Brief handgrip and isometric exercise intervention for smoking cessation: A pilot randomized trial

Yee Tak Derek Cheung PhD[a], Tai Hing Lam MD[b], Ching Han Helen Chan MPH[c], Kin Sang Ho MBBS[c], Wai-Yin Patrick Fok BSW[c], Man Ping Wang PhD[a], William Ho Cheung Li PhD[a]

[a] School of Nursing, The University of Hong Kong

[b] School of Public Health, The University of Hong Kong

[c] Integrated Centre on Smoking Cessation, Tung Wah Group of Hospitals

Corresponding author: Prof. Tai Hing Lam, School of Public Health, The University of Hong Kong, Email: hrmrlth@hku.hk Tel: +852 3917 9287

Trial registration: ClinicalTrial.gov (NCT02844296)

Abstract (294 words)

Introduction Isometric exercises reduce craving, negative affect, and withdrawal symptoms during smoking cessation. This randomized controlled trial (RCT) was the first to test if a brief intervention using a handgrip and isometric exercises including hand pushing/pulling was feasible and efficacious to increase tobacco abstinence at 6-month.

Methods This was a single-blinded, 2-arm pilot RCT in 6 community-based smoking cessation clinics in Hong Kong. Smokers who consumed 10 or more cigarettes a day and were receiving cessation services were randomized to the exercise group (n=108) who received a free handgrip and a leaflet about handgrip exercise, and watched a 5-minute video, or to the healthy-diet group (n=100) who receive a similar dosage of intervention on healthy diet. The primary outcome was self-reported abstinence in the previous 4 weeks at 6-month follow-up.

Results In the exercise group, about 36% reported doing the exercises when craving at 2-month follow-up. No significant difference in quit rate was found between groups (34% vs. 39%, OR = 0.80, P = 0.40). *A posteriori* analysis on the exercise group showed that self-reported exercises when craving (49% vs. 26%, OR = 2.69, 1.18–6.15, P = 0.02) and total adherence (including doing the exercises when craving, once a day, and/or for 2 weeks) (53% vs. 23%, OR = 3.70, 1.15–11.92, P = 0.03) were significantly associated with self-reported abstinence.

Conclusions The brief handgrip/isometric exercise intervention was feasible and achieved modest adherence without offering incentives or mandatory reminders. Preliminary evidence of benefits was observed in the intervention group if the exercises were done when craving.

Implications Our study indicates that a brief exercise intervention, including a free handgrip and educational video, was feasible for smokers receiving smoking cessation treatment. It was particularly efficacious in increasing tobacco abstinence when exercise adherence was high.

Keywords: Smoking cessation, isometric exercise, handgrip, randomized trial

1. INTRODUCTION[1]

Quitting smoking is difficult, and relapse is common because of cravings and nicotine withdrawal. In addition to pharmacotherapy and conventional counseling, exercise has shown promising effects on reducing withdrawal symptoms, negative affect, and attentional bias towards smoking in laboratory settings (Roberts, Maddison, Simpson, Bullen, & Prapavessis, 2012; Taylor, Ussher, & Faulkner, 2007). Randomized trials on smokers undergoing cessation treatments have shown that moderate or vigorous exercise (including aerobics, brisk walking, and weightlifting) increases tobacco abstinence (Abrantes, et al., 2014; Bize, et al., 2010; Marcus, Albrecht, King, & et al., 1999; Patten, et al., 2017; Prapavessis, et al., 2016; Williams, et al., 2010). However, because these trials required the participants to attend multiple exercise sessions at least once per week, participants willing to join would thus have a very high motivation to join these exercise sessions and have ample time to join, which might inflate the effect size and limit generalizability. In reality, few smokers were willing to join multiple exercise sessions for smoking cessation. Whether they are effective for the majority of smokers is uncertain.

Some researchers have explored alternative exercise types that can have a similar effect to aerobic exercise but are more easily adopted and adhered to by most smokers. For instance, isometric exercises, which involve static muscular contractions, have been examined. Randomized trials in a laboratory setting with smokers who did not aim to quit, showed that isometric exercise for 10 minutes without equipment (M. Ussher, Cropley, Playle, Mohidin, & West, 2009; M. Ussher, West, Doshi, & Sampuran, 2006) (e.g., pushing the palms of the hands together, fist clenching) was

[1] Abbreviations Used: 10s-E: 10-second exercise; TWGH: Tung Wah Group of Hospitals; PPA: point prevalence of abstinence

effective to reduce craving and withdrawal symptoms. Another randomized trial showed that progressive muscle relaxation combining isometric exercises and relaxation techniques (i.e. body scan) yielded a similar effect (Limsanon & Kalayasiri, 2015). To date, two pragmatic randomized trials have demonstrated the feasibility of practicing isometric or low-intensity physical activity to reduce craving for smokers seeking smoking cessation treatment , but the efficacy was not statistically significant (Al-Chalabi, et al., 2008; Hassandra, et al., 2017).

