Exercise interventions for smoking cessation (Review)

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Exercise interventions for smoking cessation

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ABSTRACT

Background
Taking regular exercise, whether cardiovascular-type exercise or resistance exercise, may help people to give up smoking, particularly by reducing cigarette withdrawal symptoms and cravings, and by helping to manage weight gain.

Objectives
To determine the effectiveness of exercise-based interventions alone, or combined with a smoking cessation programme, for achieving long-term smoking cessation, compared with a smoking cessation intervention alone or other non-exercise intervention.

Search methods
We searched the Cochrane Tobacco Addiction Group Specialised Register for studies, using the term 'exercise' or 'physical activity' in the title, abstract or keywords. The date of the most recent search was May 2019.

Selection criteria
We included randomised controlled trials that compared an exercise programme alone, or an exercise programme as an adjunct to a cessation programme, with a cessation programme alone or another non-exercise control group. Trials were required to recruit smokers wishing to quit or recent quitters, to assess abstinence as an outcome and have follow-up of at least six months.

Data collection and analysis
We followed standard Cochrane methods. Smoking cessation was measured after at least six months, using the most rigorous definition available, on an intention-to-treat basis. We calculated risk ratios (RRs) and 95% confidence intervals (CIs) for smoking cessation for each study, where possible. We grouped eligible studies according to the type of comparison, as either smoking cessation or relapse prevention. We carried out meta-analyses where appropriate, using Mantel-Haenszel random-effects models.

Main results
We identified 24 eligible trials with a total of 7279 adult participants randomised. Two studies focused on relapse prevention among smokers who had recently stopped smoking, and the remaining 22 studies were concerned with smoking cessation for smokers who wished to quit. Eleven studies were with women only and one with men only. Most studies recruited fairly inactive people. Most of the trials employed supervised, group-based cardiovascular-type exercise supplemented by a home-based exercise programme and combined with a multi-session cognitive behavioural smoking cessation programme. The comparator in most cases was a multi-session cognitive behav-
ioeval smoking cessation programme alone. Overall, we judged two studies to be at low risk of bias, 11 at high risk of bias, and 11 at unclear risk of bias.

Among the 21 studies analysed, we found low-certainty evidence, limited by potential publication bias and by imprecision, comparing the effect of exercise plus smoking cessation support with smoking cessation support alone on smoking cessation outcomes (RR 1.08, 95% CI 0.96 to 1.22; I² = 0%; 6607 participants). We excluded one study from this analysis as smoking abstinence rates for the study groups were not reported. There was no evidence of subgroup differences according to the type of exercise promoted; the subgroups considered were: cardiovascular-type exercise alone (17 studies), resistance training alone (one study), combined cardiovascular-type and resistance exercise (one study) and type of exercise not specified (two studies). The results were not significantly altered when we excluded trials with high risk of bias, or those with special populations, or those where smoking cessation intervention support was not matched between the intervention and control arms. Among the two relapse prevention studies, we found very low-certainty evidence, limited by risk of bias and imprecision, that adding exercise to relapse prevention did not improve long-term abstinence compared with relapse prevention alone (RR 0.98, 95% CI 0.65 to 1.47; I² = 0%; 453 participants).

Authors' conclusions

There is no evidence that adding exercise to smoking cessation support improves abstinence compared with support alone, but the evidence is insufficient to assess whether there is a modest benefit. Estimates of treatment effect were of low or very low certainty, because of concerns about bias in the trials, imprecision and publication bias. Consequently, future trials may change these conclusions.

**PLAIN LANGUAGE SUMMARY**

**Can exercise help people quit smoking?**

**Background**

We reviewed the evidence about whether exercise helps people who want to quit smoking, or have recently stopped smoking, to stop smoking for at least six months. Taking regular exercise may help people give up smoking by helping with cigarette withdrawal and cravings, and by helping them to manage weight gain, which can be a concern among people trying to quit.

**Study characteristics**

We found 24 studies with a total of 7279 people. Two studies focused on helping those who had recently stopped smoking and the rest of the studies included current smokers who wished to quit. All the studies were conducted with adults. Eleven studies were with women only and one with men only. Most studies recruited fairly inactive people. Most studies offered supervised and group-based, aerobic-type exercise. The evidence is up-to-date to May 2019.

**Key results**

When we combined the results of 21 studies (6607 participants) which compared exercise and smoking-cessation programmes to smoking cessation programmes alone, there was no evidence that exercise increased quit rates at six months or longer. There was no evidence that the effect was different for different types of exercise. When we combined results from two studies (453 participants), there was no evidence that exercise helped people who had recently quit to stay quit.

**Quality of evidence**

We judged the quality of evidence for whether exercise programmes help people quit smoking as low certainty, suggesting that future research could change these results. The low certainty is because we cannot rule out chance as an explanation for the suggested slight benefit. It could be that exercise may not help at all, or it could be that supporting people to do exercise modestly increases quit rates. We do not know which of these is true. We also consider that a good number of the trials may be biased. We have concerns that small studies which found smaller effects were less likely to be published than small studies which found bigger effects, making the average result misleading. We judged the evidence from two studies examining whether exercise helps people to avoid relapse to smoking to be of very low certainty, again suggesting that more research is needed. This is due to imprecision of the estimated effects and a high risk of bias in the methods used by one of the studies.
### Summary of findings for the main comparison. Exercise interventions for smoking cessation

<table>
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<th>Outcomes</th>
<th>Anticipated absolute effects* (95% CI)</th>
<th>Relative effect (95% CI)</th>
<th>N° of participants (studies)</th>
<th>Certainty of the evidence (GRADE)</th>
<th>Comments</th>
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<tr>
<td>Risk with smoking cessation support only</td>
<td>Risk with Exercise programme and smoking cessation support or exercise programme alone</td>
<td>RR 1.08 (0.96 to 1.22)</td>
<td>6607 (21 RCTs)</td>
<td>⊕⊕⊝⊕ ⊝LOWa,b,c</td>
<td>Results were not sensitive to the removal of 2 studies where cessation support was not matched between arms (e.g. potential risk of confounding), nor were they sensitive to the removal of the 6 studies in special population groups. In one of these studies, the intervention group was not provided with smoking cessation support.</td>
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<td>Smoking abstinence at longest follow-up assessed with: self-report and biochemical validation Follow-up: range 6 months to 16 months</td>
<td>Study population</td>
<td>126 per 1000 (121 to 153)</td>
<td>136 per 1000 (121 to 153)</td>
<td></td>
<td></td>
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<tr>
<td>Relapse prevention at longest follow-up assessed with: Self-report and biochemical validation Follow-up: range 6 months to 12 months</td>
<td>Study population</td>
<td>164 per 1000 (106 to 240)</td>
<td>160 per 1000 (106 to 240)</td>
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*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI). The assumed risk in the comparison group is a weighted average of the quit rates of the control arms in the included studies.

**CI:** Confidence interval; **RR:** Risk ratio

**GRADE Working Group grades of evidence**
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect.

Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of the effect.

---

a) Not downgraded on risk of bias. Sensitivity analysis excluding 10 studies judged to be at high risk of bias was consistent with overall effect, although point estimate showed an increase in favour of intervention (RR 1.25, 95% CI 0.99 to 1.58).

b) Downgraded by one level due to imprecision. Confidence interval spans no effect as well as clinically significant benefit.

c) Downgraded by one level due to suspected publication bias. Asymmetrical funnel plot (see Figure 3) suggests smaller studies showing larger effects were more likely to be published than smaller studies showing smaller effects.

d) Downgraded by one level due to risk of bias. We judged the larger of the two contributing studies to be at high risk of bias.

e) Downgraded by two levels due to imprecision. Confidence interval spans clinically significant harm as well as clinically significant benefit.
BACKGROUND

Description of the condition

Tobacco use is a leading cause of preventable illness and death worldwide, accounting for over seven million deaths annually (GBD 2015 Risk Factors Collaborators 2016). Based on current smoking trends, there will be approximately 400 million tobacco-related deaths between 2010 and 2050, mostly among current smokers (Jha 2011). Most smokers would like to stop (CDC 2017); however, quitting is difficult and there is a need to develop more effective interventions.

Description of the intervention

In this review, the exercise interventions focus on more formal, structured activities, such as using a stationary cycle, although some of the interventions promote ‘lifestyle’ activities, such as walking. Mode of exercise tends to be described as either predominantly cardiovascular (e.g. walking, stationary cycling), where there is an emphasis on improving cardiovascular fitness, or resistance-based (e.g. weight training), where the emphasis is on developing strength. Some interventions combine cardiovascular and resistance training, while others focus on one or the other.

Besides having the potential to help individuals to stop smoking and to avoid relapse, exercise interventions have the bonus that, if regular exercise is maintained, they have many general health benefits. These benefits have been observed for the general population as well as for people who quit smoking (Albrecht 1998; Korhonen 2011; Sh Benton 1997) and for people who continue to smoke (Col bert 2001; Hedblad 1997; Sentí 2001), and exercise meets the principles of a tobacco harm-reduction strategy (De R uiter 2006). For example, physical activity has been negatively associated with lung carcinoma among current and former smokers (Leitzmann 2009) and has been found to reduce oxidative stress in smokers (Koub a 2015). Also, smokers who adhere to physical activity guidelines show a significant reduction in mortality (Siahpush 2019). In the general population, researchers have shown that regular exercise has benefits for mental health, such as reducing symptoms of de-pression (Con ey 2013). Smokers who exercise more have been found to have less depression (Vickers 2003; Williams 2008) and exercise has been found to moderate the association between nicotine dependence and depression (Loprinzi 2014).

