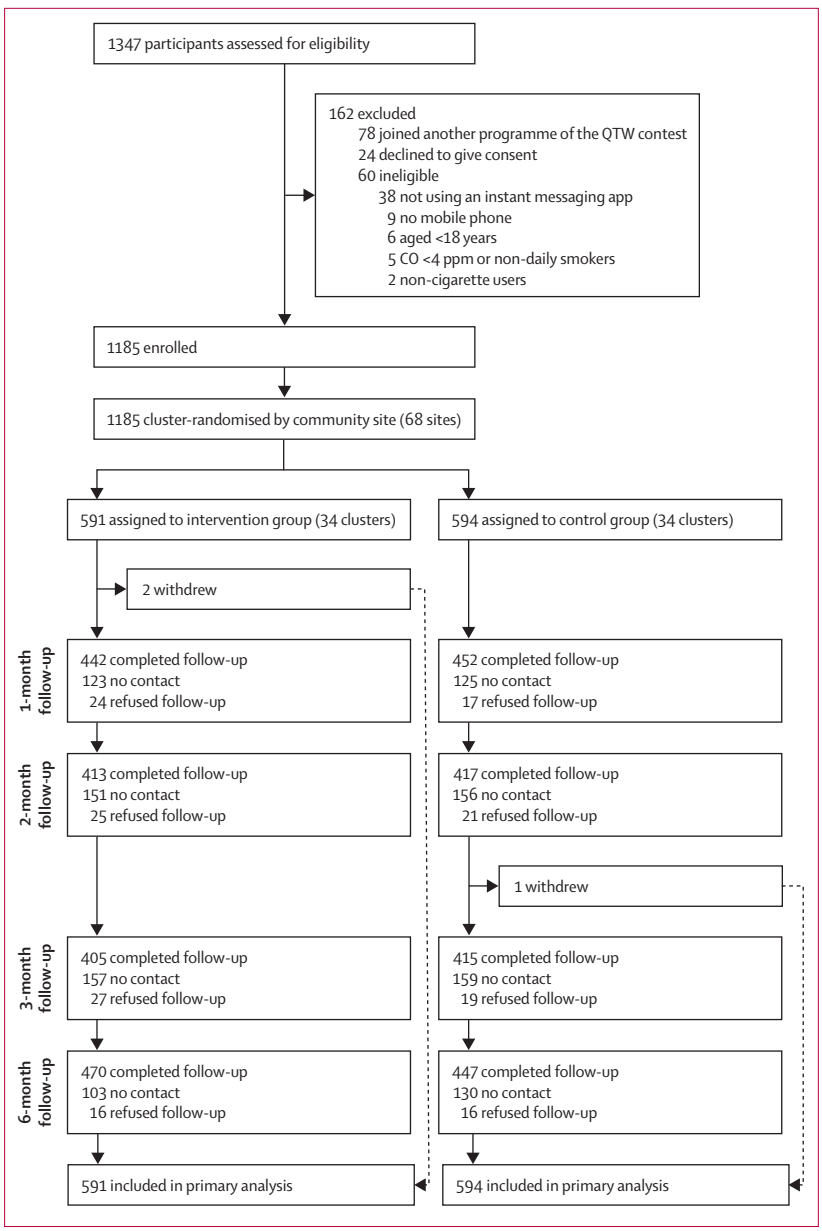

Figure: **Trial profile**
CO=carbon monoxide. ppm=parts per million. QTW=Quit to Win.

(3 months after the end of treatment),[13] verified by exhaled carbon monoxide concentrations lower than 4 ppm and cotinine concentrations lower than 10 ng/mL (appendix p 2). The main secondary outcome was validated smoking abstinence in the preceding 7 days at 3 months after baseline, for assessing the intervention effect at the end of the chat-based support in the intervention group. Participants earned a small cash incentive of HK$500 (equivalent to US$64) for passing each validation test at 3 and 6 months, which was found to have no effect on smoking abstinence in our previous QTW trial.[20] Other secondary outcomes included self-reported point-prevalence abstinence in the preceding 7 days, use of smoking cessation services (defined as a participant replying "yes" to the following question: "have you ever used a smoking cessation service since joining the QTW campaign?"), smoking reduction by at least half of the baseline daily number of cigarettes, and attempts to quit (defined as abstinence for ≥24 h) at 3 and 6 months.

In the earlier version of the protocol, the primary outcome was self-reported smoking abstinence in the preceding 7 days at 6 months after treatment initiation, as used in our previous QTW trials[16–20] and as recommended for population-based studies that assess intervention with minimal face-to-face contact.[24] In September, 2018, we changed the primary outcome to biochemically validated abstinence at 6 months (originally a secondary outcome) because increasingly more studies of digital health interventions for smoking cessation found high rates of misreporting of abstinence status.[25] The change occurred before the data on the 6-month follow-up were processed and analysed and had no effect on the trial implementation.

