Predictors of Smoking Cessation in a Lifestyle-Focused Text-Message Support Programme Delivered to People with Coronary Heart Disease: An Analysis From the Tobacco Exercise and Diet Messages (TEXTME) Randomised Clinical Trial

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ABSTRACT

BACKGROUND: Studies have demonstrated the effectiveness of text message-based prevention programs on smoking cessation, including our recently published TEXTME randomised controlled trial. However, little is known about the predictors of smoking cessation in this context and if other clinically important factors interact with the program to lead to quitting. Hence, the objective of this study was to first assess the predictors of smoking cessation in TEXTME and then determine if the effect of texting on quitting was modified by interactions with important clinical variables. This will allow us to better understand how text messaging works and thus help optimise future text-message based prevention programs.

METHODS: This sub-analysis used data collected as part of the TEXTME trial which recruited 710 participants (377 current smokers at baseline) between September 2011 and November 2013 from a large tertiary hospital in Sydney, Australia. Smokers at baseline were analysed at 6 months and grouped into those who quit and those who did not. Univariate analyses were performed to determine associations between the main outcome and clinically important baseline factors selected a priori. A multiple binomial logistic regression analysis was conducted to develop a predictive model for the dependent variable smoking cessation. A test of interaction between the intervention group and baseline variables selected a priori with the outcome smoking cessation was performed.

RESULTS: Univariate analysis identified receiving text-messages, age, and mean number of cigarettes smoked each day as being associated with quitting smoking. After adjusting for age, receiving the text-messaging program (OR 2.34; 95%CI 1.43-3.86; p<0.01) and mean number of cigarettes smoked per day (OR 1.02; 95%CI 1.00-1.04; p=0.03) were independent predictors for smoking cessation. LDL-C showed a significant interaction effect with the intervention (High LDL*Intervention OR 3.77 (95%CI 2.05-6.94); Low LDL*Intervention OR 1.42 (95%CI 0.77-2.60); P=0.03).

CONCLUSIONS: Smoking quantity at baseline is independently associated with smoking cessation and higher LDL-C may interact with the intervention to result in quitting smoking. Those who have a higher baseline risk maybe more motivated towards beneficial lifestyle change including quitting smoking, and thus more likely to respond to mHealth smoking cessation programs. The effect of text-messages on smoking cessation was independent of age, gender, psychosocial parameters, education, and baseline control of risk factors in a secondary prevention cohort.

KEYWORDS: Smoking cessation, mobile health, mHealth, predictors, text message, text messaging

Background

Smoking is still a leading cause of global mortality and accounts for about 15% of health care expenditure in high-income countries.1 In 2017, it was the second leading risk factor (high systolic blood pressure being the first) for death and disability worldwide, accounting for 7.1 million deaths (approximately 12% of all deaths) and 182 million disability-adjusted-life-years (DALYs).2 While smoking prevalence has decreased, disability related to smoking is growing especially in low- and middle-income countries.3 Yet despite overwhelming evidence on the advantages of smoking cessation, many smokers are unable to sustain long-term abstinence. During 2015, 68.0% of adult smokers wanted to stop smoking and 55.4% attempted to quit in the last year, but only 7.4% were successful.4 Interestingly, surveys suggest only 57.2% of adult smokers have been advised by a health professional to

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quit and 31.2% used cessation counselling and/or medication when trying to quit. This suggests that low rates of successful smoking cessation may be due to underutilisation of existing proven treatment strategies.

Mobile health (mHealth) interventions (smartphone applications and text messaging) have gained increasing interest as a means of modifying health behaviours, including smoking, in a scalable and affordable way. Most of the research surrounding mHealth and smoking cessation focuses on text messaging as the primary modality, with a recent review indicating that few smartphone applications (apps) advertised for smoking cessation are backed by scientific evidence. A recent meta-analysis consisting of 9887 participants in high-income countries demonstrated that smoking cessation programmes utilising text messaging alone increased abstinence rates at least in the short term (26 weeks; relative risk [RR], 1.69; 95% confidence interval [CI], 1.46–1.95). As a result of the demonstrable effectiveness of text-message interventions for smoking cessation, text messaging is currently being recommended for smoking cessation by some national bodies. However, although mHealth strategies show potential, maintaining engagement is difficult and user drop-out rates are high when applied in real-world circumstances. Thus, there is a need to understand how text-message programmes interact with patient characteristics and clinical factors to result in smoking cessation to optimise future programmes.

Research into predictors of smoking cessation using traditional methods (pharmacological and behavioural [face-to-face and web based]) have shown male gender, older age, higher motivation to quit, early success in quitting, lower nicotine dependency, social modelling (being around less smokers), and being in a relationship are important for compliance with treatment methods (which is pivotal for treatment efficacy). Although, these predictors may not apply to mHealth-based prevention programmes. There is some research which have identified lower smoking quantity, older age, male sex, higher education, and absence of depression as being associated with higher engagement with mHealth programmes, and engagement with mHealth programmes has been associated with quitting smoking.