We aimed to develop a simple, brief isometric exercise intervention and test whether these exercises, which can be easily and frequently done in real-life contexts, can reduce craving and increase quitting. A handgrip is one of the simplest, cheapest pieces of exercise equipment, used to enhance hand strength. It is a common short-bout exercise tool for lowering blood and arterial pressure (Badrov, et al., 2013; Carlson, Dieberg, Hess, Millar, & Smart, 2014; Garg, Malhotra, Kumar, Dhar, & Tripathi, 2014), improving neurovascular control of muscle blood flow in the elderly (Liu, et al., 2018; Sarmento, et al.), and improving cognitive function in patients with stroke (Kim & Yim, 2017). Gripping a handgrip statically without releasing it is an isometric exercise. Repeatedly and rapidly gripping and releasing a handgrip, even for a very short time, involves vigorous muscle contraction and causes fatigue and soreness quickly. Therefore, we designed a "10-second exercise" (10s-E) for smokers to relieve cravings by repeatedly and rapidly gripping-and-releasing a handgrip, at least 30 times in 10 seconds.

We conducted a formative study delivering a brief exercise intervention session (about 10 minutes) using 10s-E with clients in our community-based smoking cessation clinics at Tung Wah Group of Hospitals (TWGH), in Hong Kong. A trained research assistant recruited and guided 31 clients

in 2 clinics to learn and practice 10s-E. After the practice, 15 clients (48.4%) agreed that it was useful for craving relief or quitting. Some clients agreed that more exercise counseling may improve perceived efficacy, and preferred handgrips with higher resistance strength. Also, we found applicability could be increased by incorporating other simple exercises, such as hand-pushing and -pulling fiercely and continuously, when the handgrip was not available for usage.

Based on the results from the formative study, we added hand-pushing and -pulling to 10s-E, and designed and produced an educational video and a smartphone app to increase self-efficacy and adherence. This pilot trial examined the preliminary efficacy of our novel and simple exercise intervention to increase tobacco abstinence at 6-month follow-up in adult smokers who are receiving smoking cessation service (which included advices on how to handle craving). We also conducted *a posteriori* analysis to examine the participants' satisfaction of and compliance with the exercise, and the association between adherence to 10s-E and the quit rate.

2. MATERIAL AND METHODS

2.1 Study design

This single-blinded, 2-arm pilot randomized trial recruited clients receiving 8-week standard cessation treatments in all 6 community-based smoking cessation clinics under TWGHs in Hong Kong. The standard treatment was free of charge, including smoking cessation counseling (including how to handle craving), telephone follow-ups, physicians' assessment, and prescription of free NRT or varenicline. Smokers who (1) consumed 10 or more cigarettes daily at intake to the smoking cessation service, (2) had a smart mobile phone with internet access, and (3) were physically fit enough to use handgrips and isometric exercises were eligible. Their counselors

briefly introduced the trial using these exercises (treatment condition for the exercise group) and healthy diet ("control" condition for the healthy-diet group) for smoking cessation, followed by the participant's written consent and a baseline survey. Then, the counselor opened a sequentially numbered, opaque sealed envelope for the randomization. These envelopes indicated the group allocation, which was prepared by the principal investigator by generating a random sequence list of the group allocation with a random number generator and sequentially numbered identifiers. The study was approved by the Institutional Review Board of the University of Hong Kong/Hong Kong Authority Hong Kong West Cluster (IRB reference no: UW-16-351); the trial protocol was registered in the ClinicalTrial.gov (NCT02844296), and followed CONSORT.

2.2 Interventions

The participants in the intervention group were given a free handgrip (strength 25 kg; cost US$2). Then, the counselor played a 5-minute demonstration video by a professor (medical doctor and co-author of the present paper) on a tablet (https://www.youtube.com/watch?v=mZex2Wwy3fU), introducing three 10s-E to reduce craving: (1) Rapidly grip-and-release the handgrip at least 30 times in 10 seconds in either hands, (2) hand-pushing and (3) hand-pulling exercises fiercely without handgrip. Participants were encouraged to follow the instructions and practice the exercises while watching the video. The professor in the video encouraged the participants to do the 10s-E quickly whenever they had a craving or when the smoking urge was expected. He recommended that participants make sure that their handgrip was always carried, seen, and accessible for craving relief, and encouraged them to increase the frequency and intensity of the exercise as much as possible, as doing so would also increase their grip strength. After the video, the counselor helped the participants install a smartphone app in their mobile phone, which would

remind the participants to do the 10s-E at any time set by the participant. All the exercise reminders were designed based on the refined taxonomy of behavioral change techniques for physical activity (Abraham & Michie, 2008; Michie, et al., 2011). A leaflet providing exercise instructions and motivational messages based on the Health Action Process Approach theory (Schwarzer, 2008) was given to each participant (Figure S1; Schwarzer, 2008).

The healthy-diet group viewed a 5-minute video about diets with low sugar, low salt, and low oil (https://www.youtube.com/watch?v=3v1vF_zrpAc). The counselor installed another smartphone app in these participants' mobile phones, to generate daily healthy diet reminders at any time set by the participant, and provided an educational leaflet recapping the video content (Figure S2). A similar intervention dosage for the 2 trial groups would increase comparability by eliminating the confounding effect of additional nonspecific support or attention for the intervention group only (M. H. Ussher, Taylor, & Faulkner, 2014). Apart from the above, all participants received the usual smoking cessation treatment in the clinics.