For process evaluation of the chat-based intervention, participants reported whether they had ever interacted with a smoking cessation counsellor through instant messaging during the 3-month intervention period, which was verified by instant messaging log files. In this trial, we defined effective engagement with the chat-based intervention as having interacted with a smoking cessation counsellor, because participants who did not respond to the prompts from the counsellor would not receive any personalised support.[26] At the 3-month follow-up, we also asked participants the reasons for not using the chat-based intervention.

Statistical analysis

We estimated the sample size on the basis of findings from our previous QTW trial, which showed, for the intention-to-treat population, a validated smoking abstinence prevalence of 5·1% at 6 months in the control group,[17] and an anticipated intervention effect—relative risk 1·83—derived from a meta-analysis of mHealth smoking cessation interventions.[4] To detect a significant intervention effect with two-sided α of 0·05, power of 0·80, and an allocation ratio of 1:1, 586 participants in each group were required. The design effect due to cluster randomisation was considered negligible because our previous QTW trial showed that the intracluster correlation coefficient (ICC) for validated abstinence at 6 months was smaller than 0·001.[16] Therefore, the target sample size was 1172 participants.

Primary analyses were by intention to treat, and participants with missing outcome measures were considered to have no change in smoking behaviour from baseline.[27] We used generalised estimating equation models with a logit link to examine the intervention effect on outcomes, adjusting for clustering of participants within community sites with an exchangeable correlation

structure. The ICCs of all abstinence outcomes were calculated by analyses of variance.

We did three prespecified sensitivity analyses for the abstinence outcomes.[21] First, we repeated the primary analyses with adjustment of imbalanced baseline covariates between study groups. Second, we used multiple imputations by chained equations to impute missing abstinence outcomes, using study group, age, sex, education level, cigarettes smoked per day at baseline, time to first cigarette of the day, previous quit history, and readiness to quit. We used Rubin's rule to pool the estimates from 50 imputed datasets. Third, we did complete-case analyses by excluding participants with missing outcomes.

We examined the intervention effect in subgroups of age, sex, nicotine dependence, readiness to quit in the next 30 days, and previous quit history at baseline as prespecified in the published protocol,[21] and in subgroups of education level as post-hoc analysis. We tested multiplicative interactions using the corresponding interaction terms. We did a planned analysis of whether baseline factors were associated with engagement in the chat-based intervention. Post-hoc analyses were done to examine the differences in primary outcome by intervention engagement, defined by use of a smoking cessation service, effective engagement with the chat-based intervention (verified by conversation log), or both, adjusting for age, sex, nicotine dependence, previous quit history, and readiness to quit at baseline.[28] The operating cost of interventions, including the personnel for participant recruitment and intervention delivery and equipment (eg, print-based materials and smartphones for instant messaging), were calculated in both study groups.

We used Stata/MP (version 15.1) for all statistical analyses. A prespecified content analysis of the instant messaging dialogue between the participants and counsellors, with coding using the taxonomy of behavioural change techniques,[23] and a qualitative assessment of participants' perception of the chat-based intervention will be presented elsewhere. The trial is registered with ClinicalTrials.gov, number NCT03182790.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. MPW and TTL had full access to all the data in the study. MPW had final responsibility for the decision to submit for publication.

Results

Between June 18 and Sept 30, 2017, 1347 potential participants were screened for eligibility in 68 community sites; 1287 were found eligible, and 1185 provided informed consent, were included in the trial, and were randomly assigned to either intervention or control group (figure). We noted some differences in the characteristics of potential participants between smokers who were excluded for not using an instant messaging app (n=38) and daily cigarette smokers in the general population (appendix pp 2–3). By intention to treat, the primary analyses included all participants randomly assigned to the intervention group (34 clusters, 591 participants) or control group (34 clusters, 594 participants). The overall follow-up rates were 75% (n=894) at 1 month, 70% (n=830) at 2 months, 69% (n=820) at 3 months, and 77% (n=917) at 6 months, without significant differences between the