Smokers trying to quit are attracted to a more physically active lifestyle (Doherty 1998; King 1996), although most smokers are unlikely to spontaneously increase their levels of physical activity after quitting (Allen 2004; Hall 1989; Vander Weg 2001). Being physically active has been positively associated with intention to quit (Frith 2017), initiating a quit attempt (Deruiter 2008; Gauthier 2012; Haddock 2000), with confidence in maintaining smoking abstinence (King 1996) and with success at stopping smoking (Abrantes 2009; Derby 1994; Loprinzi 2016; Paavola 2001; Sedgwick 1988). Among smokers who are not ready to quit, participation in regular physical activity has been associated with reduced cigarette cravings (Haaso va 2016). Other work shows a positive trend between avoiding relapse to smoking and physical health and fitness (Metheny 1998), and among those who are more physically active there is evidence for a reduced risk of smoking relapse (López-Torrecillas 2014; McDermot 2009).

How the intervention might work

Most of the evidence exploring mechanisms for how exercise might aid smoking cessation comes from experimental studies, examining the acute effects of exercise, although it is argued that most of these mechanisms could also apply to long-term exercise, involving regular bouts of exercise. In experimental studies, temporarily abstinent smokers have consistently been shown to have reduced psychological withdrawal symptoms and desire to smoke following a bout of cardiovascular-type exercise (Haasova 2013; Haaso- va 2014; Roberts 2012; Taylor 2007b). Studies with longer bouts of exercise tended to show a more sustained effect on reducing cravings and withdrawal, and further research is needed to understand how exercise dose impacts on the duration of acute effects. However, even brief bouts of exercise, with a brief effect, may work to help abstinent smokers cope with a temporary spike in cravings. Besides exercise potentially helping smokers by reducing self-reported withdrawal and cravings, several studies have shown that a bout of exercise delays smoking or favourably influences smoking topography, possibly mediated through reduced cravings and withdrawal (De Jesus 2018b; Faulkner 2010; Hatzigeorgiadis 2016; Katomeri 2007; Kurti 2014a; Mikhail 1983; Reeser 1983; Taylor 2007a; Thayer 1993).

The mechanisms underlying these acute beneficial effects of exercise are not clear. Exercise has some similarities to smoking in its effects on stimulating the central nervous system (Russell 1983) and on neurobiological processes (Dishman 2009), including increasing beta-endorphin levels in smokers (Leelarungrayub 2010), and may provide an alternative reinforcer to smoking; there is evidence that this may also depend on the reinforcing value of physical activity versus smoking for particular individuals (Audrain-McGovern 2015). It is plausible that attention to somatic cues (e.g. bodily sensations and movements) during exercise could distract smokers from cravings, although one study showed distraction is unlikely to play a major role (Daniel 2006). There is also some evidence that exercise might work by reducing attentional bias to smoking-related cues that trigger cravings (Janse van Rensburg 2009a; Oh 2014).

Haasova 2014 used an individual participant data meta-analysis to examine a range of demographic, smoking and other characteristics as potential moderators of the acute effect of exercise on desire to smoke, and examined change in affect as a mediator. None of the characteristics examined were shown to moderate or mediate the effects of exercise. However, it is worth considering the studies in this review, and other studies, which have examined the mediators and moderators of the effects of exercise on smoking-related outcomes. For example, some studies have examined whether expectancy about the likely effects of exercise influence the effects of exercise; in one study exercise expectancy was modestly associated with psychological symptoms, but not with cigarette craving (Harper 2013), and in another study expectancy did not explain any of the effects of exercise (Daniel 2007). As regards physiological mechanisms, studies have investigated whether exercise might work by overcoming lowered cortisol levels experienced during smoking abstinence (Steptoe 2006); in four studies changes in cortisol concentration were unrelated to changes in cravings (De Jesus 2018a; Janse van Rensburg 2013; Roberts 2015; Scerbo 2010), suggesting that cortisol changes do not moderate the effects of exercise on cravings. Additionally, one study showed that changes in plasma noradrenaline may mediate the effect of exercise on cravings, although heart rate variability was not found to mediate this effect.
Taylor 2006a observed that acute reductions in urges to smoke in response to exercise were mediated by reductions in tension. Three studies involving functional magnetic resonance imaging showed that parts of the brain that are typically activated by smoking cues (images) were less activated following a bout of moderate-intensity exercise (Janse van Rensburg 2009b; Janse van Rensburg 2010; Janse van Rensburg 2012). There is also evidence to suggest that an exercise intervention might work to benefit smokers who are trying to stop smoking by reducing post-smoking cessation weight gain (Farley 2012), and by reducing cravings for sweet foods (Oh 2014; Teo 2014). Other evidence suggests that regular exercise may facilitate smoking cessation through exercise-induced increases in smoking-specific self-efficacy (Loprinzi 2015) or through fostering a physically active identity (Glowaski 2018; Verkooijen 2008; Taylor 2014). Finally, one methodologically rigorous study has shown that an exercise intervention may be effective for helping smokers to reduce their cigarette consumption (Taylor 2014), although several less rigorous studies did not find any benefit for exercise in reducing cigarette consumption (Bernard 2013; Gorini 2012; Kovelis 2012; Leelaungrayub 2010; McClure 2011; Whiteley 2007; Ybarra 2013).

Why it is important to do this review

There is evidence from large cross-sectional surveys that levels of physical activity are inversely related to smoking rates, both among adults (Boutelle 2000; Boyle 2000; Hu 2002; Picavet 2010; Schuman 2001; Swan 2018; Takemura 2000) and among adolescents (Aaron 1995; Ali 2015; Coulson 1997; Escobedo 1993; Pate 1996; Peretti-Watel 2002; Rodriguez 2004; Rodriguez 2008; Verkooijen 2008; Ward 2003). A review of studies examining associations between smoking and physical activity has been published by Kaczynski 2008. However, a review of randomised controlled trials is needed to establish whether these associations are causal. This review of exercise interventions for smoking cessation was first published in 2000, in Addiction (Ussher 2000a), and was converted into a Cochrane Review the same year (Ussher 2000b). Since our last update in 2014, we have become aware of new trials that needed to be considered for inclusion. Furthermore, the Cochrane Tobacco Addiction Group editorial team suggested incorporating a meta-analysis and other improvements. The aim of this review is therefore to update the evidence in this area, using improved methods.

OBJECTIVES

To determine the effectiveness of exercise-based interventions alone, or combined with a smoking cessation programme, for achieving long-term smoking cessation, compared with a smoking cessation intervention alone or other non-exercise intervention.

METHODS

Criteria for considering studies for this review

Types of studies

Randomised controlled trials (RCTs) and cluster-RCTs.

Types of participants

Tobacco smokers wishing to quit, or recent quitters.

Types of interventions

Interventions aimed at increasing exercise, either alone or as an adjunct to a smoking cessation intervention, compared with a smoking cessation programme alone or another type of non-exercise control group. We excluded interventions which included exercise in a multiple-component programme, since the specific effects of exercise on smoking abstinence could not be addressed. We therefore excluded yoga-based interventions, which involved a combination of exercise, meditation and breathing exercises.

Types of outcome measures

Our primary outcome was smoking cessation at the longest follow-up reported. We excluded trials with less than six months' follow-up. Where multiple measures of cessation were reported, we preferred continuous/prolonged cessation over point prevalence cessation, and biochemically validated over self-reported cessation. As discussed in the Background section, it is postulated that exercise might aid smoking cessation through a range of mechanisms, including effects on tobacco cravings, withdrawal symptoms, or other psychological symptoms, or effects on fitness or physiological or cognitive processes, as well as effects on weight/body mass index (BMI) and reductions in cigarette consumption; we therefore considered any potential mechanisms of action that were examined in the studies.

Search methods for identification of studies

We searched the Cochrane Tobacco Addiction Group Specialised Register in May 2019 for reports of studies including the terms 'exercise' or 'physical activity' in the title, abstract or keywords. The Register has been developed from electronic searching of the Cochrane Central Register of Controlled trials (CENTRAL), MEDLINE, Embase and PsycINFO, together with handsearching of specialist journals, conference proceedings and reference lists of previous trials and overviews. For details of the searches used to create the Specialised Register see the Cochrane Tobacco Addiction Group Website. At the time of the Register search, results from the following databases were included:

- Cochrane Central Register of Controlled trials (CENTRAL), issue 1, 2018;
- MEDLINE (via OVID) to update 20190409;
- Embase (via OVID) to week 201915;
- PsycINFO (via OVID) to update 20190401.