Research on text-message-based smoking cessation programmes has largely focused on assessing efficacy, rather than assessing predictors of efficacy such as certain patient characteristics. The messages themselves guide the participants through the quitting process by providing tips and advice, as well as referring to other sources external to the message programme. The exact mechanisms responsible for the observed effects and the predictors of smoking cessation are unknown, and more research is needed to understand the nuances of engagement and treatment efficacy.

Insight into the predictors of smoking cessation have been provided by the Txt2Stop randomised controlled trial (RCT). This was a 6-month study involving 5800 (2915 smokers allocated to the intervention arm) adults aged 16 to 78 in the United Kingdom and was the largest single-blind RCT for a specific text-based smoking intervention programme. A subanalysis revealed that female gender, younger age, and nonmanual employment were independent predictors of resuming smoking after quitting, whereas years of education, nicotine dependence, and previous quit attempts were not, after adjusting for other variables. However, this was a bidirectional interactive programme targeting smoking only, and it is unclear whether the results are generalisable to noninteractive programmes or programmes targeting multiple risk factors. Furthermore, this study reported 7-day abstinence, and it is unknown whether these predictors lead to sustained effects.

We conducted the Australian Tobacco, Exercise, and Diet Messages (TEXTME) RCT, which was a single-centre trial targeting multiple cardiovascular risk factors (i.e. not a dedicated smoking cessation text-message programme) in 710 patients with known coronary heart disease (CHD). The intervention consisted of a 6-month noninteractive semi-personalised text-message support programme. The subjects received 4 messages per week that provided advice, motivation, and support on smoking, diet, physical activity, and general cardiovascular information. The primary outcome was low-density lipoprotein cholesterol (LDL-C) at 6 months, and smoking cessation was a secondary outcome. At 6-month follow-up, participants receiving the text messages had significantly lower LDL-C, and were 33% more likely to quit smoking compared to those who did not receive the text messages (RR, 1.33; 95% CI, 1.19–1.49; P < .001). The predictors of smoking cessation and whether there were interactions between patient characteristics or clinical variables and the intervention to mediate the effect on smoking cessation are unknown.

The aim of this article was to first assess the predictors of smoking cessation in TEXTME and then determine whether the effect of texting on smoking cessation was modified by interactions with clinical variables selected a priori. The exploration of the interaction of texting intervention will allow us to better understand in which subgroups the text-messaging approach is particularly effective in improving smoking cessation.

Methods
This study is a subanalysis which used data collected as part of the TEXTME trial, a single-blind RCT, which recruited 710 participants (377 current smokers at baseline) between September 2011 and November 2013 from a large tertiary hospital in Sydney, Australia. In this subgroup analysis, the adults who were defined as smokers at baseline were included in the analysis. Objective measures of cardiovascular risk factors (LDL-C level, blood pressure, body mass index [BMI], waist circumference, and self-reported measures of physical activity, diet, and medications) were obtained at baseline and 6 months post-randomisation as previously described. Demographic information, including age, sex, education, and self-reported
ethnic origin, was obtained at baseline. Medical history was obtained including a formal diagnosis of hypertension and diabetes. Smoking status (current smoker, former smoker, and never smoked) was self-reported at baseline and confirmed with a carbon monoxide metre breath analyser (MicroPlus Smokerlyzer, Airmet Scientific).

The TEXTME intervention group received 4 text messages per week for 6 months. Participants who were smokers at baseline each week received 1 message from 4 different categories: (1) general cardiovascular health and medications, (2) nutrition, (3) physical activity, and (4) smoking cessation. Nonsmokers received an additional random message from the first 3 categories instead of a message on smoking cessation. Messages included the recipients preferred name and were sent in random order and no message was repeated. The messages were unidirectional and did not allow 2-way communication about clinical management (i.e. not interactive). The messages provided advice, motivation, information, and support to quit smoking (for smokers) and to engage in healthy diets and exercise. Examples of smoking cessation messages include: ‘It’s never too late to quit smoking’; ‘It may take several attempts to quit, so keep trying’; and ‘Check out the website www.icanquit.com.au for tips and to track your progress’.22

**Measures**

**Smoking status.** Smoking status was grouped into 3 groups: (1) Current Smoker, (2) Former Smoker, and (3) Never Smoked. Current smoker was defined as smoking regularly at least 5 cigarettes per day within the last 12 months. Only current smokers at baseline were included in this analysis. The current smokers were assessed at 6 months follow-up to determine self-reported smoking status (either still smoking or quit smoking) and confirmed with a carbon monoxide metre breath analyser. Amount of smoking per day was dichotomised into less than 11 cigarettes per day and 11 or more cigarettes per day.

**Sociodemographic variables.** Gender was categorised in to 2 groups: male and female. Age was divided into categories less than 57 years and greater than or equal to 57 years, as this was the median age of the sample. Ethnicity was separated into 2 groups: Caucasians and non-Caucasians. Education level was categorised into 2 categories: less than or equal to 12 years and greater than 12 years.

**Psychosocial factors.** Quality of life was assessed using the Short Form 12 Health survey (SF-12) and results grouped into Physical Composite Scale (PCS) score and Mental Composite Scale (MCS) score. Lifetime history of depression was determined at baseline and categorised into 4 groups depending on treatment (antidepressants only, counselling only, both antidepressants and counselling, and no treatment).