	Intervention group (n=591)	Control group (n=594)
Age (years)	40 (30–50)	42 (30–53)
Sex		
Men	450 (76%)	468 (79%)
Women	141 (24%)	126 (21%)
Highest education level		
Primary or below	25 (4%)	41 (7%)
Secondary	265 (45%)	252 (42%)
Tertiary	75 (13%)	69 (12%)
Did not answer	226 (38%)	232 (39%)
Number of cigarettes per day		
1–10	317 (54%)	310 (52%)
11–20	232 (39%)	236 (40%)
21–30	24 (4%)	22 (4%)
≥31	16 (3%)	26 (4%)
Time to first cigarette of the day (min)*		
>60	120/550 (22%)	139/557 (25%)
31–60	95/550 (17%)	86/557 (15%)
6–30	142/550 (26%)	137/557 (25%)
≤5	193/550 (35%)	195/557 (35%)
Nicotine dependence (HSI score)*		
Low (0–2)	284/550 (52%)	288/557 (52%)
Moderate (3–4)	236/550 (43%)	230/557 (41%)
High (5–6)	30/550 (5%)	39/557 (7%)
Previous quit attempt*		
Never	261/547 (48%)	313/561 (56%)
Over 1 year ago	226/547 (41%)	196/561 (35%)
Within 1 year	60/547 (11%)	52/561 (9%)
Previous reduction attempt*		
Never	337/541 (62%)	337/544 (62%)
Over 1 year ago	135/541 (25%)	127/544 (23%)
Within 1 year	69/541 (13%)	80/544 (15%)
Readiness to quit*		
Not decided yet	347/567 (61%)	354/566 (63%)
Within next 60 days	25/567 (4%)	35/566 (6%)
Within next 30 days	69/567 (12%)	70/566 (12%)
Within next 7 days	126/567 (22%)	107/566 (19%)
Perception of quitting (0–10)		
Importance	7·1 (2·1)	6·9 (2·1)
Difficulty	7·1 (2·2)	6·8 (2·3)
Confidence	5·9 (2·2)	5·6 (2·1)

Data are n (%), n/N (%), median (IQR), or mean (SD). HSI=Heaviness of smoking index. *Data not available for all randomly assigned participants.

Table 1: **Baseline characteristics**

	Intervention group (n=591)	Control group (n=594)	Generalised estimating equation model			
			Crude OR (95% CI)	p value	Adjusted OR (95% CI)*	p value
Biochemically validated abstinence						
3 months	45 (8%)	24 (4%)	1·95 (1·19–3·22)	0·0085	1·69 (1·01–2·84)	0·046
6 months	48 (8%)	30 (5%)	1·68 (1·03–2·74)	0·040	1·70 (1·03–2·81)	0·037
Self-reported 7-day point-prevalent abstinence						
1 month	63 (11%)	46 (8%)	1·40 (0·87–2·24)	0·16	1·37 (0·81–2·30)	0·24
2 months	85 (14%)	54 (9%)	1·76 (1·13–2·76)	0·013	2·07 (1·31–3·29)	0·0019
3 months	90 (15%)	60 (10%)	1·61 (1·12–2·30)	0·0094	1·83 (1·28–2·61)	0·0009
6 months	111 (19%)	68 (11%)	1·80 (1·28–2·52)	0·0007	1·93 (1·34–2·78)	0·0004
Smoking reduction by at least 50% of baseline†						
1 month	102/528 (19%)	95/548 (17%)	1·14 (0·81–1·60)	0·45	1·15 (0·81–1·63)	0·43
2 months	103/506 (20%)	94/540 (17%)	1·20 (0·86–1·69)	0·28	1·12 (0·78–1·61)	0·54
3 months	96/501 (19%)	96/534 (18%)	1·07 (0·76–1·50)	0·69	0·99 (0·67–1·44)	0·95
6 months	130/480 (27%)	134/526 (25%)	1·09 (0·82–1·50)	0·56	1·14 (0·82–1·59)	0·43
Quit attempt						
1 month	139 (24%)	122 (21%)	1·22 (0·82–1·79)	0·33	1·12 (0·76–1·65)	0·58
2 months (cumulative)	190 (32%)	164 (28%)	1·32 (0·92–1·90)	0·13	1·24 (0·84–1·83)	0·28
3 months (cumulative)	203 (34%)	190 (32%)	1·15 (0·83–1·60)	0·40	1·10 (0·76–1·58)	0·62
6 months (cumulative)	245 (41%)	215 (36%)	1·27 (0·95–1·70)	0·10	1·17 (0·83–1·65)	0·38
Smoking cessation service use						
1 month	56 (9%)	8 (1%)	7·69 (3·56–16·6)	<0·0001	6·10 (2·69–13·8)	<0·0001
2 months (cumulative)	76 (13%)	11 (2%)	7·82 (4·08–15·0)	<0·0001	6·71 (3·37–13·4)	<0·0001
3 months (cumulative)	91 (15%)	13 (2%)	8·11 (4·33–15·2)	<0·0001	7·28 (3·65–14·5)	<0·0001
6 months (cumulative)	102 (17%)	23 (4%)	5·15 (3·27–8·11)	<0·0001	4·50 (2·66–7·61)	<0·0001

Data are n (%) or n/N (%) unless specified otherwise. All analyses were by intention to treat unless specified otherwise. OR=odds ratio. *Adjusted for age, previous quit attempt, and perceived importance of and confidence in quitting. †Excluding participants who self-reported quitting.