We also searched CINAHL, and Web of Science Indices (SCI-EXPANDED, SSCI, A&HCI, CPCi-S, CPCi-SSH, BKCI-S, BKCI-SSH, ESCI) using the terms ‘smoking’, ‘smoking cessation’, ‘exercise’, ‘physical activity’, and ‘intervention’ (searches completed 26 April 2019), and carried out a handsearch of reference lists, conducted searches on key authors, and contacted key authors. In addition, we searched the following online trial registries to identify unpublished studies: ClinicalTrials.gov and the International Clinical Trials Registry Platform (ICTRP).
Data collection and analysis

Selection of studies

Two review authors (from MU, AT, GF, KA) independently screened the title and abstract of each record returned for eligibility. Where there was uncertainty, we put the record forward to the next round of screening. We then retrieved the full-text reports of any trials considered potentially relevant. Two review authors (from MU, AT, GF, KA) independently assessed the full texts for inclusion, and referred any disagreements to a third review author.

Data extraction and management

Two review authors (from MU, AT, GF, KA) independently extracted the following information about each eligible trial, where available:
- Details of study design, including methods of randomisation and recruitment;
- Participant characteristics, e.g. demographic descriptors (age, sex, ethnicity), cigarette consumption, exercise levels at entry, pre-existing conditions;
- Description of the exercise intervention(s), including the nature, frequency and duration of exercise;
- Description of comparator(s)/control(s), including the nature, frequency and duration of the smoking cessation programme;
- Rates of exercise adherence and use of techniques to support exercise adherence;
- Primary outcome measures: definition of smoking cessation used for primary outcome, timing of longest follow-up, any biochemical validation;
- Secondary outcome measures: cigarette consumption, craving and withdrawal symptoms and other psychological symptoms, fitness, BMI and body weight;
- Loss to follow-up;
- Funding source;
- Declarations of interest.

We then compared and amalgamated extraction for each study, with any disagreements referred to a third review author.

Assessment of risk of bias in included studies

In accordance with the Cochrane guidelines for clinical trials (Higgins 2011; Higgins 2017) and using the Cochrane 'Risk of bias' tool, we assessed studies for risk of selection bias (random sequence generation and allocation sequence concealment), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective outcome reporting) and other potential sources of bias. Following the standard methods of the Cochrane Tobacco Addiction Group, we rated studies at high risk of detection bias if smoking cessation was not biochemically validated (as the nature of these studies precludes blinding of participants, and in the case of self-report the participant is the outcome assessor), and at low risk if biochemical validation was used. We did not assess the performance bias domain (blinding of participants and personnel), as blinding of participants and personnel is not feasible due to the nature of the intervention; this domain would not allow us to discriminate between how well the studies were conducted. Two review authors (from MU, AT, GF, KA) independently rated each domain as being at high, low or unclear risk of bias, for each study. We resolved any disagreements through discussion with a third review author. Overall, we considered studies to be at high risk of bias if we rated them at high risk in one or more domains, at low risk if we judged all domains to be at low risk, and at unclear risk otherwise.

Measures of treatment effect

For our primary outcome, we extracted the most stringent definition of smoking cessation for each study (i.e. longest follow-up, continuous/prolonged versus point prevalence, and biochemically validated versus self-report). Where possible, we expressed trial effects as a risk ratio (RR), calculated as: (quitters in treatment group / total randomised to treatment group) / (quitters in control group / total randomised to control group), with a 95% confidence interval (CI). A risk ratio greater than 1 indicates a potentially better outcome in the intervention group than in the control group. Potential mechanisms of action (cigarette consumption, craving and withdrawal symptoms and other psychological symptoms, fitness, BMI and body weight) were discussed narratively.

Unit of analysis issues

We considered both individually- and cluster-randomised trials. We deemed no cluster-randomised trials to be eligible for inclusion.

Dealing with missing data

We conducted our analyses on an intention-to-treat basis, i.e. using all participants randomised to their original groups as denominators where data were available, and assuming that those lost to follow-up were continuing to smoke (West 2005). We extracted numbers lost to follow-up from study reports and used these to assess the risk of attrition bias. Where any required primary outcome data were not available in study reports, we contacted the authors in an attempt to obtain them.

Assessment of heterogeneity

Before pooling studies, we considered both methodological and clinical variance between studies. Where pooling was deemed appropriate, we investigated statistical heterogeneity using the I² statistic (Higgins 2003). This describes the percentage of the variability in effect estimates that is due to heterogeneity rather than to sampling error (chance).

Assessment of reporting biases

We used a funnel plot to assess small-study effects and investigate the possibility of publication bias for the 'exercise versus other smoking cessation treatment' comparisons. There were not enough studies (fewer than 10) included in the analysis for relapse prevention studies to create a funnel plot.

Data synthesis

For our primary outcome of smoking cessation, we synthesised groups of studies using Mantel-Haenszel random-effects models to estimate separate pooled treatment effects (as RRs and 95% CIs), for two types of comparison:
- Effects of exercise versus no exercise intervention, on smoking cessation outcomes (comparison 1, i.e. aimed at current smokers wishing to quit smoking);
- Effects of exercise versus no exercise intervention, on relapse prevention outcomes (comparison 2, i.e. aimed at recent quitters).
Subgroup analysis and investigation of heterogeneity
In view of possible heterogeneity between studies, where relevant and if there were sufficient studies we analysed the trials in subgroups stratified by the type of exercise.

Sensitivity analysis
We carried out the following sensitivity analyses to see if the pooled results of analyses were sensitive to the removal of:

- Studies judged to be at high risk of bias;
- Studies with special populations;
- Studies where the smoking cessation support was not matched between the intervention and control groups.

'Summary of findings' table
Following standard Cochrane methodology (Schünemann 2017), we created a 'Summary of findings' table for the comparison of the effects of exercise versus no exercise intervention on outcomes for smoking cessation and for relapse prevention.

RESULTS
Description of studies
See Characteristics of included studies; Characteristics of excluded studies; and Characteristics of ongoing studies tables for details of studies.

Results of the search
Our most recent search produced 1957 records. After duplicates were removed, we screened 1772 records for title and abstract. At this stage, we excluded 1705 records, and screened the full text for 67 records. We identified six completed studies and four ongoing studies, and excluded 57 studies. See Figure 1 for the PRISMA flow diagram.
Figure 1. Study flow diagram for 2019 update

1957 records identified through database searching

Zero additional records identified through other sources

1772 records after duplicates removed

1772 records screened

1705 records excluded

67 full-text articles assessed for eligibility

57 full-text articles excluded. Reasons:
29 Ineligible design
10 Protocol only
6 Ineligible outcome
6 Follow-up < 6 months
5 Ineligible intervention
1 Included in previous version of review

10 studies included in qualitative synthesis:
6 included studies
4 ongoing studies

overall for qualitative synthesis
Included studies

This review includes 24 individually-randomised RCTs. We have added six studies since the last version of this review (Bernard 2015; Hassandra 2017; Patten 2017; Prapavessis 2016; Smits 2016; Ussher 2015). We now exclude two studies from the last version of the review, as we decided that they did not meet the inclusion criteria: one was a multi-component yoga intervention, in which the independent effects of exercise could not be examined (Bock 2012), while the other included some participants who did not wish to stop smoking (Horn 2011). Fourteen studies had more than one associated publication or abstract and these are listed under their study identifier in the reference section.

Two trials were conducted in France (Bernard 2015; Bize 2010), two in New Zealand (Maddison 2014; Prapavessis 2007), two in the UK (Ussher 2003; Ussher 2015), one in Finland (Hassandra 2017), 15 in the USA (Abrantes 2014; Ciccolo 2011; Hill 1993; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Martin 1997; McKay 2008; Patten 2017; Russell 1988; Smits 2016; Taylor 1988; Whiteley 2012) and two in Canada (Hill 1985; Prapavessis 2016).

Participants

There was a total of 7279 participants randomised in the included studies, the largest study being an Internet trial with 2318 participants (McKay 2008). Nine trials had fewer than 30 individuals in each treatment arm (Ciccolo 2011; Hassandra 2017; Hill 1985; Hill 1993; Marcus 1991; Marcus 1995; Patten 2017; Russell 1988; Taylor 1988) and three of these were described as pilot or feasibility studies (Ciccolo 2011; Hassandra 2017; Patten 2017). Only nine studies had a sufficiently large sample size to have a good prospect of detecting treatment effects (Bize 2010; Maddison 2014; Marcus 1995; Marcus 2005; Martin 1997; McKay 2008; Prapavessis 2016; Ussher 2003; Ussher 2015). Two studies focused on relapse prevention and recruited those who had recently attempted to stop smoking (Hassandra 2017; Prapavessis 2016); the remaining studies randomised current smokers who wished to quit. Six studies recruited from special populations: one trial recruited people with post-acute myocardial infarction (AMI) (Taylor 1988); another targeted pregnant smokers (Ussher 2015); two recruited individuals with symptoms reflecting moderate to severe depression (Bernard 2015; Patten 2017); one study involved those with high levels of anxiety sensitivity (Smits 2016); and one was among those recovering from alcohol dependence (Martin 1997). The remaining trials recruited from the general population of smokers.