2.3 Outcomes

The primary outcome was self-reported point prevalence of abstinence (PPA) for 4 weeks as reported at 6-month telephone follow-up. The secondary outcomes were biochemically validated abstinence, defined by exhaled carbon monoxide (CO) below 4 ppm at 6 months (Cropsey, et al., 2014), and self-reported PPA for 7 days at 2- and 6-month follow-up. All telephone follow-ups were done by trained interviewers who were blinded to the group allocation. At 6-month follow-up, all participants were invited to participate in a voluntary biochemical validation (i.e. test of

exhaled carbon monoxide) within 2 weeks of the survey completion. Participants could choose the validation time and venue, which should be any public indoor area.

At baseline, all participants completed a survey about their socio-demographic characteristics, physical activity level measured with short form of International Physical Activity Questionnaire (Lee, Macfarlane, Lam, & Stewart, 2011), nicotine dependence measured with Fagerstrom Test for Nicotine Dependence (Huang, Lin, & Wang, 2006), satisfaction to the intervention (Table S1), carving frequency in the past week (0 = no craving, 1 = less than once per day, 2 = 1–2 times a day, 3 = 3 times or more a day, 4 = every hour), craving intensity in the past day (0 = no craving, 1 = slight, 2 = mild, 3 = moderate, 4 = severe), the smoking self-efficacy questionnaire (SEQ) (Leung, Chan, Lau, Wong, & Lam, 2008) and the Minnesota Nicotine Withdrawal Scale (MNWS) (Yu, et al., 2010). At 2-month follow-up, the exercise and healthy-diet groups were asked if they perceived that 10s-E and healthy diet, respectively, relieved their cravings. The exercise group was also asked whether they had done 10s-E at all in the past 2 months, in the first week after they had learnt this exercise, and/or during craving, and for how long they continued it. At 2- and 6-month follow-up, craving frequency and intensity, the SEQ and the MNWS were assessed. Grip strength measurements at 1- and 6-month follow-up were also included in the original protocol, but we did not include these results, as the response rate was low (44/208, 21.2%).

2.4 Pre-registered hypothesis

We hypothesized that the exercise group would have a higher self-reported PPA in the previous 4 weeks and validated abstinence prevalence at 2- and 6-month follow-up than the healthy-diet group (https://clinicaltrials.gov/ct2/show/NCT02844296?term=NCT02844296&rank=1).

2.5 Statistical analysis

Assuming that our RCT had a small effect size (risk ratio) of 1.3, and the self-reported quit rate of control group was 39% (same as the previous trial with the same setting) (Cheung, et al., 2015), a significance level of 5%, statistical power of 80%, a sample size of 566 participants (283 in each group) was required. As this was a pilot trial to examine preliminary efficacy of the exercise intervention, we did not recruit a large number of participants. Due to the budget constrain, one hundred participants were recruited in each group (total N=200).

Data were entered into IBM SPSS for Windows version 23 for analysis. Descriptive statistics including frequency, percentage, and mean were used to summarize the baseline characteristics, satisfaction variables, adherence, and main outcomes. By intention-to-treat (ITT) analysis, participants who were lost or who refused to follow up were treated as smokers without changes in smoking behavior. We examined the intervention effect with generalized estimating equation (GEE) models, which modelled the correlated binary outcomes due to clustered recruitment sites. Linear mixed model was used to examine the changes of other smoking-related variables by allocation group over the study period. *A posteriori* analysis on the association between adherence and 10s-E at 2 months and quitting outcomes at 6 months was done using logistic regression models.

3. RESULTS

3.1 Group allocation and follow-up retention

From October 2016 to April 2017, 454 clients were screened for eligibility; 208 of them (45.8%) participated, with 108 allocated to the exercise group and 100 to the healthy-diet group, and were included in the final analysis. (Figure 1) At 2-month and 6-month follow-up, respectively, 89% and 79% completed the telephone surveys, and at 6-month follow-up, 41% of the participants provided an exhaled CO sample for validation. The retention rates between the two trial groups at all follow-ups showed no significant differences.

3.2 Baseline characteristics

Most of the participants were male (75%), married (54%), and had attained moderate (36%) or high (43%) intensity of physical activity at baseline. (Table 1) No substantial group differences in socio-demographic characteristics were found. Nearly half had severe nicotine dependence, and the mean daily cigarette consumption at clinic intake was about 15. Most reported craving every day (85%). No substantial differences in nicotine dependence, craving frequency, intensity, or withdrawal symptoms were found between the two groups.

3.3 Satisfaction with the intervention

The exercise group showed significantly greater interest in the video, understanding of the content, perception that 10s-E help quitting, confidence, and plan to do 10s-E than the healthy-diet group showed on the corresponding items for the healthy-diet intervention. (Table S1) About 51% of the exercise group participants reported they had followed most or all exercise demonstrations in the video during the intervention section.