Table 2: **Primary and secondary outcomes**

two study groups at all four follow-ups (p=0·079–0·90). Attrition at 6 months was associated with younger age, female sex, not reporting their education level, having no preceding quit attempts, lower readiness to quit, and lower perceived importance of quitting, but was not associated with level of nicotine dependence at baseline (appendix pp 3–5).

The mean age of the participants was 41·5 years (SD 14·0) years and 918 (77%) of 1185 were men. About half of participants had low level of nicotine dependence, no preceding attempt to quit or reduce smoking, and no plan to quit at baseline (table 1). Baseline characteristics were similar between study groups except that the intervention group had a lower mean age, more participants with preceding quit attempts, and higher scores in perception of quitting than the control group (table 1). The mean time used to recruit a participant and deliver baseline interventions in the intervention group (11·3 min, SD 4·3) and control group (10·6 min, 3·7) were similar between groups.

Of 179 participants who self-reported abstinence at the 6-month follow-up, 83 (46%) participated in the face-to-face biological validation and 78 (94%) of them passed the validation. Participation rates were not significantly different between the intervention group and the control group (48 [44%] of 110 *vs* 35 [52%] of 67; p=0·27). For the primary outcome at 6 months, more participants in the intervention group were validated quitters than in the control group (table 2; unadjusted odds ratio 1·68, 95% CI 1·03–2·74; p=0·040). The 3-month validated abstinence was likewise greater in the intervention group than in the control group (1·95, 1·19–3·22; p=0·0085), as were self-reported 7-day point-prevalent abstinence assessed at all follow-up timepoints (table 2). These results did not change after adjusting for imbalanced baseline covariates (table 2). Analyses done with use of multiple imputations and by complete case also yielded similar point estimates of intervention effect (appendix p 5). The ICC for validated abstinence at 6 months was 0·0062 (95% CI <0·0001–0·0478), which was slightly higher than our estimation (appendix p 6).

The proportions of participants who continued to smoke but with a reduction in smoking frequency and participants who made a quit attempt were slightly higher in the intervention group than in the control group at all follow-up timepoints; however, these estimates were not significant (table 2). The intervention group had significantly higher rates of smoking cessation service use than those of the control group at all follow-up timepoints (table 2).

The intervention effect was significantly stronger in participants with moderate to high nicotine dependence (*vs* low nicotine dependence, p=0·031), in those with a previous quit attempt over 1 year before baseline (*vs* no previous quit attempt; p=0·0099), and in those who were not ready to quit in 30 days (*vs* ready to quit in 30 days; p<0·0001) at baseline (table 3). After correcting for multiple comparisons, only the results for readiness to quit remained significant (p<0·0001).

In the intervention group, after excluding ten participants whose responses were inconsistent with the instant messaging log, 99 (17%) of 591 participants in the intervention group reported having interacted with a counsellor through instant messaging. Among non-users who provided a reason for not using the chat-based intervention (n=252), "too busy" was reported in 211 (84%) of 252 participants and was the most commonly reported reason for non-usage, followed by "don't know how to send a message" in seven participants (2%) and "not interested" in five participants (2%). Older age, readiness to quit within 7 or 30 days, and higher perceived importance of quitting were associated with engagement in the chat-based intervention, after adjusting for other baseline characteristics (appendix pp 6–8). Engagement in either or both smoking cessation services and chat-based intervention significantly predicted higher prevalence of validated abstinence at 6 months (table 4). The results were similar for intervention engagement and validated abstinence, both assessed at 3 months (data not shown).

The total intervention cost was US$12 930 in the intervention group and $4919 in the control group. The corresponding cost for each participant was $21·9 in the intervention group and $8·3 in the control group. The cost per additional validated quitter in the intervention group was $445.