Eleven trials were limited to women (Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Patten 2017; Prapavessis 2007; Prapavessis 2016; Russell 1988; Ussher 2015; Whiteley 2012) and one was restricted to men (Taylor 1988). Sixteen studies recorded ethnic status, and all reported a predominantly white sample. Six studies did not present the participants’ level of exercise at baseline (Abrantes 2014; Ciccolo 2011; Hill 1985; McKay 2008; Russell 1988; Taylor 1988). All the remaining studies, except Hassandra 2017 and Ussher 2015, reported that they had recruited fairly sedentary participants.

Exercise interventions

Most of the trials used supervised, group-based cardiovascular-type exercise supplemented by a home-based programme, but with some deviation from this formula. Five studies did not provide a home programme (Ciccolo 2011; Marcus 1991; Marcus 1995; Marcus 1999; Smits 2016). Ciccolo 2011 focused exclusively on an individual programme of resistance exercise (i.e. weight training). Whiteley 2012 offered both supervised cardiovascular exercise and resistance exercise. One study used only brief one-to-one counselling towards pursuing home-based exercise, with the type of exercise not specified (Ussher 2003); one focused on telephone-based counselling towards cardiovascular-type exercise (Maddison 2014); one provided a web-based programme designed to encourage engagement in a personalised fitness programme (McKay 2008), although a description of the type of exercise promoted was not provided; and another study focused on providing an app, with brief face-to-face instruction, which encouraged short bouts of various types of exercise to manage cigarette cravings (Hassandra 2017).

Only five of the studies promoted exercise as a coping strategy for managing cigarette cravings (Bernard 2015; Hassandra 2017; Patten 2017; Ussher 2003; Ussher 2015). One study promoted exercise as an “opportunity to re-establish a sense of safety around intense bodily sensations” (Smits 2016).

Sixteen studies began the exercise programme before the quit date (Abrantes 2014; Bernard 2015; Bize 2010; Hill 1993; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Patten 2017; Prapavessis 2007; Prapavessis 2016; Smits 2016; Ussher 2003; Ussher 2015; Whiteley 2012), three on the quit date (Ciccolo 2011; Hill 1985; Martin 1997), and four after the quit date (Hassandra 2017; Maddison 2014; Russell 1988; Taylor 1988). One study did not state the timing of the exercise programme relative to quit date (McKay 2008).

In Marcus 2005, among participants in the exercise group, those with higher adherence to the exercise prescription were significantly more likely to achieve smoking cessation at the end of treatment than were participants reporting lower adherence to exercise. During the treatment period, researchers used a range of behaviour change techniques to improve adherence to the exercise programme. All the studies included goal-setting, 14 used self-monitoring (Abrantes 2014; Bernard 2015; Hassandra 2017; Hill 1985; Kinnunen 2008; Maddison 2014; Martin 1997; Patten 2017; Prapavessis 2016; Russell 1988; Taylor 1988; Whiteley 2012; Ussher 2003; Ussher 2015), six included some element of reinforcement (Bernard 2015; Martin 1997; Patten 2017; Prapavessis 2016; Ussher 2003; Ussher 2015), Hill 1993 used telephone follow-up in the case of non-attendance, Prapavessis 2016 offered a telephone maintenance programme, and Taylor 1988 used remote monitoring of heart rate. To assist self-monitoring, two studies provided pedometers (Maddison 2014; Ussher 2015) and one supplied Kinetic Activity Monitors (Prapavessis 2016). Six trials used comprehensive exercise counselling, including a broad range of behaviour change techniques (Bernard 2015; Maddison 2014; Patten 2017; Prapavessis 2016; Ussher 2003; Ussher 2015).

Where supervised exercise was offered, attendance at these sessions was high, except in two studies where fewer than 50% of sessions were attended (Smits 2016; Ussher 2015). Where the emphasis was on independent/home-based exercise (Bize 2010; Maddison 2014; Marcus 2005; McKay 2008; Ussher 2003), only a minority of the participants achieved the target level of exercise, except where an exercise app was promoted, in which case exercise levels were significantly higher for the exercise group compared with controls at six-month follow-up, despite low uptake of the app (Hassan...
Besides reporting on attendance at supervised exercise sessions, most studies assessed changes in self-reported physical activity levels (Abrantes 2014; Bernard 2015; Bize 2010; Ciccolo 2011; Hassandra 2017; Hill 1985; Kinnunen 2008; Maddison 2014; McKay 2008; Patten 2017; Prapavessis 2016; Ussher 2003; Ussher 2015; Whiteley 2012). Of the 11 studies comparing activity levels for exercise versus control groups (Abrantes 2014; Bernard 2015; Bize 2010; Hassandra 2017; Maddison 2014; McKay 2008; Patten 2017; Prapavessis 2016; Ussher 2003; Ussher 2015; Whiteley 2012), seven reported significantly higher activity levels for exercise versus control participants at one follow-up at least (Abrantes 2014; Bize 2010; Hassandra 2017; Maddison 2014; Ussher 2003; Ussher 2015; Whiteley 2012). Only two studies objectively assessed changes in physical activity (Bernard 2015; Ussher 2015), both using accelerometers, and one of the studies only tested a sub-sample of participants (Ussher 2015); neither study showed a significant difference in objectively-assessed activity levels between the study groups.

Smoking cessation programmes/Comparator

Twenty-two studies included smoking cessation support as the comparator, and two studies had relapse prevention support as the comparator (Hassandra 2017; Prapavessis 2016), with 23 studies offering this support for both exercise and control groups; one study provided this support only for the control group (McKay 2008). Twenty-one of the studies provided a multisession cognitive behavioural smoking cessation or relapse prevention programme for both intervention and control groups, with one study delivering the programme by telephone (Abrantes 2014), another by face-to-face and telephone contact (Maddison 2014), and the rest were all face-to-face. Among the remaining three studies, one provided a single cessation session for all participants (Taylor 1988); in another study the exercise group received cessation counselling on alternate weeks whereas the control group only received one brief session of cessation counselling (Bernard 2015), which confounds the effects of exercise; the third study delivered a smoking cessation programme through the Internet, only for the non-exercise condition (McKay 2008). Twelve studies provided pharmacotherapy for smoking cessation or relapse prevention, which in all cases was matched between intervention and control: eight studies included nicotine patches (Abrantes 2014; Ciccolo 2011; Marcus 2005; Patten 2017; Prapavessis 2007; Prapavessis 2016; Smits 2016; Ussher 2003); one study provided nicotine gum (Kinnunen 2008); two offered several types of nicotine replacement therapy (Bize 2010; Maddison 2014); and one offered patches, gum or varenicline (Bernard 2015).

Twenty of the 22 studies recruiting current smokers set a quit date, and one set a quit date for the non-exercise condition but did not specify whether or not the exercise group set a quit date (McKay 2008). In fifteen studies the cessation programme began prior to the quit day (Abrantes 2014; Bernard 2015; Hassandra 2017; Hill 1993; Kinnunen 2008; Maddison 2014; Marcus 1995; Marcus 2005; Patten 2017; Prapavessis 2007; Prapavessis 2016; Smits 2016; Ussher 2003; Ussher 2015; Whiteley 2012).

In summary, 22 studies compared exercise plus smoking cessation support to this support alone, and provided an unconfounded estimate of the effect of exercise on smoking cessation. Neither of the two relapse prevention studies provided an unconfounded estimate of exercise plus smoking relapse prevention support compared with this support alone.

Outcomes for smoking abstinence

The strictest measure of abstinence was continuous in 11 studies, prolonged abstinence in three, point prevalence in eight, and was not specified in two. Smoking abstinence was validated objectively in all but three studies (Hassandra 2017; Maddison 2014; McKay 2008). In six studies the method of validation was both measurement of carbon monoxide (CO) in expired air and saliva cotinine (Kinnunen 2008; Marcus 1999; Marcus 2005; Prapavessis 2007; Smits 2016; Ussher 2015), 10 studies used expired CO alone (Abrantes 2014; Bernard 2015; Bize 2010; Ciccolo 2011; Hill 1985; Hill 1993; Martin 1997; Prapavessis 2016; Russell 1988; Ussher 2003), four studies used cotinine alone (Marcus 1991; Marcus 1995; Patten 2017; Whiteley 2012) and one used plasma thiocyanate (Taylor 1988).

Excluded studies

We list 108 studies that were potentially relevant but excluded, with detailed reasons, in the Characteristics of excluded studies table. We summarise reasons for excluding studies at full-text stage in Figure 1. The reason for excluding most studies at full-text screening stage was because the study had an ineligible design, and in most cases this was because the study was examining the acute effects of exercise rather than examining effects on smoking cessation outcomes. We have added 56 new excluded studies since the previous version of the review. We also classify seven studies as ongoing (see Characteristics of ongoing studies table), which are likely to be relevant for inclusion once reported.