**Diet.** Diet was assessed by self-report of servings of vegetables and fruit consumed in the prior 7 days. Diet according to guidelines was defined as 2 or more servings of fruit and 5 or more servings of vegetables each day. Average units of alcohol per week was determined by self-report.

**Physical activity.** Physical activity was assessed using the Global Physical Activity Questionnaire (GPAQ) and reported in MET minutes per week. Regular exercise was defined as the equivalent of at least 150 minutes of moderate-level exercise each week.

**Statistical analysis**

In this study, SPSS Statistics, version 24.0, for Windows (SPSS Inc. An IBM Company, Chicago, Illinois) was used for data analysis, and the forest plot was created using R (version 3.5.2) (R Core Team 2018). Sample distributions of demographics and clinical characteristics at baseline were examined using descriptive statistics. For univariate analyses, 2-sample t-tests for continuous variables or chi-square tests of independence for categorical variables were performed to determine associations between the main outcome, smoking cessation at 6 months, and clinically important baseline factors selected a priori. Factors selected a priori included: gender, age, education, quantity smoked, quality of life (SF12 physical and mental health scores), depression, exercising according to guidelines, baseline LDL-C, waist circumference, BMI, systolic blood pressure, and diabetes. Variables found to have P-values greater than .05 on univariate analyses were included in the multivariable logistic regression model for smoking cessation. The criterion for the removal of the candidate predictor variables from the multivariable model was set at P-value lesser than .10. The interaction of the texting intervention and the prespecified subgroups was added to the final adjusted model to address the primary aim of whether there is a difference in smoking cessation in response to texting for each subgroup. The odds ratio and 95% confidence interval within each subgroup will be presented in a forest plot.

Any continuous subgroup variable will be dichotomised based on median (education was dichotomised based on completing at least high school [year 12] equivalent). There are 13 interactions that will be tested, and therefore, the Bonferroni method23 to adjust for multiple comparisons will be used – P-values less than .004 (P-value .05/13 variables) will be considered significant.

**Results**

This study included 377 current smokers at baseline (53% of the TEXTME population), of which 369 were present for the 6-month follow-up (6 were lost to follow-up, and 2 ‘opted out’ of the programme). Table 1 presents the characteristics of the
Table 1. Baseline characteristics.

| SMOKER STATUS                  | CURRENT SMOKERS NO. 377 | FORMER SMOKERS NO. 160 | NEVER SMOKED NO. 173 |
|--------------------------------|--------------------------|-------------------------|----------------------|
| Age – mean (SD)                | 56.7 (±8.9)              | 59.8 (±8.9)             | 57.6 (±9.7)          |
| Male – n (%)                   | 327 (86.7)               | 138 (86.2)              | 117 (67.6)           |
| SF-12 (PCS)                    |                          |                         |                      |
| Mean (SD)                      | 40.0 (±6.4)              | 40.0 (±6.4)             | 40.6 (±5.7)          |
| Missing                        | 3 (0.8%)                 | 1 (0.6%)                | 1 (0.6%)             |
| SF-12 (MCS)                    |                          |                         |                      |
| Mean (SD)                      | 53.6 (±5.5)              | 52.6 (±6.3)             | 52.7 (±6.1)          |
| Missing                        | 3 (0.8%)                 | 1 (0.6%)                | 1 (0.6%)             |
| Depression – n (%)             | 64 (17.0)                | 25 (15.6)               | 20 (11.6)            |
| Depression treatment – n (%)   |                          |                         |                      |
| On antidepressant only         | 7 (1.9)                  | 2 (1.2)                 | 0 (0.0)              |
| Counselling only               | 27 (7.2)                 | 11 (6.9)                | 12 (6.9)             |
| Both                           | 9 (2.4)                  | 5 (3.1)                 | 2 (1.2)              |
| No treatment                   | 21 (5.6)                 | 7 (4.4)                 | 6 (3.5)              |
| Total physical activity (MET min/week) |       |                         |                      |
| Mean (SD)                      | 322.4 (±1504.2)          | 522.4 (±1633.1)         | 371.8 (±1157.5)     |
| Missing                        | 0 (0%)                   | 1 (0.6%)                | 2 (1.2%)             |
| *Regular exercise – n (%)      | 32 (8.5)                 | 17 (10.6)               | 19 (11.0)            |
| BMI, kg/m² – mean (SD)         | 29.8 (±5.8)              | 30.0 (±6.4)             | 29.1 (±5.6)          |
| BMI groups – n (%)             |                          |                         |                      |
| Under (BMI < 18.5)             | 1 (0.3)                  | 1 (0.6)                 | 0 (0)                |
| Normal (18.5 < BMI < 25)       | 83 (22.0)                | 33 (20.6)               | 41 (23.7)            |
| Overweight (25 < BMI < 30)     | 142 (37.7)               | 60 (37.5)               | 70 (40.5)            |
| Obese (BMI ≥ 30)               | 153 (40.6)               | 66 (41.3)               | 62 (35.8)            |
| Waist circumference (cm)       |                          |                         |                      |
| Mean (SD)                      | 105.4 (±16.2)            | 104.5 (±17.4)           | 99.7 (±14.6)         |
| Missing                        | 5 (1.3%)                 | 2 (1.2%)                | 6 (3.5%)             |
| Diabetes – n (%)               | 122 (32.4)               | 58 (36.2)               | 49 (28.3)            |
| Total Cholesterol (mmol/L)     |                          |                         |                      |
| Mean (SD)                      | 4.8 (±1.2)               | 4.4 (±1.1)              | 4.4 (±1.0)           |
| Missing                        | 2 (0.5%)                 | 3 (1.9%)                | 2 (1.2%)             |
| LDL-C (mmol/L)                 |                          |                         |                      |
| Mean (SD)                      | 2.8 (±1.0)               | 2.5 (±0.9)              | 2.5 (±0.9)           |
| Missing                        | 13 (3.4%)                | 7 (4.4%)                | 6 (3.5%)             |