	Intervention group (n=591)	Control group (n=594)	OR (95% CI)	p value for interaction
Age (years)	..	..	..	0·058
18–34	16/208 (8%)	7/182 (4%)	2·06 (0·81–5·25)	..
35–54	18/212 (8%)	13/201 (6%)	1·35 (0·63–2·91)	..
≥55	13/86 (15%)	7/106 (7%)	2·26 (1·01–5·06)	..
Sex	..	..	..	0·063
Men	34/450 (8%)	20/468 (4%)	1·82 (1·09–3·03)	..
Women	14/141 (10%)	10/126 (8%)	1·28 (0·54–3·01)	..
Nicotine dependence (HSI score)	..	..	..	0·031
Low (0–2)	27/284 (10%)	20/288 (7%)	1·40 (0·77–2·52)	..
Moderate to high (3–6)	19/266 (7%)	8/269 (3%)	2·52 (1·07–5·90)	..
Previous quit attempt	..	..	..	0·0099
Within 1 year	7/60 (12%)	4/52 (8%)	1·59 (0·44–5·72)	..
Over 1 year ago	27/226 (12%)	11/196 (6%)	2·30 (1·09–4·85)	..
Never	13/261 (5%)	14/313 (4%)	1·09 (0·53–2·25)	..
Ready to quit in 30 days	..	..	..	<0·0001
Yes	28/195 (14%)	19/177 (11%)	1·39 (0·76–2·53)	..
No	18/372 (5%)	9/389 (2%)	2·10 (1·05–4·22)	..
Highest education level	..	..	..	0·088
Primary or below	5/25 (20%)	5/41 (12%)	1·81 (0·54–6·04)	..
Secondary	31/265 (12%)	16/252 (6%)	1·99 (1·02–3·89)	..
Tertiary	10/75 (13%)	4/69 (6%)	2·49 (0·74–8·40)	..

Data are n/N (%) unless specified otherwise. All analyses were by intention to treat. OR=odds ratio. HSI=Heaviness of Smoking Index.

Table 3: **Biochemically validated abstinence at 6 months by subgroups**

	Validated abstinence at 6 months	Crude OR (95% CI)	p value	Adjusted OR (95% CI)*	p value
Intention-to-treat analysis†					
None	14/430 (3%)	1 (ref)	..	1 (ref)	..
Smoking cessation service alone	10/62 (16%)	5·69 (2·44–13·31)	0·0001	6·42 (2·26–18·24)	0·0005
Chat-based support alone	12/59 (20%)	7·41 (3·28–16·77)	<0·0001	5·60 (2·13–14·78)	0·0005
Both	12/40 (30%)	12·5 (5·37–29·25)	<0·0001	9·23 (3·42–24·94)	<0·0001
Complete-case analysis					
None	14/315 (4%)	1 (ref)	..	1 (ref)	..
Smoking cessation service alone	10/58 (17%)	4·50 (1·91–10·63)	0·0006	5·18 (1·80–14·84)	0·0022
Chat-based support alone	12/59 (20%)	5·41 (2·37–12·32)	0·0001	4·17 (1·58–11·03)	0·0040
Both	12/39 (31%)	9·53 (4·04–22·44)	<0·0001	7·50 (2·74–20·53)	0·0001

Data are n/N (%) unless specified otherwise. OR=odds ratio. *Adjusted for age, sex, nicotine dependence, previous quit attempt, and readiness to quit. †Participants lost to follow-up were assumed to have not used any smoking cessation services.

Table 4: **Associations of intervention engagement with validated abstinence at 6 months in the intervention group**

Discussion

Our pragmatic, cluster-randomised controlled trial found that a proactive intervention model, integrating chat-based instant messaging support with offers of referral to a smoking cessation service and brief advice, was more effective in increasing abstinence and use of smoking cessation services in community smokers than was brief advice alone. We observed significant effects on validated abstinence at the end of the chat-based intervention (3 months after baseline) and 3 months post-treatment (6 months after baseline). Although a direct comparison is difficult because of differences in study settings, smoker characteristics, methods of intervention delivery, and intervention durations, the observed effect on validated abstinence was similar to those of previous mobile phone-based interventions for smoking cessation.[4]

To our knowledge, this was the first trial of chat-based support for smoking cessation delivered through an understudied mHealth method—mobile instant messaging apps. The chat-based intervention, developed on the basis of the complex trial design framework, was integrated into a multicomponent, proactive treatment model for community smokers. The complex design of the two-group pragmatic trial restricted the ability of the

study to fully assess the contribution of the intervention to cessation outcomes. Factorial trials in which participants are randomly assigned to receive either control treatment or chat-based support, brief advice, or both are needed to assess the additive and interactive effect of the individual components. Nevertheless, we found that participants who engaged only in the chat-based intervention had similar results on validated abstinence compared with those who only used a smoking cessation service. The greater point estimate observed in participants who used both interventions (compared with those of control treatment or single interventions) was also suggestive of an additive effect. The associations remained significant after adjusting for other important predictors of cessation outcomes, including previous quit history, motivation to quit, and nicotine dependence.[28] This suggested that chat-based support might be a crucial component of the combined intervention model.