Risk of bias in included studies

Full details of ‘Risk of bias’ assessments are given for each trial within the Characteristics of included studies table. Overall, we judged two studies to be at low risk of bias (low risk of bias across all domains), 11 at high risk of bias (high risk of bias in at least one domain), and the remaining 11 at unclear risk of bias. A summary illustration of the ‘Risk of bias’ profile across trials is shown in Figure 2.
Figure 2. Risk of bias summary: review authors’ judgements about each risk of bias item for each included study.
Table 1. Study Characteristics

<table>
<thead>
<tr>
<th>Study</th>
<th>Exercise Interventions</th>
<th>Smoking Cessation</th>
<th>Follow-Up</th>
<th>Withdrawals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maddison 2014</td>
<td>+</td>
<td>+</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td>Marcus 1991</td>
<td>?</td>
<td>+</td>
<td>2</td>
<td>+</td>
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<td>3</td>
<td>+</td>
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<td>?</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Marcus 2005</td>
<td>+</td>
<td>+</td>
<td>5</td>
<td>+</td>
</tr>
<tr>
<td>Martin 1997</td>
<td>?</td>
<td>+</td>
<td>6</td>
<td>?</td>
</tr>
<tr>
<td>McKay 2008</td>
<td>+</td>
<td>?</td>
<td>7</td>
<td>+</td>
</tr>
<tr>
<td>Patten 2017</td>
<td>?</td>
<td>+</td>
<td>8</td>
<td>+</td>
</tr>
<tr>
<td>Prapavessis 2007</td>
<td>+</td>
<td>+</td>
<td>9</td>
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<td>Prapavessis 2016</td>
<td>+</td>
<td>+</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Russell 1988</td>
<td>?</td>
<td>+</td>
<td>11</td>
<td>?</td>
</tr>
<tr>
<td>Smits 2016</td>
<td>+</td>
<td>+</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Taylor 1988</td>
<td>?</td>
<td>+</td>
<td>13</td>
<td>?</td>
</tr>
<tr>
<td>Ussher 2003</td>
<td>+</td>
<td>-</td>
<td>14</td>
<td>+</td>
</tr>
<tr>
<td>Ussher 2015</td>
<td>+</td>
<td>+</td>
<td>15</td>
<td>+</td>
</tr>
<tr>
<td>Whiteley 2012</td>
<td>+</td>
<td>+</td>
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<td>+</td>
</tr>
</tbody>
</table>
Allocation
We assessed selection bias through investigating methods of random sequence generation and allocation concealment for each study. We rated 15 studies as having low risk for random sequence generation, and the remaining nine as having unclear risk. We judged nine studies to be at low risk for allocation concealment, 14 at unclear risk, and one study at high risk (Ussher 2003). We rated Ussher 2003 at high risk as study personnel used a list of random numbers, and therefore knew which condition a person was in before they were randomised. We judged studies as having unclear risk of selection bias when authors provided insufficient information about methods used.

Outcome assessment (detection bias)
We rated 19 studies at low risk for detection bias, as smoking cessation was biochemically validated. We judged two studies to be at unclear risk of detection bias, as we were unsure whether abstinence rates were biochemically verified. We judged three studies to be at high risk of detection bias (Hill 1985; Maddison 2014; McKay 2008), as these studies relied on self-report alone.

Incomplete outcome data
We judged studies to be at a low risk of attrition bias where the numbers of participants lost to follow-up were clearly reported, the overall number lost to follow-up was not more than 50%, and the difference in loss to follow-up between groups was no greater than 20%. This is consistent with ‘Risk of bias’ guidance produced by the Cochrane Tobacco Addiction Group for assessing smoking cessation studies. We judged 13 studies to be at low risk of bias, three at unclear risk and eight at high risk. We judged these eight studies to be at high risk because overall loss to follow-up was more than 50% (Bernard 2015; Bize 2010; Kinnunen 2008; Marcus 2005; McKay 2008; Prapavessis 2016; Smits 2016), or because the groups had a difference in loss to follow-up of more than 20% (Prapavessis 2007). We assigned judgements of unclear risk because information on follow-up was not reported (Martin 1997; Russell 1988; Taylor 1988).

Selective reporting
We rated all the studies at a low risk of reporting bias, as all studies reported the outcomes for smoking cessation as stated in their Methods.

Other potential sources of bias
We did not identify any other sources of bias.

Effects of interventions
See: Summary of findings for the main comparison Exercise interventions for smoking cessation

Smoking abstinence
See: Summary of findings for the main comparison; Analysis 1.1; and Analysis 1.2.

We included 23 of the 24 studies in analyses; we dropped one study as it did not provide separate abstinence data for the experimental and control groups, although it was reported that no significant difference was found between the groups (Russell 1988).

For the first analysis (see Analysis 1.1), we pooled 21 studies comparing exercise versus no exercise intervention, on smoking cessation outcomes (i.e. aimed at current smokers wishing to quit smoking). This resulted in a pooled risk ratio (RR) of 1.08 (95% CI 0.96 to 1.22; 6607 participants), with no statistical heterogeneity ($I^2 = 0%$). This provides no evidence for an effect of the exercise intervention on smoking cessation. We then analysed the trials in subgroups, stratified by type of exercise. The exercise types/subgroups were: cardiovascular-type exercise (17 studies, 3635 participants), resistance training (1 study, 25 participants), cardiovascular-type exercise and resistance training combined (1 study, 330 participants), or exercise type not specified (2 studies, 2617 participants). There was no evidence of subgroup differences ($P = 0.72, I^2 = 0%$).

We then conducted a sensitivity analysis to see if the overall results were sensitive to exclusion of the six studies with special populations; i.e. those with mental health issues (Bernard 2015; Martin 1997; Patten 2017), with other specific psychological symptoms (Smits 2016), with a pregnant population (Ussher 2015), and with a physical health condition (Taylor 1988). Excluding these studies did not affect the interpretation of the results (RR 1.06, 95% CI 0.92 to 1.22; $I^2 = 0%$; 5376 participants). We conducted a further sensitivity analysis removing the 10 studies judged to be at high risk of bias (see Figure 2); the pooled estimate was higher than in the main analysis (RR 1.25, 95% CI 0.99 to 1.58; $I^2 = 0%$; 1802 participants), but the interpretation remained the same. A post hoc sensitivity analysis removing the two studies where smoking cessation support was not matched between the intervention and control arms (Bernard 2015; McKay 2008) also did not affect the results (RR 1.09, 95% CI 0.95 to 1.25; $I^2 = 0%$; 4219 participants).

Next we conducted an analysis pooling the two relapse prevention studies (i.e. aimed at smokers who had recently quit) (Hassandra 2017; Prapavessis 2016). This resulted in a pooled RR of 0.98 (95% CI 0.65 to 1.47; $I^2 = 0%$; 453 participants), providing no evidence for exercise interventions aiding relapse prevention (see Analysis 1.2). We judged one of these studies (Prapavessis 2016) as having high risk of bias.

Potential mechanisms of action
As none of the included studies detected a statistically significant benefit in favour of the intervention we did not assess mechanisms of action as they related to individual study findings. We summarise below the findings related to the all the different mechanisms examined in the studies.

Smoking reduction
Six of the included studies assessed changes in levels of cigarette consumption as a secondary outcome (Bernard 2015; Hill 1985; Taylor 1988; Prapavessis 2007; Maddison 2014; Ussher 2015). None of these studies reported a significant smoking reduction for the exercise versus the control group. Two studies observed significantly lower absolute levels of smoking for an exercise group versus control at 23 week post-treatment (Taylor 1988) and 24 weeks after quit day (Maddison 2014), although they did not analyse the changes in smoking relative to baseline. One trial reported significantly lower smoking levels for a cessation programme versus an exercise programme (Prapavessis 2007).
Cigarette cravings, withdrawal symptoms and other psychological measures

Nine studies assessed effects on cigarette withdrawal symptoms or cravings or both, and there was little evidence for the exercise interventions having a beneficial effect. Abrantes 2014 reported significantly lower somatic withdrawal symptoms and sleep disturbance for the exercise versus control group during the treatment period; there were no group differences for craving. Ussher 2003 observed a reduction in some withdrawal symptoms for exercise versus controls up to three weeks post-cessation. Other studies assessing withdrawal symptoms or cravings or both observed no overall effect of the intervention on these outcomes (Bernard 2015; Bize 2010; Martin 1997; Kinnunen 2008; Maddison 2014; Marcus 1999; Ussher 2015), although Marcus 1999 observed a beneficial acute reduction in withdrawal and cravings for the exercise versus control group (see Bock 1999).

Nine studies examined symptoms of depression, mood or anxiety. When assessing mood/depression, five studies observed no significant effect of the intervention (Abrantes 2014; Bernard 2015; Bize 2010; Martin 1997; Patten 2017); two of these focused on those with symptoms of moderate to severe depression (Bernard 2015; Patten 2017) and a further study recruited those recovering from alcohol dependence (Martin 1997). Marcus 2005 observed that those who increased their fitness were more likely to report decreases in depressive symptoms (see Williams 2008). Among pregnant smokers, Ussher 2015 observed a significant increase in self-reports of depression symptoms for the exercise group compared with the control group at the end of pregnancy (see Daley 2018). Based on qualitative work (Giatras 2017), the authors concluded that having to cope with changing two health behaviours simultaneously (i.e. smoking and exercise), while also coping with being pregnant and attending multiple treatment sessions, may have negatively affected participants’ mood. Bernard 2015 found no effect of the intervention on reports of anxiety, but Russell 1988 detected a significant increase in tension-anxiety scores for the active group compared with the controls. Among those with high levels of anxiety sensitivity, Smits 2016 showed that the intervention reduced anxiety sensitivity.