(Continued)
### Table 1. (Continued)

| SMOKER STATUS | CURRENT SMOKERS NO. 377 | FORMER SMOKERS NO. 160 | NEVER SMOKED NO. 173 |
|---------------|-------------------------|-------------------------|----------------------|
| **Systolic blood pressure (mm Hg)** | | | |
| Mean (SD) | 128.6 (±11.8) | 129.5 (±13.5) | 128.3 (±12.1) |
| Missing | 2 (0.5%) | 0 (0%) | 2 (1.2%) |
| Hypertension – n (%) | 228 (60.5) | 101 (63.1) | 111 (64.2) |
| **Units of alcohol per week** | | | |
| Mean (SD) | 14.2 (±16.3) | 12.9 (±13.2) | 6.6 (±6.1) |
| Missing | 263 (69.8%) | 101 (63.1%) | 135 (78.0%) |
| Caucasian – n (%) | 257 (68.2) | 113 (70.6) | 103 (59.5) |
| Diet according to guidelines – n (%) | 1 (0.3) | 1 (0.6) | 3 (1.7) |
| **Years of education** | | | |
| Mean (SD) | 11.0 (±3.4) | 11.8 (±3.6) | 11.7 (±3.5) |
| Missing | 2 (0.5%) | 1 (0.6%) | 1 (0.6%) |
| Education group – n (%) | | | |
| ≤12 years | 273 (72.4) | 106 (66.2) | 115 (66.5) |
| >12 years | 102 (27.1) | 53 (33.1) | 57 (32.9) |
| Missing | 2 (0.5) | 1 (0.6) | 1 (0.6) |
| Programme attrition – n (%) | 2 (0.5) | 3 (1.9) | 0 (0.0) |
| Lost to follow-up – n (%) | 8 (2.1) | 7 (4.4) | 2 (1.2) |

### Table 2. Baseline variables of interest by smoking cessation in a univariate logistic regression.

| QUIT SMOKING AT 6 MONTHS | P-VALUE |
|--------------------------|---------|
| Treatment arm – n (%) | <.001 |
| Control | NO. 184 | YES | NO. 185 |
| | 114 (59.4) | 78 (40.6) | |
| Text-message arm | 70 (39.5) | 107 (60.5) | |
| Age – mean (SD) | 55.7 (±8.8) | 57.6 (±8.9) | .04 |
| Gender–n(%) | .53 |
| Female | 27 (54.0) | 23 (46.0) | |
| Male | 157 (49.2) | 162 (50.8) | |
| Cigarettes smoked per day at baseline | .03 |
| Mean (SD) | 20.3 (±12.6) | 23.9 (±14.8) | |
| Missing | 30 (16.3%) | 67 (36.2%) | (Continued)
### Table 2. (Continued)