Consistent with the law of attrition, which notes that a substantial proportion of participants do not engage with the intervention in any digital health trial,[29] the prevalence of effective engagement with the chat-based intervention was low (17%) in our trial. We found that participants less motivated to quit were less likely to engage with the chat-based intervention. This supports similar findings in the USA and the UK, wherein smokers who were not motivated to quit had less desire to use mHealth for quitting than those who were motivated to quit.[30] The low proportion of participants ready to quit in 7 or 30 days at baseline (34%) might thus explain the low engagement in our trial. The effective engagement became 30% when it was limited to participants who were ready to quit in 7 or 30 days at baseline, which was similar to the full adherent rate (24%) reported in a trial of a smartphone cessation app done in similarly motivated smokers.[31] The unavailability of interactive support outside office hours might have led to the low engagement, because most participants reported "too busy" as the reason for not using the intervention. The smaller effect on validated abstinence observed at 3 months after the end of the chat-based intervention also suggests that extending the duration and service hours of the intervention might improve engagement and abstinence. Some participants who were not interested in receiving the chat-based support might have used the blocking function of instant messaging apps. Our content analyses of the chat dialogue, to be reported elsewhere, shall provide some data on this issue.

The use of youth counsellors to engage smokers at smoking hotspots in the community and deliver brief interventions in this trial had several advantages. The proactive recruitment strategy allowed us to recruit a more representative sample of community smokers than if more passive approaches (eg, advertisement) were used. This strategy also presents a novel, foot-in-the-door approach to extend tobacco dependence treatment to hard-to-reach smokers, as indicated by our enrolment of a large proportion of smokers without any plan to quit (701 [62%] of 1133). Despite a lower usage rate of the chat-based intervention in these participants compared with that of participants who planned to quit, we noted a stronger intervention effect on abstinence in participants not ready to quit than in those ready to quit in 30 days. The chat-based intervention focused on identifying a value to increase commitment to quit by using ACT, which might be particularly effective in participants who did not have a motivator to quit and not as effective in those who already had a reason to quit.[10] Our results also corroborate previous qualitative findings in the USA that smokers not interested in quitting might be receptive to mHealth support, which was regarded as a novel way to change their smoking behaviour.[32]

The mean cost of recruiting a participant and delivering brief advice at baseline was low (US$8·2), suggesting a high scalability of the proactive, lay counsellor-delivered treatment model in places where health-care resources are scarce (eg, in low-income and middle-income countries). The higher mean cost ($21·9) observed in the intervention group was mostly due to the personnel and equipment needed to deliver the chat-based intervention. The mean cost for each additional validated quitter at 6 months ($445) was higher than that of a trial of automatic text-messaging support done in UK treatment seekers (£278, corresponding roughly to US$368).[33]

However, the cost of chat-based support will likely decrease because current cessation counsellors can be trained to use chat-based support. As artificial intelligence and related techniques (such as natural language processing) continue to advance, chatbots could also be developed to provide automated personalised support to smokers and to lower the cost of interventions.[7]

Our study has some limitations. First, our trial design precluded estimation of the independent effects of chat-based support and baseline interventions on cessation outcomes, although our engagement analyses were indicative of the individual and additive benefits of both interventions. Explanatory trials with a factorial design are warranted to better estimate these independent effects. Nevertheless, we have provided real-world evidence of the effectiveness of the intervention model, which was designed to be readily implementable in community settings. Second, despite a good retention rate of 77%, given the high risk for attrition in community-based proactive treatment trials, non-response bias remains a possibility. Our sensitivity analyses with use of multiple imputations and by complete case yielded similar results to those of the main analyses. Third, about half of self-reported quitters did not validate their abstinence and the lower, though not significant, participation rate in the intervention than that of control groups might have skewed the observed effects towards the null. The challenge of verifying abstinence in digital health smoking cessation trials is well documented, and a 2017 study also showed high discrepancy between self-reported and

biochemically validated abstinence.[25] It is likely that self-reported quitters who refused to provide a sample for biochemical validation did not quit. Fourth, residual and unmeasured confounding on the observed associations of intervention engagement with abstinence cannot be excluded, although we have adjusted for important predictors of smoking cessation, including previous quit history, motivation to quit, and nicotine dependence.[28] Fifth, the study provided insufficient data on the mechanisms underlying the intervention effect on cessation outcomes. Our prespecified content analyses, based on the taxonomy of behavioural change techniques, might provide some insight on these mechanisms. Sixth, the trial was community-based and used a proactive approach to recruit participants. Whether the findings are generalisable to smokers in clinical settings and those who self-selected to go for treatment needs to be tested, but ample research has shown the effectiveness of mobile phone-based interventions on quitting in treatment seekers.[1,2,4] Finally, although our sample was largely representative of daily cigarette smokers in the general population, the participants tended to be younger, probably because of the lower uptake of smartphone technologies in older smokers.[34] The generalisability of our findings might also be reduced by the greater proportion of previous quit attempts in our sample than in smokers in the general population.