Fitness measures

Thirteen studies examined changes in fitness levels (Abrantes 2014; Bernard 2015; Ciccolo 2011; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Patten 2017; Prapavessis 2007; Russell 1988; Taylor 1988; Whiteley 2012 ) (sub-sample only)) and five of these showed significant gains in cardiovascular fitness for an exercise versus control group at end of treatment (Bernard 2015; Patten 2017; Prapavessis 2007; Taylor 1988; Whiteley 2012 ). A further four studies reported significant gains in cardiovascular fitness at end of treatment within an exercise group but not within a control group, although they did not compare the groups statistically (Marcus 1991; Marcus 1995; Marcus 1999) (see also Albrecht 1998; Marcus 2005).

Weight or body mass index

Twelve studies examined weight changes, and one study assessed BMI. Marcus 1999 reported a significantly smaller weight gain for those in the exercise condition compared with the controls at the end of treatment; however, those in the exercise condition weighed more than the controls at baseline, and this difference was not controlled for, which makes interpretation of the finding problematic. This study did not find any significant differences in weight change between the study groups at the three-month or 12-month follow-ups. Prapavessis 2007 observed no difference in weight gain at end of treatment when comparing cognitive-behavioural support plus nicotine patches with exercise plus nicotine patches; however, at end of treatment those in the exercise-only condition gained significantly less weight than those receiving only cognitive-behavioural support. Other studies found no difference in weight gain for the exercise versus controls at end of treatment (Bernard 2015; Marcus 1991; Marcus 1995; Marcus 2005; Ussher 2003; Whiteley 2012), at three- and six-month follow-ups (Ciccolo 2011), at 12 months post-cessation (Bize 2010; Ussher 2003) or at end of pregnancy (Ussher 2015). Patten 2017 observed no group difference for BMI at end of treatment.

DISCUSSION

Summary of main results

This update contributed six new studies evaluating exercise programmes for smoking cessation. The review includes 24 trials in total. Twenty-one of these trials compared a combined exercise and smoking cessation intervention with smoking cessation support alone, one compared exercise alone to smoking cessation support (McKay 2008), and two compared a combined exercise and relapse prevention intervention with relapse prevention alone (Hassandra 2017; Prapavessis 2016). One study could not be included in meta-analysis (Russell 1988).

A meta-analysis, pooling all 21 available studies comparing exercise to smoking cessation treatment indicated no evidence of a benefit for the exercise intervention on smoking cessation. We judged this estimate to be of low certainty, as it was imprecise and there was suspected publication bias (see Quality of the evidence; Summary of findings for the main comparison). There was no evidence of different effects by the type of exercise, and the estimate remained the same when we removed six studies with special populations, and when we removed two studies in which smoking cessation support was not matched between the intervention and control arms. When we removed 10 studies at high risk of bias, the point estimate changed to be more in favour of exercise, but the interpretation was unchanged.

Pooling the two relapse prevention studies provided no evidence for the exercise interventions aiding relapse prevention. Due to one of these studies being rated at high risk of bias and to a lack of precision around the CI, we judged the estimate as being of very low certainty.

Overall completeness and applicability of evidence

There were marked variations between the studies in the length, type, and timing of the exercise intervention, and in the design of the control condition and cessation programme. Despite this variation, the observed effects were very consistent, with no evidence of any statistical heterogeneity. Although pooled analyses did not show evidence of an effect, there are a number of limitations to the evidence base which could potentially have impacted effectiveness and which need to be considered when planning further research in this area.

The studies were mainly conducted in the USA, with others taking place in other high-income countries; studies are needed in low- and middle-income countries where population smoking rates...
are higher. Most of the studies were conducted among the general population of smokers, with only six studies among various special populations. These special populations might find it harder to stop smoking and to increase exercise levels, so we conducted a sensitivity analysis excluding the six studies. Reassuringly, results were not sensitive to the exclusion of these studies. Trials are needed among other special populations of smokers who might especially benefit from an exercise intervention. There is a high prevalence of smoking among those with serious mental illness, and those with such disorders are likely to be receptive to exercise as an aid to cessation (Arbour-Nicitopoulos 2011; Arbour-Nicitopoulos 2011b; Faulkner 2007); trials are therefore needed in this population. Studies are also needed to examine the effect of exercise interventions on smoking cessation in younger smokers; an excluded study showed that young smokers may benefit from exercise (Horn 2011). People with overweight or obesity who quit smoking may have a particular need for weight control interventions, such as exercise (Lyczek 2011), and we have yet to see a trial of exercise focusing on this population, although there was little evidence in this review to suggest that exercise interventions are likely to have an impact on weight change during smoking cessation. However, among the included studies not observing any effect on weight, several were too small to have a realistic chance of detecting a treatment effect (Bernard 2015; Ciccolo 2011; Marcus 1993; Marcus 1995; Patten 2017; Whiteley 2012). Moreover, the studies by Bernard 2015, Bize 2010, Marcus 2005, Patten 2017, Ussher 2003, and Whiteley 2012 included NRT, and post-cessation weight gain is likely to be less pronounced when using NRT (Farley 2012). The potential for exercise to moderate weight gain was therefore reduced. It is possible that exercise provides a role in weight management once an individual has stopped using NRT, but this has yet to be explored. Only two of the studies recruited reasonably active smokers (Hassand 2017; Ussher 2015). A substantial proportion of smokers may be physically active (Deroite 2008; Emmons 1994; Scioi 2009; Ward 2003) and there is some evidence that regular exercisers may be more successful at quitting (Aranteres 2009; Derby 1994; Paavola 2001), but it is not clear whether exercise interventions are effective as an aid to smoking cessation in more active populations.

It has been recommended that a smoking cessation programme should start before the quit date and continue into the period of abstinence (Raw 1998). However, almost half of the trials did not do this (Ciccolo 2011; Hill 1985; Maddison 2014; Marcus 1993; Marcus 1995; Martin 1997; McKay 2008; Russell 1985; Taylor 1988) and one study, testing an app, only provided a single session of support after the quit day (Hassand 2017).

There is some evidence that exercise is effective for reducing cigarette cravings even when a nicotine lozenge is used (Titter 2015). Further studies are needed to establish whether exercise offers additional benefits to those provided by NRT and other smoking cessation medications. It is feasible that exercise could address psychosocial and physical needs that are not currently met by NRT-based programmes. Alternatively, exercise may have limited impact on cigarette cravings if cravings have been reduced by NRT; it is worth noting that most acute exercise studies have shown significantly reduced cravings following experimentally elevated cravings (Haasova 2013).

For those studies beginning exercise either on or after the quit date (Ciccolo 2011; Hassand 2017; Hill 1985; Maddison 2014; Martin 1997; Russell 1988; Taylor 1988) success rates may have been hampered by the demand to cope simultaneously with two major changes in health behaviour (Emmons 1994; Hyman 2007; King 1996; Patten 2003). In studies where the exercise programme started after a period of smoking abstinence, the potential for exercise to moderate withdrawal symptoms during this period was lost (Haasova 2013; Roberts 2012). A review of the comparative efficacy of simultaneous versus sequential multiple health behaviour change interventions concluded that the approaches should be considered equally efficacious (James 2016). In practice, when the exercise programme begins may depend on individual capabilities and preferences (Everson-Hock 2010b).

More attention may need to be given to strategies for increasing exercise adherence. In the two studies with exercise programmes lasting for less than six weeks (Hill 1985; Martin 1997), the intervention may have been of insufficient length to encourage long-term exercise adherence. Where a home/unsupervised exercise programme was not provided it is possible that the participants’ high level of dependence on supervised exercise reduced their level of post-intervention activity. Most of the studies involved cardiovascular-type exercise and more studies are needed with non-cardiovascular exercise. For example, isometric exercise has been shown to reduce tobacco cravings and urges to smoke (Ussher 2006; Ussher 2009), and has been successfully piloted (Al-Chalabi 2008).

Only five studies promoted exercise as a coping strategy for managing cigarette cravings (Bernard 2015; Hassand 2017; Patten 2017; Ussher 2003; Ussher 2015). The effect of the interventions may have been stronger if exercise were actively presented as such a coping strategy (Taylor 2010). The evidence consistently demonstrates the benefits of an acute bout of exercise in alleviating cravings and withdrawal symptoms under optimum conditions for observing such an effect (i.e. with experimentally manipulated increased baseline cravings – through temporary abstinence, and in some cases in the presence of smoking-related cues, prior to exercising). As regards relapse prevention, exercise could be presented as a strategy which increases self-esteem and pride in one’s health, and reinforces an identity as a non-smoker and as a physically active person (Verkoojen 2006; Taylor 2014) in such a way that being a smoker is incompatible with these perceptions. Critically, if exercise aids smoking cessation, it is likely that exercise needs to be maintained for it to continue to support smoking cessation.

Among the included studies, only two offered digital support towards pursuing independent/home-based exercise (Hassand 2017; McKay 2008), providing Internet and app-based support respectively. Further studies need to consider offering these types of support, as well as other common digital support such as text/ SMS messaging. Patten 2018 has recently shown that smokers are receptive to robotic-assisted exercise coaching, and other novel digital interventions need to be explored for supporting independent exercise among smokers who are trying to quit. Only two studies objectively assessed changes in physical activity (Bernard 2015; Ussher 2015); future studies need to assess exercise dosage through including both self-reported and objective measures of physical activity, as well as recording supervised exercise attendance.