|                                      | QUIT SMOKING AT 6 MONTHS | P-VALUE |
|--------------------------------------|--------------------------|---------|
|                                      | **NO** NO. 184           | **YES** NO. 185 |
| Cigarettes smoked per day groups – n (%) |                           | .39     |
| <11 cigs per day                     | 39 (61.9)                | 24 (38.1) |
| >11 cigs per day                     | 115 (55.0)               | 94 (45.0) |
| Missing                              | 30 (16.3)                | 67 (36.2) |
| Years smoked at baseline             |                           | .73     |
| Mean (SD)                            | 17.2 (±5.7)              | 17.0 (±4.0) |
| Missing                              | 30 (16.3%)               | 66 (35.7%) |
| Number of previous quit attempts at baseline |                   | .67     |
| Mean (SD)                            | 2.8 (±3.3)               | 2.7 (±2.6) |
| Missing                              | 39 (21.2%)               | 73 (39.5%) |
| SF-12 (PCS)                          |                           | .93     |
| Mean (SD)                            | 39.9 (±6.1)              | 40.0 (±6.6) |
| Missing                              | 2 (1.1%)                 | 1 (0.5%)  |
| SF-12 (MCS)                          |                           | .86     |
| Mean (SD)                            | 53.5 (±5.8)              | 53.6 (±5.0) |
| Missing                              | 2 (1.1%)                 | 1 (0.5%)  |
| Depression – n (%)                   |                           | .39     |
| No history of depression             | 150 (48.9)               | 157 (51.1) |
| History of depression                | 34 (54.8)                | 28 (45.2) |
| Depression treatment – n (%)         |                           | .39     |
| Antidepressants                      | 3 (42.9)                 | 4 (57.1)  |
| Counselling                          | 17 (63.0)                | 10 (37.0) |
| Both                                 | 4 (44.4)                 | 5 (55.6)  |
| None                                 | 10 (52.6)                | 9 (47.4)  |
| Total Physical Activity (MET min/week) | 300.5 (±1422.7)        | 342.2 (±1612.0) |
|                                      |                           | .79     |
| aRegular exercise – n (%)            |                           | .47     |
| No                                   | 170 (50.4)               | 167 (49.6) |
| Yes                                  | 14 (43.8)                | 18 (56.2) |
| BMI kg/m² – mean (SD)                | 29.6 (±5.8)              | 29.9 (±5.9) |
|                                      |                           | .64     |
| Waist circumference (cm)             |                           | .47     |
| Mean (SD)                            | 105.9 (±16.8)            | 104.7 (±15.5) |
| Missing                              | 1 (0.5%)                 | 4 (2.2%)  |
Table 2. (Continued)

| Diabetes – n (%) | OUIT SMOKING AT 6MONTHS | P-VALUE |
|------------------|-------------------------|---------|
|                  | NO | YES |        |        |
| No               | 120 (48.2) | 129 (51.8) | .36    |
| Yes              | 64 (53.3)  | 56 (46.7)   |        |

| Total cholesterol (mmol/L) | P-VALUE |
|---------------------------|---------|
|                           | .81     |
| Mean (SD)                 | 4.7 (±1.1) | 4.8 (±1.2) |
| Missing                   | 0 (0%)  | 2 (1.1%)   |

| LDL-C (mmol/L) | P-VALUE |
|----------------|---------|
|                | .92     |
| Mean (SD)      | 2.8 (±1.0) | 2.8 (±1.0) |
| Missing        | 7 (3.8%)  | 6 (3.2%)   |

| Systolic blood pressure (mm Hg) | P-VALUE |
|---------------------------------|---------|
|                                | .85     |
| Mean (SD)                      | 128.7 (±12.5) | 129.0 (±10.8) |
| Missing                        | 1 (0.5%)  | 1 (0.5%)     |

| Caucasian – n (%) | P-VALUE |
|-------------------|---------|
| No                | .77     |
| 58 (48.7)         | 61 (51.3) |
| Yes               | .54     |
| 126 (50.4)        | 124 (49.6) |

| Years of education | P-VALUE |
|--------------------|---------|
| Mean (SD)          | .42     |
| 11.1 (±3.6)        | 10.9 (±3.1) |
| Missing            | 1 (0.5%)  | 1 (0.5%)   |

| Education group – n (%) | P-VALUE |
|-------------------------|---------|
| <12 years               | .42     |
| 129 (48.5)              | 137 (51.5) |
| >12 years               | .54     |
| 54 (53.5)               | 47 (46.5)   |
| Missing                 | 1 (50.0)  | 1 (50.0)   |

SF-12, Short Form 12 Health Survey; PCS, Physical Health Composite Scale; MCS, Mental Health Composite Scale. MET, metabolic equivalent of task; BMI, body mass index; LDL-C, low-density lipoprotein cholesterol. *Regular exercise = at least 150 minutes of moderate activity per week.

Table 3. Comparison of logistic models for smoking cessation at 6 months: odds ratios and 95% confidence intervals.

| SMOKING CESSATION AT 6 MONTHS         | UNADJUSTED MODEL | FINAL ADJUSTED MODEL |
|---------------------------------------|------------------|----------------------|
| Treatment arm (Ref: control)          | 2.23*** (1.48, 3.40) | 2.34*** (1.43, 3.86) |
| Baseline cigarettes per day           | 1.02** (1.00, 1.04)  |                      |
| N                                     | 369              | 272                  |
| Akaike Inf. Crit.                     | 500.96           | 362.25               |

**P < .05. ***P < .01
total sample at baseline categorised into ‘Current Smokers’, ‘Former Smokers’, and ‘Never Smoked’. Of the current smokers, the mean age was 56.7 ± 8.9 years, 86.7% male, 68% were Caucasian, and 27% had more than 12 years of education. The vast majority were either overweight or obese (78%) with a mean BMI of 29.8 ± 5.8 kg/m², and 32% had diabetes of which 35% were on insulin treatment. For current smokers, the average total cholesterol and LDL-C were above recommended targets (mean 4.75 ± 1.20 and 2.78 ± 1.05 mmol/L, respectively).