Further research is encouraged to ascertain the usefulness of mobile instant messaging for smoking cessation and other preventive behaviours. Mobile instant messaging apps are the most widely used smartphone apps and thus, are a more conducive mHealth platform for cessation support than other smartphone apps, because many community smokers unmotivated to quit are unlikely to install a smoking cessation app.[30] Some instant messaging apps have now developed into broad platforms with additional functions other than messaging. For instance, WeChat (an instant messaging app with over a billion monthly active users) includes a mobile payment platform (WeChat Pay) and a mini programme or app-in-app system for add-on functions (eg, games). These features present new opportunities to integrate other behavioural change strategies with the chat-based intervention, such as monetary incentive for rewarding action taken to achieve abstinence (eg, attending a smoking cessation service) and gamified support. Our intervention model might also be adapted and tested for treatment of other behaviours (eg, harmful drinking).

Extending tobacco dependence treatment to unmotivated smokers and increasing use of smoking cessation services have enormous public health implications. Our pragmatic trial suggests that a proactive intervention model integrating chat-based instant messaging support with brief interventions can increase quit rates, especially in smokers not ready to quit. We also provided initial evidence that chat-based support might increase abstinence as a standalone therapy and in combination with adjuvant treatment provided by external smoking cessation services.

Contributors

MPW and THL conceived the study. MPW, TTL, and THL designed the study. TTL coordinated the field work. TTL and YW did the statistical analysis. MPW and TTL wrote the first draft of the manuscript. All authors interpreted the data, participated in the critical review of the report, and provided final approval for publication submission. MPW and TTL are accountable for the accuracy and integrity of the study.

Declaration of interests

We declare no competing interests.

Data sharing

The study protocol and de-identified individual participant data generated during this study are available from the investigators on reasonable request. Requests should be directed to the corresponding author by email.

Acknowledgments

We would like to thank the participants for their participation in the study; the student helpers and volunteers for recruiting participants in the community; and the research personnel from the Smoking Cessation Research Team, School of Nursing, University of Hong Kong, China, for implementing the study.

References

1 Free C, Knight R, Robertson S, et al. Smoking cessation support delivered via mobile phone text messaging (txt2stop): a single-blind, randomised trial. *Lancet* 2011; **378:** 49–55.

2 Abroms LC, Boal AL, Simmens SJ, Mendel JA, Windsor RA. A randomized trial of Text2Quit: a text messaging program for smoking cessation. *Am J Prev Med* 2014; **47:** 242–50.

3 Hoeppner BB, Hoeppner SS, Abroms LC. How do text-messaging smoking cessation interventions confer benefit? A multiple mediation analysis of Text2Quit. *Addiction* 2017; **112:** 673–82.

4 Whittaker R, McRobbie H, Bullen C, Rodgers A, Gu Y. Mobile phone-based interventions for smoking cessation. *Cochrane Database Syst Rev* 2016; **4:** CD006611.

5 Haskins BL, Lesperance D, Gibbons P, Boudreaux ED. A systematic review of smartphone applications for smoking cessation. *Transl Behav Med* 2017; **7:** 292–99.

6 Naslund JA, Kim SJ, Aschbrenner KA, et al. Systematic review of social media interventions for smoking cessation. *Addict Behav* 2017; **73:** 81–93.

7 Hoermann S, McCabe KL, Milne DN, Calvo RA. Application of synchronous text-based dialogue systems in mental health interventions: systematic review. *J Med Internet Res* 2017; **19:** e267.

8 Shen C, Wang MP, Wan A, Viswanath K, Chan SSC, Lam TH. Health information exposure from information and communication technologies and its associations with health behaviors: population-based survey. *Prev Med* 2018; **113:** 140–46.

9 Cheung YTD, Chan CH, Lai CK, et al. Using WhatsApp and Facebook online social groups for smoking relapse prevention for recent quitters: a pilot pragmatic cluster randomized controlled trial. *J Med Internet Res* 2015; **17:** e238.

10 Luk TT, Wong SW, Lee JJ, Chan SS, Lam TH, Wang MP. Exploring community smokers' perspectives for developing a chat-based smoking cessation intervention delivered through mobile instant messaging: qualitative study. *JMIR MHealth UHealth* 2019; **7:** e11954.

11 Fiore MC, Jaen CR, Baker T, et al. Treating tobacco use and dependence: 2008 update. Rockville, MD: US Department of Health and Human Services, 2008.

12 Fu SS, van Ryn M, Sherman SE, et al. Proactive tobacco treatment and population-level cessation: a pragmatic randomized clinical trial. *JAMA Intern Med* 2014; **174:** 671–77.

13 Gilbert H, Sutton S, Morris R, et al. Effectiveness of personalised risk information and taster sessions to increase the uptake of smoking cessation services (Start2quit): a randomised controlled trial. *Lancet* 2017; **389:** 823–33.