Those adequately-powered trials not showing a consistent effect of exercise on smoking abstinence (Bize 2010; Maddison 2014; Marcus 2005; McKay 2008; Papavassisi 2016; Ussher 2003; Ussher 2015) promoted moderate- or moderate to vigorous-intensity exercise,
rather than vigorous-intensity exercise. One of these studies relied solely on brief exercise counselling (Ussher 2003), and another focused on telephone-based counselling (Maddison 2014). In two other studies supervised exercise was only provided once a week (Bize 2010; Marcus 2005), and another study relied on a web-based programme (McKay 2008). In these studies the exercise intervention may have been insufficiently intense to benefit smoking abstinence. Future studies should consider providing more intensive interventions. Intensity here refers to both the exercise intensity itself (i.e. light, moderate or vigorous) and the extentiveness of the support being provided (e.g. the number of supervised exercise sessions). The findings from Marcus 2005 suggest that abstaining smokers may need to accumulate at least 110 minutes of activity a week to maintain abstinence (at least during the intervention period), and supervised exercise on two or three days a week may be necessary to achieve this. A pilot study showed promising findings for an intervention involving moderate-intensity exercise supervised on three days a week over eight weeks (Williams 2010); this needs to be tested in a larger trial.

Only five of the studies provided any post-intervention exercise programming (Hassandra 2017; Hill 1993; Maddison 2014; Pappavessis 2016; Ussher 2003), and this may have increased post-intervention exercise adherence. Hassandra 2017 made an exercise-promoting app available for use through to six-month follow-up, and observed that self-reported physical activity levels were higher for the exercise versus control group at six months. Pappavessis 2016 offered telephone counselling up to 12 months post-treatment and found no difference in activity levels for the study groups between baseline and six or 12 months after treatment. For the other studies providing post-intervention exercise programming it is not possible to draw any conclusions about whether the intervention affected levels of exercise adherence after the formal supervised programme ended, because none of these studies reported rates of adherence for this period.

Quality of the evidence
As described above and in Summary of findings for the main comparison, we rated the evidence in this review to be of low certainty for smoking cessation. Although 21 studies contributed to the meta-analysis of smoking cessation, many of them were small, and imprecision remained an issue, with confidence intervals spanning both no effect and a clinically significant benefit. A funnel plot (Figure 3) was asymmetrical, suggesting the presence of publication bias, with small studies appearing more likely to be published if they detected a greater effect. This sort of asymmetry risks inflating the estimated effect. In addition, we judged 10 of the 21 studies contributing to the main analysis to be at high risk of bias. However, when we removed these studies findings were consistent with the overall analysis, although the point estimate more clearly favoured the intervention.
Only two studies contributed to the analysis of relapse prevention; here quality was very low, due to serious imprecision (confidence intervals spanning both a clinically significant benefit and clinically significant harm) and to risk of bias (we judged the larger of the two studies contributing to the analysis to be at high risk of bias).

Overall, our judgement is that the true effect of exercise interventions for smoking cessation may be substantially different from the effect estimate observed when pooling the available data.

Potential biases in the review process

We followed standard Cochrane methods and are unaware of any introduced bias. Three review authors were authors of included studies, but these studies were assessed independently by other members of the author team, again following standard Cochrane methods. Our search strategy included the Cochrane Tobacco Addiction Group Specialised Register and we also searched trial registries and contacted key authors in an attempt to capture unpublished and ongoing studies. There may be unpublished data that our searches did not reveal, and our funnel plot indicates that this may bias results for the comparison for smoking cessation.

Agreements and disagreements with other studies or reviews

The findings are consistent with previous versions of this review and with a previous meta-analysis of exercise interventions for smoking cessation (Klinsophon 2017). The findings are not consistent with a multitude of 'laboratory' studies showing that brief bouts of exercise can acutely reduce withdrawal and cravings (Haasova 2013; Haasova 2014; Roberts 2012), which presents probably the most plausible explanation of how an exercise intervention might aid smoking cessation or relapse prevention. This inconsistency may be because the acute studies involved temporarily abstinent smokers rather than those attempting to stop smoking completely. Moreover, as this evidence comes from single bouts of acute exercise it is possible that for the laboratory results to be replicated during quit attempts individuals will need to take part in multiple bouts of exercise throughout the day. It is also plausible that the effect of exercise does not last very long and it is not feasible for people to exercise with sufficient frequency through the day. The intervention effect is therefore short-lived and not that effective. We observed little evidence for exercise having an impact on weight, but, when pooling the results from three studies in this review (Bize 2010; Marcus 1999; Ussher 2003), Farley 2012 found
no evidence for exercise moderating weight gain at end of treatment, but reported a benefit at 12-month follow-up, concluding that "More studies are needed to clarify whether this is an effect of treatment or a chance finding". Additionally, Spring 2009 conducted a meta-analysis with 10 studies of weight management interventions during smoking cessation, including five of the studies included in our review (Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Ussher 2003), and observed a significant benefit for the intervention in the short term (less than three months), but not in the long term (more than six months).

**AUTHORS’ CONCLUSIONS**

**Implications for practice**

There is insufficient evidence to support exercise as a specific aid to smoking cessation.

**Implications for research**

Further trials are needed with larger sample sizes, sufficiently intense exercise interventions, techniques for maximising exercise adherence, and objective measures of exercise levels. Studies are needed in low- and middle-income countries, and among special populations of smokers who might especially benefit from an exercise intervention, such as those with serious mental illness, younger smokers, and people with overweight or obesity.

**ACKNOWLEDGEMENTS**

We would like to acknowledge Robert West and Andrew McEwen, who contributed to earlier versions of this review. We would also like to thank Professor Harry Prapavessis and an anonymous researcher for conducting peer review, and Lee Bromhead for providing consumer review.

This project was supported by the National Institute for Health Research (NIHR), via Cochrane Infrastructure and Cochrane Programme Grant funding to the Cochrane Tobacco Addiction Group. The views and opinions expressed therein are those of the authors and do not necessarily reflect those of the Systematic Reviews Programme, NIHR, NHS, or the Department of Health and Social Care. JHB is also part-funded by the NIHR Oxford Biomedical Research Centre (BRC).
References to studies included in this review

Abrantes 2014 (published data only)


Bernard 2015 (published data only)

Bize 2010 (published data only)


Ciccolo 2011 (published data only)

Hassandra 2017 (published data only)


Hill 1985 (published data only)

Hill 1993 (published data only)

Kinnunen 2008 (published data only)


Maddison 2014 (published data only)


Marcus 1991 (published data only)
Exercise interventions for smoking cessation (Review)

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Marcus 1995 (published data only)

Marcus 1999 (published data only)


Marcus 2005 (published data only)


Martin 1997 (published data only)


McKay 2008 (published data only)

Patten 2017 (published data only)

Prapavessis 2007 (published data only)


Prapavessis 2016 (published data only)


Russell 1988 (published data only)

Smiths 2016 (published data only)

Smiths JAJ, Zvolensky MJ, Rosenfield D, Marcus BH, Church TS, Frierson GM, et al. The efficacy of vigorous-intensity exercise as an aid to smoking cessation in adults with elevated anxiety...


Taylor 1988 *published data only*

Ussher 2003 *published data only*


Ussher 2015 *published data only*


Whiteley 2012 *published data only*


References to studies excluded from this review

Abrantes 2017 *published data only*

Abrantes 2018 *published data only*

Aggarwal 2017 *published data only*

Al-Chalabi 2008 *published data only*

Al-Eisa 2016 *published data only*

Allen 2018a *published data only*

Allen 2018b *published data only*

Angeli 2018 *published data only*

Arbour-Nicitopoulos 2011 *published data only*
Arbour-Nicitopoulos KP, Faulkner GE, Hsin A, Selby P. A pilot study examining the acute effects of exercise on craving...

**Audrain-McGovern 2015 (published data only)**


**Bernard 2013 (published data only)**


**Blank 2017 (published data only)**


**Bock 2012 (published data only)**


**Caliani 2004 (published data only)**


**Chaney 2008 (published data only)**


**Cinciripini 1996 (published data only)**


**Clark 2005 (published data only)**


**Conklin 2017 (published data only)**


**Cooke 2016 (published data only)**


**Copeland 2006 (published data only)**


**Daley 2004 (published data only)**


**Daniel 2004 (published data only)**


**Daniel 2006 (published data only)**


**Daniel 2007 (published data only)**


**De Jesus 2014 (published data only)**


**De Jesus 2018a (published data only)**

De Jesus S, Prapavessis H. Affect and cortisol mechanisms through which acute exercise attenuates cigarette cravings during a temporary quit attempt. *Addictive Behaviors* 2018;80:92-8.

**De Jesus 2018b (published data only)**


**Elisero 2011 (published data only)**


**Everson 2006 (published data only)**

Everson 2008  {published data only}

Faulkner 2010  {published data only}

Fong 2014  {published data only}

Fortmann 1995  {published data only}

Garcia 2019  {published data only}

Gorini 2012  {published data only}


Grove 1993  {published data only}

Grove 2006  {published data only}

Haasova 2011  {published data only}
Haasova M, Oh H, Taylor AT. The acute effects of brisk walking and isometric exercise versus rest on cigarette cravings and attentional bias. Paper presented at ASH Wales; 2011 Oct; Cardiff, UK.