3.4 10s-E adherence

At 2-month follow-up, in the exercise group, about 64% reported they had done 10s-E at least once in the past 2 months. (Table S2.) About 36% had done it when they had a craving. About one-fourth (28%) had done it more than once a day in the first week. About 18% had sustained 10s-E for more than one month.

3.5 Main outcomes of smoking cessation

Table 1 shows that, by intention-to-treat analysis, the primary outcome of 6-month self-reported abstinence in the past 4 weeks was similar between the exercise and healthy-diet group (34% vs. 39%, Odds ratio (OR) = 0.80, 95%CI 0.48–1.34, P = 0.40). (Table 2) For secondary outcomes, there was no significant group difference in validated abstinence (12% versus 15%, OR = 0.79, 95%CI 0.38–1.63, P = 0.52) or self-reported 7-day abstinence (43% versus 46%, OR = 0.86, 95%CI 0.60–1.24, P = 0.42) at 6-month follow-up. At 2-month follow-up, the 2 groups showed no significant difference in 4-week or 7-day abstinence. Complete-case analysis showed similar findings. (Table S3.) Self-efficacy of smoking cessation improved while craving intensity and frequency and withdrawal symptoms significantly reduced in both groups, but no significant group difference was found (Figure S3–S7). More participants in the exercise group perceived 10s-E as effective for craving relief than participants in the healthy-diet group perceiving healthy diet as effective (40% vs 19%, P < 0.01) (not shown in the tables or supporting information).

3.6 Association between adherence and outcomes

Compared to those who did not, self-reporting having done any 10s-E in past 2 months (41% vs. 23%, OR = 2.28, 95%CI 0.94–5.52, P = 0.07), having done so when craving (49% vs. 26%, OR = 2.69, 1.18–6.15, P = 0.02), and total adherence (yes to all 4 indicators) (53% vs. 23%, OR = 3.70,

1.15–11.92, P = 0.03) doubled the rate of self-reported abstinence at 6-month. (Table 3.) Similarly, those who reported such adherence had at least doubled the rate of validated abstinence at 6 months, though the odds ratios were not significant. Greater satisfaction with the intervention video and greater perceived effectiveness at baseline were associated with greater adherence. (Table S4.)

4. DISCUSSION

This novel pilot trial showed that the brief 10s-E intervention was well accepted by the smokers, with greater satisfaction and perceived effectiveness for smoking cessation than the healthy-diet intervention. We found about one-third of the exercise group did these exercises when craving. The exercise group did not show greater abstinence than the healthy-diet group at 2- or 6-month follow-up. A *posteriori* analysis showed that total adherence (doing 10-E in the first week, when craving, and for 2 weeks or more) significantly increased self-reported abstinence, but not the validated abstinence at 6-month follow-up.

The absence of more benefits from the exercise intervention over the healthy-diet intervention can be explained by three points. First, the adherence to 10s-E was modest. While 84% of the participants in the exercise group reported daily craving at baseline, only one-third reported doing 10s-E to reduce craving at 2-month. Nonetheless, the exercise adherence was considered satisfactory, as we provided no incentive for adherence and the exercise reminders were only voluntarily received by the participants. Second, the healthy-diet group received behavioral intervention on healthy diet at a similar intervention dosage as the exercise group, which could have led to some unintended positive effects on smoking cessation by increasing their awareness of general health and strengthening their capacity of self-regulation for health behavior changes,

like quitting smoking (Gailliot, Plant, Butz, & Baumeister, 2007; Webb, Sniehotta, & Michie, 2010), hence reducing the outcome difference. Last, all participants were already receiving smoking cessation counseling or medications in the clinics, and thus some might already have reached the effect ceiling, so that the 10s-E as a brief adjunct intervention could not further increase abstinence.

Nevertheless, our findings were consistent with a previous pilot trial that isometric exercise is feasible and accepted by smokers enrolled in a cessation clinic (Al-Chalabi, et al., 2008). We have provided preliminary evidence that greater adherence to 10s-E increased self-reported abstinence. Also, this intervention incurred only very low cost and was highly accepted by the smokers in the real-life setting of the smoking cessation clinics. As greater satisfaction with the intervention and greater perceived effectiveness of the exercise were associated with exercise adherence, further randomized trials to increase adherence so as to increase the effectiveness of handgrip and isometric interventions are warranted. Moreover, the use of information and communication technology to motivate and remind participants to do the exercises should be further developed and incorporated into the trials.

The smartphone app used in this trial included exercise reminders “pushed” to the participants and content vitality, which corresponded to the suggestions from a previous study on web-based exercise programs (McKay, Danaher, Seeley, Lichtenstein, & Gau, 2008). Future app design work needs to focus on increasing exercise adherence, by including more attractive components, like monetary incentives, gamification, and/or online peer support..

4.1 Limitations

Three limitations of this study should be noted. First, the findings may not be generalizable to smokers who have not sought help from a smoking cessation clinic. Thus, the intervention should also be tested on different types of smokers and in different settings. Second, the biochemical validation at 6 months was attended by only 41% of the participants, including both self-reported quitters and non-quitters; some participants might have been too busy to undertake the validation. Despite this limitation, the retention rate remained higher than our previous trial that used similar recruitment setting and targeted participants (Cheung, et al., 2015). Third, as the control condition was healthy diet intervention (which controlled for intervention time and nonspecific attention), we could not confirm that the intervention effect was attributed to the physiological effect of exercise or distraction effect due to the exercise.