14 Vidrine DJ, Frank-Pearce SG, Vidrine JI, et al. Efficacy of mobile phone-delivered smoking cessation interventions for socioeconomically disadvantaged individuals: a randomized clinical trial. *JAMA Intern Med* 2019; **179:** 167–74.

15 Census and Statistics Department. Thematic household survey report no. 64: pattern of smoking and personal computer and internet penetration. 2018. https://www.statistics.gov.hk/pub/B11302642018XXXXB0100.pdf (accessed Feb 1, 2019).

16 Chan SS, Cheung YTD, Wong YMB, Kwong A, Lai V, Lam TH. A brief smoking cessation advice by youth counselors for the smokers in the Hong Kong Quit to Win contest 2010: a cluster randomized controlled trial. *Prev Sci* 2018; **19:** 209–19.

17 Wang MP, Suen YN, Li WH, et al. Intervention with brief cessation advice plus active referral for proactively recruited community smokers: a pragmatic cluster randomized clinical trial. *JAMA Intern Med* 2017; **177:** 1790–97.

18 Wang MP, Li WH, Cheung YT, et al. Brief advice on smoking reduction versus abrupt quitting for smoking cessation in Chinese smokers: a cluster randomized controlled trial. *Nicotine Tob Res* 2017; **20:** 67–72.

19 Chan SS, Wong DC, Cheung YTD, et al. A block randomized controlled trial of a brief smoking cessation counselling and advice through short message service on participants who joined the Quit to Win Contest in Hong Kong. *Health Educ Res* 2015; **30:** 609–21.

20 Cheung YTD, Wang MP, Li HC, et al. Effectiveness of a small cash incentive on abstinence and use of cessation aids for adult smokers: a randomized controlled trial. *Addict Behav* 2017; **66:** 17–25.

21 Luk TT, Li WH, Cheung DYT, et al. Chat-based instant messaging support combined with brief smoking cessation interventions for Chinese community smokers in Hong Kong: rationale and study protocol for a pragmatic, cluster-randomized controlled trial. *Contemp Clin Trials* 2019; **77:** 70–75.

22 Hayes SC, Luoma JB, Bond FW, Masuda A, Lillis J. Acceptance and commitment therapy: model, processes and outcomes. *Behav Res Ther* 2006; **44:** 1–25.

23 Michie S, Hyder N, Walia A, West R. Development of a taxonomy of behaviour change techniques used in individual behavioural support for smoking cessation. *Addict Behav* 2011; **36:** 315–19.

24 SRNT Subcommittee on Biochemical Verification. Biochemical verification of tobacco use and cessation. *Nicotine Tob Res* 2002; **4:** 149–59.

25 Cha S, Ganz O, Cohn AM, Ehlke SJ, Graham AL. Feasibility of biochemical verification in a web-based smoking cessation study. *Addict Behav* 2017; **73:** 204–08.

26 Yardley L, Spring BJ, Riper H, et al. Understanding and promoting effective engagement with digital behavior change interventions. *Am J Prev Med* 2016; **51:** 833–42.

27 West R, Hajek P, Stead L, Stapleton J. Outcome criteria in smoking cessation trials: proposal for a common standard. *Addiction* 2005; **100:** 299–303.

28 Vangeli E, Stapleton J, Smit ES, Borland R, West R. Predictors of attempts to stop smoking and their success in adult general population samples: a systematic review. *Addiction* 2011; **106:** 2110–21.

29 Eysenbach G. The law of attrition. *J Med Internet Res* 2005; **7:** e11.

30 Borrelli B, Bartlett YK, Tooley E, Armitage CJ, Wearden A. Prevalence and frequency of mHealth and eHealth use among US and UK smokers and differences by motivation to quit. *J Med Internet Res* 2015; **17:** e164.

31 Zeng EY, Heffner JL, Copeland WK, Mull KE, Bricker JB. Get with the program: adherence to a smartphone app for smoking cessation. *Addict Behav* 2016; **63:** 120–24.

32 McClure JB, Heffner J, Hohl S, Klasnja P, Catz SL. Design considerations for mHealth programs targeting smokers not yet ready to quit: results of a sequential mixed-methods study. *JMIR MHealth UHealth* 2017; **5:** e31.

33 Guerriero C, Cairns J, Roberts I, Rodgers A, Whittaker R, Free C. The cost-effectiveness of smoking cessation support delivered by mobile phone text messaging: txt2stop. *Eur J Health Econ* 2013; **14:** 789–97.

34 Luk TT, Wang MP, Shen C, et al. Short version of the Smartphone Addiction Scale in Chinese adults: psychometric properties, sociodemographic, and health behavioral correlates. *J Behav Addict* 2018; **7:** 1157–65.