Table 2 shows the baseline variables of interest selected a priori for the current smokers by smoking cessation at the conclusion of the TEXTME trial. Participants in the texting arm were more likely to quit smoking (60.5% vs 40.6%, \( P < .001 \)). In addition, those who quit smoking were older, and on average, smoked more than those who did not quit smoking (23.9 ± 14.8 vs 20.3 ± 12.6 cigs/day; \( P = .03 \)). Other smoking behaviours (years smoked and number of quit attempts) were not significantly different. More males quit than females (162 [50.8%] males vs 23 [46.0%] females), although this was not statistically significantly different. More participants without depression quit than those with depression (157 [51.1%] without depression vs 28 [45.2%] with depression); however, this difference was not statistically significant. There were no statistically significant differences in objective cardiovascular risk measures (total cholesterol, LDL-C, systolic blood pressure, BMI, and waist circumference). In addition, there were no significant difference in quality-of-life measures (SF-12 PCS and MCS), change in physical activity (MET min/week), or maximum level of education attained. Only one had a diet according to recommended guidelines (5 serves of vegetables and 2 serves of fruit per day) at baseline, and this participant had quit smoking by the end of the trial.

As shown in Table 2, univariate analysis identified receiving text messages, being older, and smoking more cigarettes per day at baseline as being associated with quitting smoking at the end of the trial (\( P \)-values < .05). These variables were included in the multivariate logistic regression analysis to identify a model to predict smoking cessation.

Table 3 shows the unadjusted treatment only model and the final multivariable regression model fitted via backwards elimination. In the final model, receiving the text-messaging programme more than doubles the odds of quitting over the control group (OR, 2.34; 95% CI, 1.43–3.86; \( P \)-value < .001).
and each one extra cigarette smoked per day at baseline increases the odds of quitting by 2% (OR, 1.02; 95% CI, 1.00-1.04; P-value = .026).

We assessed for interaction effects between clinically important prespecified subgroups and receiving the text-message programme on smoking cessation. This is shown in detail in Figure 1. All continuous variables were dichotomised for this analysis. Low-density lipoprotein cholesterol at baseline showed a significant interaction effect with the intervention, high LDL, and intervention (OR, 3.77; 95% CI, 2.05-6.94); low LDL and intervention (OR, 1.42; 95% CI, 0.77-2.60); P = .03. However, this was not statistically significant when adjusting for multiple comparisons at the conservative P < .004 level. There were no evidence for any other significant interactions with the treatment variable.

Discussion

We previously demonstrated that a text-message-based programme designed for control of multiple risk factors resulted in smoking cessation at 6-month follow-up. In this article, we found evidence that receiving a text-message prevention programme and quantity of cigarettes smoked at baseline independently predicted quitting smoking at 6 months in participants enrolled in TEXTME. In addition, baseline LDL-C interacted with the intervention for the primary outcome of smoking cessation.

In our study, the presence of other cardiovascular risk factors at baseline did not significantly affect the outcome of smoking cessation. However, the combination of high baseline LDL-C and receiving text messages increased the odds of quitting by almost 4 times. This may be because those who had higher LDL-C at baseline (i.e. higher overall risk of a future cardiac event) were more motivated to quit smoking than those who did not. This did not reach statistical significance after adjusting for multiple comparisons and thus would need to be explored further in future studies.

Interestingly, in our study, smoking more cigarettes on average at baseline was associated with smoking cessation at 6 months. However, this was inconsistent with the results from an app-based smoking cessation study which demonstrated that heavier smokers were less likely to be engaged with the programme, although whether this resulted in smoking cessation was not assessed. Another study, which assessed a text-message-based smoking cessation programme in adolescent smokers demonstrated that less cigarettes smoked per day at baseline was associated with quitting smoking, although it is reasonable to suggest that motivational factors in adults are likely to be different to adolescents. The reason for our inconsistent findings may be due to a random association. Importantly, there were missing data for baseline cigarettes smoked, number of previous quit attempts, and number of years smoked (Table 2), and thus our results should be interpreted with caution. However, it is also possible that in our study population, adults who smoke less were less motivated to quit smoking perhaps because they perceive less harm associated with lower quantities.

Although older smokers were more likely to quit smoking at follow-up, age did not remain an independent predictor in the adjusted model as shown in Table 3. In addition, we did not find statistically significant gender differences between those who continued to smoke at the end of the study versus those who quit. This is different to Txt2Stop trial (2915 smokers) which demonstrated in their adjusted model that younger females were less likely to quit smoking and remain abstinent. Similarly, in an adolescent population receiving a text-message-based smoking cessation programme, males were more likely to quit smoking. The lack of statistical significance with gender and age in our adjusted model is likely because our population was predominantly men (18% females in the total TEXTME cohort compared to 45% in Txt2Stop), and on average older compared to Txt2Stop population (mean age 56.7 vs 36.8 years). Similar to Txt2Stop, in TEXTME, the level of education and previous quit attempts were not independent predictors of smoking cessation.

Psychosocial factors (SF-12 scores and diagnosis of major depression) in this study did not affect the primary outcome of smoking cessation. This is in contrast to the Text2Quit study, where a subanalysis (RCT with 409 adult smokers) demonstrated smoking cessation programmes work by improving psychosocial processes related to quitting rather than through the use of directing to outside resources such as Quitline or interventions such as nicotine replacement therapy. Although, they did not measure standardised quality-of-life scores such as SF-12, which may explain our contrasting results. Our findings indicate that text-message-based smoking cessation programmes may be effective (at least in a secondary prevention cohort) independent of sex, age, education, and psychosocial parameters. In addition, baseline risk does not affect the smoking cessation, although high LDL-C may be a strong motivator in those receiving text messages.