5. CONCLUSIONS

The present trial showed that the brief 10s-E intervention was feasible, but exercise adherence appeared to be only modest when no incentive and mandatory reminders were offered. Preliminary evidence of benefits was observed in the intervention group when these exercises were done while craving. Interventions, including the use of information technology, to increase adherence to these simple, brief exercises for quitting should be developed and tested by randomized trials.

References

Abraham, C., & Michie, S. (2008). A taxonomy of behavior change techniques used in interventions. *Health Psychology, 27*, 379-387.

Abrantes, A. M., Bloom, E. L., Strong, D. R., Riebe, D., Marcus, B. H., Desaulniers, J., Fokas, K., & Brown, R. A. (2014). A preliminary randomized controlled trial of a behavioral exercise intervention for smoking cessation. *Nicotine & Tobacco Research*.

Al-Chalabi, L., Prasad, N., Steed, L., Stenner, S., Aveyard, P., Beach, J., & Ussher, M. (2008). A pilot randomised controlled trial of the feasibility of using body scan and isometric exercises for reducing urge to smoke in a smoking cessation clinic. *BMC Public Health, 8*, 349.

Badrov, M., Bartol, C., DiBartolomeo, M., Millar, P., McNevin, N., & McGowan, C. (2013). Effects of isometric handgrip training dose on resting blood pressure and resistance vessel endothelial function in normotensive women. *European Journal of Applied Physiology, 113*, 2091-2100.

Bize, R., Willi, C., Chiolero, A., Stoianov, R., Payot, S., Locatelli, I., & Cornuz, J. (2010). Participation in a population-based physical activity programme as an aid for smoking cessation: a randomised trial. *Tobacco Control, 19*, 488-494.

Carlson, D. J., Dieberg, G., Hess, N. C., Millar, P. J., & Smart, N. A. (2014). Isometric exercise training for blood pressure management: a systematic review and meta-analysis. *Mayo Clinic Proceedings, 89*, 327-334.

Cheung, Y. T. D., Chan, C. H. H., Lai, C.-K. J., Chan, W. F. V., Wang, M. P., Li, H. C. W., Chan, S. S. C., & Lam, T.-H. (2015). Using WhatsApp and Facebook online social

groups for smoking relapse prevention for recent quitters: A pilot pragmatic cluster randomized controlled trial. *Journal of Medical Internet Research, 17*, e238.

Cropsey, K. L., Trent, L. R., Clark, C. B., Stevens, E. N., Lahti, A. C., & Hendricks, P. S. (2014). How low should you go? Determining the optimal cutoff for exhaled carbon monoxide to confirm smoking abstinence when using cotinine as reference. *Nicotine & Tobacco Research, 16*, 1348-1355.

Gailliot, M. T., Plant, E. A., Butz, D. A., & Baumeister, R. F. (2007). Increasing self-regulatory strength can reduce the depleting effect of suppressing stereotypes. *Personality and Social Psychology Bulletin, 33*, 281-294.

Garg, R., Malhotra, V., Kumar, A., Dhar, U., & Tripathi, Y. (2014). Effect of isometric handgrip exercise training on resting blood pressure in normal healthy adults. *Journal of clinical and diagnostic research : JCDR, 8*, BC08-10.

Hassandra, M., Lintunen, T., Hagger, M. S., Heikkinen, R., Vanhala, M., & Kettunen, T. (2017). An mHealth app for supporting quitters to manage cigarette cravings with short bouts of physical activity: A randomized pilot feasibility and acceptability study. *JMIR Mhealth Uhealth, 5*, e74.

Huang, C.-L., Lin, H.-H., & Wang, H.-H. (2006). The psychometric properties of the Chinese version of the Fagerstrom Test for Nicotine Dependence. *Addict Behav, 31*, 2324 - 2327.

Kim, J., & Yim, J. (2017). Effects of an exercise protocol for improving handgrip strength and walking speed on cognitive function in patients with chronic stroke. *Medical Science Monitor, 23*, 5402-5409.

Lee, P. H., Macfarlane, D. J., Lam, T. H., & Stewart, S. M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 8*, 115.

Leung, D. Y. P., Chan, S. S. C., Lau, C. P., Wong, V., & Lam, T. H. (2008). An evaluation of the psychometric properties of the smoking self-efficacy questionnaire (SEQ-12) among Chinese cardiac patients who smoke. *Nicotine & Tobacco Research, 10*, 1311-1318.

Limsanon, T., & Kalayasiri, R. (2015). Preliminary effects of progressive muscle relaxation on cigarette craving and withdrawal symptoms in experienced smokers in acute cigarette abstinence: A randomized controlled trial. *Behavior Therapy, 46*, 166-176.

Liu, K., Zhou, Y., Xie, W., Gu, Z., Jin, Y., Ye, X., Chen, X., Fan, B., Wang, H., & Cui, Y. (2018). Handgrip exercise reduces peripherally-inserted central catheter-related venous thrombosis in patients with solid cancers: A randomized controlled trial. *International Journal of Nursing Studies, 86*, 99-106.

Marcus, B. H., Albrecht, A. E., King, T. K., & et al. (1999). The efficacy of exercise as an aid for smoking cessation in women: A randomized controlled trial. *Archives of Internal Medicine, 159*, 1229-1234.

McKay, H. G., Danaher, B. G., Seeley, J. R., Lichtenstein, E., & Gau, J. M. (2008). Comparing Two Web-Based Smoking Cessation Programs: Randomized Controlled Trial. *J Med Internet Res, 10*, e40.

Michie, S., Ashford, S., Sniehotta, F. F., Dombrowski, S. U., Bishop, A., & French, D. P. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. *Psychology & Health, 26*, 1479-1498.

Patten, C. A., Bronars, C. A., Vickers Douglas, K. S., Ussher, M. H., Levine, J. A., Tye, S. J., Hughes, C. A., Brockman, T. A., Decker, P. A., DeJesus, R. S., Williams, M. D., Olson, T. P., Clark, M. M., & Dieterich, A. M. (2017). Supervised, vigorous intensity exercise intervention for depressed female smokers: A pilot study. *Nicotine & Tobacco Research, 19*, 77-86.

Prapavessis, H., De Jesus, S., Fitzgeorge, L., Faulkner, G., Maddison, R., & Batten, S. (2016). Exercise to enhance smoking cessation: the getting physical on cigarette randomized control trial. *Annals of Behavioral Medicine, 50*, 358-369.

Roberts, V., Maddison, R., Simpson, C., Bullen, C., & Prapavessis, H. (2012). The acute effects of exercise on cigarette cravings, withdrawal symptoms, affect, and smoking behaviour: systematic review update and meta-analysis. *Psychopharmacology, 222*, 1-15.

Sarmento, A. d. O., Santos, A. d. C., Trombetta, I. C., Dantas, M. M., Marques, A. C. O., Nascimento, L. S. d., Barbosa, B. T., Santos, M. R. D., Andrade, M. d. A., Jaguaribe-Lima, A. M., & Brasileiro-Santos, M. d. S. Regular physical exercise improves cardiac autonomic and muscle vasodilatory responses to isometric exercise in healthy elderly. *Clinical Interventions in Aging, 12*, 1021-1028.

Schwarzer, R. (2008). Modeling health behavior change: How to predict and modify the adoption and maintenance of health reviews. *Applied Psychology, 57*, 1-29.

Taylor, A. H., Ussher, M. H., & Faulkner, G. (2007). The acute effects of exercise on cigarette cravings, withdrawal symptoms, affect and smoking behaviour: a systematic review. *Addiction, 102*, 534-543.

Ussher, M., Cropley, M., Playle, S., Mohidin, R., & West, R. (2009). Effect of isometric exercise and body scanning on cigarette cravings and withdrawal symptoms. *Addiction, 104*, 1251-1257.

Ussher, M., West, R., Doshi, R., & Sampuran, A. K. (2006). Acute effect of isometric exercise on desire to smoke and tobacco withdrawal symptoms. *Human Psychopharmacology: Clinical and Experimental, 21*, 39-46.

Ussher, M. H., Taylor, A. H., & Faulkner, G. E. J. (2014). Exercise interventions for smoking cessation. *Cochrane Database of Systematic Reviews 2014*, CD002295.

Webb, T. L., Sniehotta, F. F., & Michie, S. (2010). Using theories of behaviour change to inform interventions for addictive behaviours. *Addiction, 105*, 1879-1892.

Williams, D. M., Whiteley, J. A., Dunsiger, S., Jennings, E. G., Albrecht, A. E., Ussher, M. H., Ciccolo, J. T., Parisi, A. F., & Marcus, B. H. (2010). Moderate intensity exercise as an adjunct to standard smoking cessation treatment for women: A pilot study. *Psychology of Addictive Behaviors, 24*, 349-354.

Yu, X., Xiao, D., Li, B., Liu, Y., Wang, G., Chen, J., Bai, C., Pan, J., Wan, H., Li, Q., Zhou, X., Liao, R., Li, Q., Wang, C., Chen, R., Tang, Y., Mo, H., Zhao, M., Du, J., Li, J., Kang, L., & Wang, C. (2010). Evaluation of the Chinese versions of the Minnesota Nicotine Withdrawal Scale and the Questionnaire on Smoking Urges-Brief. *Nicotine & Tobacco Research, 12*, 630-634.