There are some limitations of this study. This is a subanalysis study which was not powered for the primary outcome of smoking cessation (the primary outcome in the original study was LDL-C) and thus significant clinical predictors for smoking cessation may have been missed. Second, nicotine dependence as measured with a Fagerstrom score was not assessed in TEXTME and has been shown to be important for smoking cessation in traditional programmes. However, not assessing Fagerstrom score does not limit the interpretation of our results, given our study outcome was smoking cessation and not nicotine dependence. Finally, the results are only applicable to patients who have a history of ischaemic heart disease, and include a cohort that is at higher cardiovascular risk than other text message-based smoking cessation programmes.

An overall limitation of text-message-based programmes is the ability to directly measure engagement. With smartphone
app-based programmes, it is possible to measure number of times a user has accessed the app, track personal progress over time, and measure total app-usage. However, with text-message-based programmes, we have been reliant on qualitative assessments from participants. We have previously reported on utility and perceived acceptability of TEXTME by intervention participants. Most participants reported that TEXTME was useful (91%), easy to understand (97%), and motivated them to change their diet (81%) and physical activity (73%). In addition, 96% read at least three-fourths of messages and 55% shared messages with family, friends, and/or clinicians. We previously examined factors related to increasing engagement with TEXTME and these included (1) ability to save and share messages, (2) support from providers and family/friends, (3) feeling of support through participation in the programme, (4) timing the initiation of the programme close to their index cardiac event, (5) personalisation, (6) initial face-to-face contact with a researcher, and (7) programme content was perceived to be from a credible source.

It would be important to elucidate in future studies the relationship between the frequency of smoking cessation messages (intervention intensity) and the effect on smoking cessation, as well as the ideal level of interactivity. The TEXTME trial, for instance, targeted multiple risk factors and delivered 1 smoking cessation message per week for 6 months without any further personalisation. On the other hand, the Txt2Step and Text2Quit trials were both interactive allowing 2-way communication and sent messages only on smoking cessation with frequency between 1 message a week up until 5 a day, for 6 months, depending on their timepoint along the programme and the degree of interactivity.

Literature assessing predictors of smoking cessation in the context of text-message-based prevention programmes are scant, and we could not find any literature assessing predictors of smoking cessation in mHealth programmes targeting multiple risk factors. Targeting multiple cardiovascular risk factors is an important principle of cardiovascular disease prevention and is more likely to be cost-effective than treating individual risk factors. Furthermore, engagement is likely important in leading to abstinence, and understanding the nuances of how participants interact with mHealth programmes and how this differs between different demographics and leads to smoking cessation is critical in optimising future programmes. Future larger studies are needed targeting multiple risk factors but powered for smoking cessation to better understand the predictors of smoking cessation and interactions of clinical variables with text messaging.

Conclusions

Our findings demonstrate that smoking quantity at baseline is independently associated with smoking cessation and that higher LDL-C may interact with the intervention to result in quitting smoking. This may suggest that those who have a higher baseline risk maybe more motivated towards beneficial lifestyle change including quitting smoking, and thus more likely to respond to mHealth smoking cessation programmes. The effect of text messages on smoking cessation was independent of age, gender, psychosocial parameters, education, and baseline control of risk factors in a secondary prevention cohort. Large-scale studies powered for smoking cessation in high-risk individuals are needed to further assess predictors and mediators of quitting in text-message-based programmes targeting multiple risk factors.

Author Contributions

HK, SM and CKC conceived the study and analysed the data. AVH analysed the data and created the forest plot. HK wrote the first draft of the manuscript. HK, SM, AVH, AT and CKC made critical revisions, reviewed and approved the final manuscript.