Figure 1 CONSORT diagram of the randomized trial

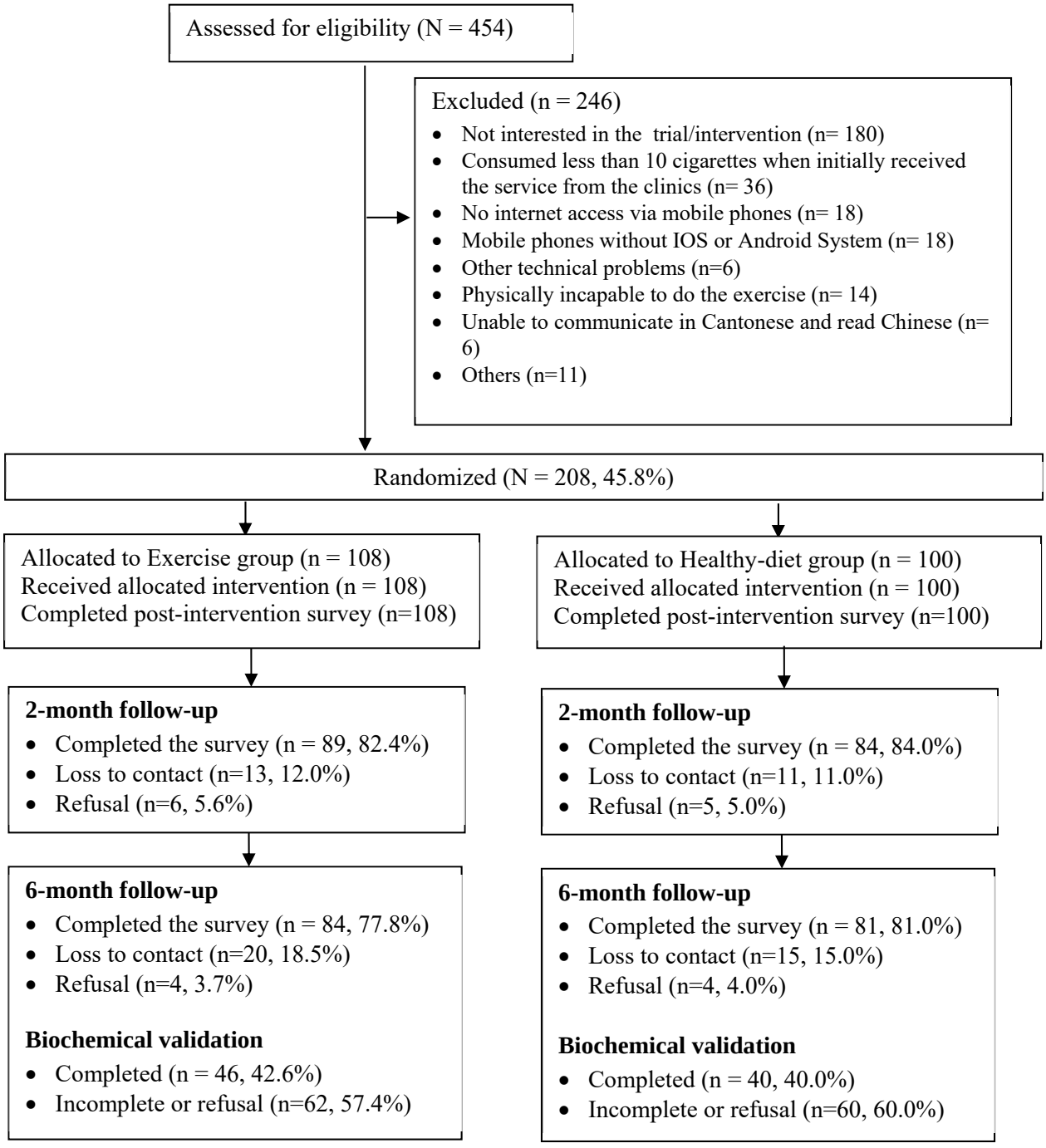

Table 1 Socio-demographic and baseline smoking characteristics of participants (N=208)

Baseline characteristics	Exercise group N=108		Healthy-diet group N=100		P*
Sex, n (%)					0.42
Male	79	(73)	78	(78)	
Female	29	(27)	22	(22)	
Age (years), mean (SD)	39.3	(8.7)	41.2	(11.1)	0.34
Marital status, n (%)					0.03
Single	30	(28)	32	(32)	
Married	53	(49)	60	(60)	
Other	24	(22)	8	(8)	
Missing	1	(1)	0	(0)	
Monthly personal income (HK$), n (%)					0.39
<$10,000	15	(14)	11	(11)	
$10,000-$19,999	39	(36)	36	(36)	
$20,000-$29,999	18	(17)	20	(20)	
≥$30,000	20	(19)	11	(11)	
Missing	16	(15)	22	(22)	
Housing, n (%)					0.55
Public rental housing	38	(35)	43	(43)	
Private housing	36	(33)	25	(25)	
Other	18	(17)	16	(16)	
Missing	16	(15)	16	(16)	
Physical activity level (IPAQ-short)					0.94
Low	23	(21)	21	(21)	
Moderate	40	(37)	35	(35)	
High	45	(42)	44	(44)	
FTND, n (%)					0.08
Mild	28	(26)	17	(17)	
Moderate	22	(20)	33	(33)	
Severe	58	(54)	50	(50)	
Any quit attempt before ICSC service intake*, n (%)	75	(70)	78	(79)	0.15
Daily cigarette consumption, mean (SD)	15.8	(10.1)	15.0	(9.9)	0.65
Frequency of smoking urge in past week n (%)					0.33
Never	0	(0)	3	(3)	
Occasionally	7	(6)	5	(5)	
1-2 times per day	13	(12)	18	(18)	
3-9 times per day	42	(39)	34	(34)	
10 times or more per day	36	(33)	34	(34)	
Missing	10	(9)	6	(6)	

Intensity of smoking urge in past 24 hours, n (%)					0.07
No urge	7	(6)	1	(1)	
Slight	14	(13)	20	(20)	
Moderate	37	(34)	40	(40)	
Severe	30	(28)	29	(29)	
Very severe	20	(19)	10	(10)	
Nicotine withdrawal (MNWS), mean (SD)	2.1	(0.7)	2.2	(0.8)	0.22
Smoking self-efficacy (SEQ-12), mean (SD)					
Internal Stimuli	2.51	(0.84)	2.36	(0.83)	0.17
External Stimuli	2.85	(0.97)	2.70	(0.87)	0.41
Readiness to quit, n (%)					0.76
Quit already or today	64	(59)	58	(58)	
Quit within 7 days	25	(23)	29	(29)	
Quit within 30 days	8	(7)	6	(6)	
Not decided to quit	8	(7)	6	(6)	
Missing	3	3)	1	(1)	

All variables were assessed at baseline of the RCT, except that "any quit attempt before intake" was assessed at the intake of the ICSC service.
Chi-square test for categorical variables; Mann-Whitney U test for continuous variables with non-normal distribution;
FTND: Fagerstrom Test for Nicotine Dependence (1-3=mild, 4-5=moderate, 6-10=severe), measured at the service intake;
IPAQ-short: International Physical Activity Questionnaire (short form);
MNWS: Minnesota Nicotine Withdrawal Scale (Scale 0-4), greater values indicate stronger self-rated withdrawal symptoms;
SEQ-12: Smoking Self-efficacy Questionnaire (Scale 1-5), greater values indicate higher self-efficacy of smoking cessation.
All between-group differences were due to chance (from randomization). P-values are for reference only.

Table 2 Main outcomes (Intention-to-treat analysis)

	Exercise group (N=108)	Healthy-diet group (n=100)	Odds ratio (95%CI)	P
Primary outcome (6-month follow-up)				
Self-reported abstinence in past 4 weeks	37 (34)	39 (39)	0.80 (0.48-1.34)	0.40
Secondary outcomes				
6-month follow-up				
Validated abstinence (Exhaled CO < 4ppm)	13 (12)	15 (15)	0.79 (0.38-1.63)	0.52
Self-reported abstinence in past 7 days	46 (43)	46 (46)	0.86 (0.60-1.24)	0.42
2-month follow-up				
Self-reported abstinence in past 4 weeks	36 (33)	37 (37)	0.86 (0.58-1.28)	0.46
Self-reported abstinence in past 7 days	51 (47)	47 (47)	1.01 (0.67-1.53)	0.96

Numbers in parentheses are column percentages.
Intention-to-treat analysis assumed the non-respondents did not change their smoking behavior (currently smoking).
Odds ratios were obtained from generalized estimating equation models.

Table 3 10-second exercise (10s-E) adherence (assessed at 2-month follow-up) predicted self-reported 4-week tobacco abstinence and biochemically validated abstinence at 6-month follow-up in the exercise group only (n=108)

	Self-reported abstinence	OR (95%CI)	P	Validated abstinence	OR (95%CI)	p
1. Any 10s-E in past 2 months						
Yes	41% (28/69)	2.28 (0.94-5.52)	0.07	16% (11/69)	3.51 (0.73-16.7)	0.12
No	23% (9/39)	1 (ref)		5% (2/39)	1 (ref)	
2. Doing 10s-E at least once per day in the first week						
Yes	43% (16/37)	1.81 (0.79-4.14)	0.16	19% (7/37)	2.30 (0.71-7.40)	0.16
No	30% (21/71)	1 (ref)		9% (6/71)	1 (ref)	
3. Doing 10s-E when craving						
Yes	49% (19/39)	2.69 (1.18-6.15)	0.02	18% (7/39)	2.06 (0.74-5.74)	0.17
No	26% (18/69)	1 (ref)		9% (6/69)	1 (ref)	
4. Doing 10s-E for 2 weeks or more						
Yes	36% (14/39)	1.12 (0.49-2.55)	0.79	15% (6/39)	1.61 (0.50-5.19)	0.79
No	33% (23/69)	1 (ref)		10% (7/69)	1 (ref)	
5. Overall adherence						
None / missing	23% (9/39)	1 (ref)		5% (2/39)	1 (ref)	
Any one of the adherence measures 2-4	36% (18/50)	1.88 (0.79-3.09)	0.19	16% (8/50)	3.52 (0.70-17.65)	0.14
Total adherence	53% (10/19)	3.70 (1.15-11.92)	0.03	16% (3/19)	3.47 (0.53-22.80)	0.20

OR (95%CI): Odds ratio (95% confidence interval).
Odds ratios and P-values were obtained from binary logistic regression.