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REFERENCES

1. Ekpu VU, Brown AK. The economic impact of smoking and of reducing smoking prevalence: review of evidence. Tob Use Insights. 2015;8:1-35. doi:10.4137/TUI.51628.
2. GBD Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392:1923-1994. DOI 10.1016/S0140-6736(18)32225-6.
3. GBD Tobacco Collaborators. Smoking prevalence and attributable disease burden in 195 countries and territories, 1990-2015: a systematic analysis from the Global Burden of Disease Study 2015. Lancet. 2017;389:1885-1906. doi:10.1016/S0140-6736(17)30819-X.
4. Babb SMA, Schauer G, Asman K, Jamal A. Quitting smoking among adults – United States, 2000–2015. MMWR Morb Mortal Wkly Rep. 2017:1457-1464. doi:10.15585/mmwr.mm6602a1.
5. Klimis H, Thakkar J, Chow CK. Breaking barriers: mobile health interventions for cardiovascular disease. Can J Cardiol. 2018;34:905-913. doi:10.1016/j.cjc.2018.02.012.
6. Haskins BL, Lesperance D, Gibbons P, Boudreaux ED. A systematic review of smartphone applications for smoking cessation. Tran Behav Med. 2017;7:292-299. doi:10.1007/s13142-017-0495-2.
7. Whitaker R, McRobbie H, Bullen C, Rodgers A, Gy V. Mobile phone-based interventions for smoking cessation. Cochrane Database Syst Rev. 2016;4:CD006611. doi:10.1002/14651858.CD006611.pub4.
8. Abrams LC, Whittaker R, Free C, Mendel Van Aalten J, Schindler-Ruwisch JM. Development and Pretesting a text messaging program for health behavior change: recommended steps. JMIR Mhealth Uhealth. 2015;3:e107. doi:10.2196/mhealth.4917.
9. Augustson E, Cole-Lewis H, Sanders A, et al. Analysing user-reported data for enhancement of SmokefreeTXT: a national text message smoking cessation intervention. Tob Control. 2017;26:683-689. doi:10.1136/tobaccocontrol-2016-052945.
10. Coa KI, Wiseman KP, Higgins B, Augustson E. Associations between engagement and outcomes in the SmokefreeTXT program: a growth mixture modeling analysis. Nicotine Tob Res. 2019;21:663-669.
11. Ben Taleb Z, Ward KD, Aksar T, Bahelah R, Maziak W. Predictors of adherence to pharmacological and behavioral treatment in a cessation trial among smokers in Aleppo, Syria. Drug Alcohol Depend. 2015:153:167-172. doi:10.1016/j.drugalcdep.2015.05.038.
12. Siegener L, Brusse-Keizer MG, Postel MG, et al. Blended smoking cessation treatment: exploring measurement, levels, and predictors of adherence. J Med Internet Res. 2018;20:e246. doi:10.2196/jmir.9696.
13. Heffner JL, Lewis DF, Winhusen TM. Preliminary evidence that adherence to counseling mediates the effects of pretreatment self-efficacy and motivation on outcome of a cessation attempt in smokers with ADHD. Nicotine Tob Res. 2013;15:393-400. doi:10.1093/ntr/nts135
14. Hays JT, Leischow SJ, Lawrence D, Lee TC. Adherence to treatment for tobacco dependence: association with smoking abstinence and predictors of adherence. *Nicotine Tob Res*. 2010;12:574-581. doi:10.1093/ntr/ntp047

15. Zeng EY, Vilardaga R, Heffner JL, Mull KE, Bricker JB. Predictors of utilization of a novel smoking cessation smartphone app. *Telemed J E Health*. 2015;21:998-1004. doi:10.1089/tmj.2014.0232

16. 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;63:120-124. doi:10.1016/j.addbeh.2016.07.007

17. Abrams 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;47:242-250. doi:10.1016/j.amepre.2014.04.010

18. Hoeppner BB, Hoeppner SS, Abrams LC. How do text-messaging smoking cessation interventions confer benefit? a multiple mediation analysis of Text2Quit. *Addiction*. 2017;112:673-682. doi:10.1111/add.13685

19. 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. doi:10.1016/S0140-6736(11)60701-0

20. Devries KM, Kenward MG, Free CJ. Preventing smoking relapse using text messages: analysis of data from the txt2stop trial. *Nicotine Tob Res*. 2013;15:77-82. doi:10.1093/ntr/ntt086

21. Chow CK, Redfern J, Hillis GS, et al. Effect of lifestyle-focused text messaging on risk factor modification in patients with coronary heart disease: a randomized clinical trial. *JAMA*. 2015;314:1255-1263. doi:10.1001/jama.2015.10945

22. Chow CK, Redfern J, Thigalingam A, et al. Design and rationale of the tobacco, exercise and diet messages (TEXT ME) trial of a text message-based intervention for ongoing prevention of cardiovascular disease in people with coronary disease: a randomised controlled trial protocol. *BMJ Open*. 2012;2:e000606. doi:10.1136/bmjopen-2011-000606

23. Bland JM, Altman DG. Multiple significance tests: the Bonferroni method. *BMJ*. 1995;310:170. doi:10.1136/bmj.310.6973.170

24. Haug S, Schaumb MP, Schmid H. Predictors of adolescent smoking cessation and smoking reduction. *Patient Educ Couns*. 2014;95:378-383. doi:10.1016/j.pec.2014.03.004

25. Redfern J, Santo K, Coorey G, et al. Factors influencing engagement, perceived usefulness and behavioral mechanisms associated with a text message support program. *PLoS ONE*. 2016;11:e0163929. doi:10.1371/journal.pone.0163929

26. Ndindjock R, Gedeon J, Mendis S, Paccaud F, Bovet P. Potential impact of single-risk-factor versus total risk management for the prevention of cardiovascular events in Seychelles. *Bull World Health Organ*. 2011;89:286-295. doi:10.2471/BLT.10.082370

27. World Health Organisation. Global action plan for the prevention and control of NCDs. 2013-2020. [http://www.who.int/nmh/events/ncd_action_plan/en/](http://www.who.int/nmh/events/ncd_action_plan/en/). Accessed March 23, 2019