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Harper 2013  {published data only}

Hassandra 2012  {published data only}

Hatzigeorgiadis 2016  {published data only}

Ho 2014  {published data only}

Horn 2011  {published data only}


Hurt 1994  {published data only}

Hwang 2012  {published data only}

Janse van Rensburg 2008  {published data only}
Janse van Rensburg 2009a \{published data only\}

Janse van Rensburg 2009b \{published data only\}

Janse van Rensburg 2010 \{unpublished data only\}

Janse van Rensburg 2012 \{published data only\}

Janse van Rensburg 2013 \{published data only\}

Jones 2001 \{published data only\}

Jonsdottir 2001 \{published data only\}

Katomeri 2007 \{published data only\}

Kinnunen 2013 \{published data only\}

Kinnunen 2009 \{published data only\}


Kovelis 2012 \{published data only\}

Kurti 2014a \{published data only\}

Kurti 2014b \{published data only\}

Leeharungrayub 2010 \{published data only\}

Linke 2012 \{published data only\}

Loprinzi 2015 \{published data only\}

Luo 2019 \{published data only\}

Mantoani 2014 \{published data only\}

McClure 2009 \{published data only\}

McClure 2011 \{published data only\}
Mctver 2004 (published data only)

Mikhail 1983 (published data only)

Nair 2017 (published data only)

Nguyen 2012 (published data only)

Oenema 2008 (published data only)

Oh 2014 (published data only)

Ortega Sanchez-Pinilla 2006 (published data only)

Pomerleau 1987 (published data only)

Prapavessis 2014 (published data only)

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Prochaska 2008 (published data only)

Ramsay 2004 (published data only)

Reeser 1983 (published data only)

Reid 2014 (published data only)

Roberts 2015 (published data only)

Saltychev 2012 (published data only)

Scherbo 2010 (published data only)


Schneider 2015 (published data only)

Spring 2004 (published data only)

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Taylor AH, Katomeri M. Effects of a brisk walk on blood pressure responses to the Stroop, a speech task and a smoking cue among temporally abstinent smokers. Psychopharmacology (Berl) 2006;184(2):247-53.

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Ussher 2001 (published data only)

Ussher 2006 (published data only)

Ussher 2008 (published data only)

Ussher 2009 (published data only)

Vander Weg 2008 (published data only)

Vickers 2005 (published data only)

Vickers 2009 (published data only)

Whiteley 2007 (published data only)

Williams 2010 (published data only)

Williams 2011 (published data only)

Ybarra 2013 (published data only)
Zwick 2006 *(published data only)*


References to ongoing studies

Ciccolo 2014 *(published data only)*


NCT01951456. Resistance training as an aid to smoking cessation treatment. clinicaltrials.gov/ct2/show/NCT01951456 (first received 26 September 2013).

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Vander Weg 2018 *(published data only)*


Additional references

Aaron 1995


Abrantes 2009


Albrecht 1998


Ali 2015


Allen 2004


Arbour-Nicitopoulos 2011b


Bock 1999


Borrelli 2002


Boutelle 2000


Boyle 2000


CDC 2017

Colbert 2001


Cooney 2013


Coulson 1997


Daley 2018


De Ruiter 2006


Derby 1994


Deruiter 2008


Dishman 2009


Doherty 1998


Emmons 1994


Escobedo 1993


Everson-Hock 2010b


Farley 2012


Faulkner 2007


Frith 2017


Gauthier 2012


GBD 2015 Risk Factors Collaborators 2016


Giatras 2017


Glowski 2018


Haasaova 2013

Haasova 2014

Haasova 2016

Haddock 2000

Hall 1989

Hedblad 1997

Higgins 2003

Higgins 2011

Higgins 2017

Hu 2002

Hyman 2007

James 2016

Jha 2011

Kaczynski 2008

King 1996

Klinschopf 2017

Korhonen 2011

Koubaa 2015

Leitzmann 2009

Loprinzi 2014

Loprinzi 2016

Lycett 2011
Lycett D, Munafô M, Johnstone E, Murphy M, Aveyard P. Associations between weight change over 8 years and baseline
Exercise interventions for smoking cessation (Review)

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López-Torrecillas 2014

McDermot 2009

Metheny 1998

Paavola 2001

Pate 1996

Patten 2003

Patten 2018

Peretti-Watel 2002

Picavet 2010

Raw 1998

Roberts 2012

Rodriguez 2004

Rodriguez 2008

Russell 1983

Schuman 2001

Schünemann 2017

Sciolli 2009

Sedgwick 1988

Senti 2001

Shinton 1997
Characteristics of included studies [ordered by study ID]

Siahpush 2019

Spring 2009

Steptoe 2006

Swan 2018

Takemura 2000

Taylor 2007a

Taylor 2007b

Taylor 2010

Teo 2014

Vander Weg 2001

Verkooijen 2008

Vickers 2003

Ward 2003

West 2005

Williams 2008

References to other published versions of this review

Ussher 2000a

Ussher 2000b

Ussher 2005

* Indicates the major publication for the study
**Abrantes 2014**

**Methods**  
Country: USA  
Randomisation: Computer-generated, using URN procedure

**Participants**  
61 participants, 65.6% female, mean age 47, mean CPD 20, FTCD score 5.8, "physically inactive"

**Interventions**  
(a) Intervention: CV equipment: facility, began at 20 mins per session with weekly gradual increases, 55% – 69% of age-predicted maximal heart rate (once a week for 12 weeks) + group PA counselling (once a week for 12 weeks) + telephoned-based CP (once a week for 8 weeks), including nicotine patches for 8 weeks  
(b) Control: health education (once a week for 12 weeks) + CP as (a)  
Exercise began before quit date  
Both groups received financial incentives to attend

**Outcomes**  
Continuous abstinence  
Validation: CO < 10 ppm. Where CO not available, significant other reports were used for 1 participant at the 6-month follow-up and 1 participant at the 12-month follow-up  
Follow-up: end of treatment, 6 months, 12 months

**Notes**  
Contact time balanced between (a) and (b)  
Funding: This work was supported by a National Institute on Drug Abuse-funded grant (K23 DA019950) awarded to Dr. AMA  
Conflict of interest: None declared

**Risk of bias**

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
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<td>Unclear risk</td>
<td>No information</td>
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<tr>
<td>Blinding of outcome assessment</td>
<td>Low risk</td>
<td>Details of blinding not specified. However as self-reports of smoking were validated objectively by expired CO risk is considered as low</td>
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<tr>
<td>Incomplete outcome data</td>
<td>Low risk</td>
<td>ITT analysis. Number of missing self-reports counted as smoking is not stated. Only 5 lost to follow-up</td>
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<tr>
<td>Selective reporting</td>
<td>Low risk</td>
<td>Smoking outcomes reported as stated in Methods</td>
</tr>
</tbody>
</table>

**Bernard 2015**

**Methods**  
Country: France  
Randomisation: Computer-generated
Participants
70 participants, 59% female, mean age 48, mean CPD 21, mean FTND score 6.4, engaged in physical activity for < 3 days a week for ≥ 20 mins, current depressive symptoms defined as a score of > 8 on the depression subscale of the Hospital Anxiety and Depression Scale, 7% diagnosed with a major depressive disorder, 39% with dysthymia (persistent mild depression)

Interventions
(a) Exercise intervention: 40 mins group-based at facility, supervised cycle ergometry at 60% - 85% maximum heart rate, twice a week for 2 weeks, then once a week for 6 weeks plus home-based exercise once a week, plus 40 mins physical activity counselling alternative weeks + CP (1 brief initial brief counselling session, then 40 mins smoking cessation counselling alternative weeks for 8 weeks, plus 12 weeks of NRT or varenicline)
(b) Control: health education (group-based and matched for contact time with (a)) + 1 brief initial brief counselling session and 12 weeks of NRT or varenicline

Outcomes
Continuous abstinence
Validation: CO ≤ 10 ppm
Follow-up: end of treatment, and 12, 24, 52 weeks after quit date

Notes
Control group balanced with exercise group for contact time. Limitations: small sample size, the exercise group received 40 mins smoking cessation counselling on alternate weeks but the control group only received 1 brief session of cessation counselling, low follow-up rate, no record of exercise outside of supervised exercise, over ⅔ of participants were taking antidepressant medication, limiting the potential of the exercise intervention influence depression
Funding: This work was supported by the University Hospital of Montpellier (AOI 2009) and French Committee against Respiratory Diseases.
Declared COIs: Pr Quantin received research funds and served on the scientific board of Lilly, Bohringer, Roche, and Pfizer. Pr Courtet has received grants and served as consultant or speaker for the following entities: AstraZeneca, Roche, Servier, Bristol-Myers Squibb, Janssen-Cilag, Lundbeck, Otsuka, Pfizer, Sanofi- Aventis, and Servier. Dr. Guillaume has received compensation as a consultant for AstraZeneca, Bristol-Myers Squibb, Lundbeck, Otsuka, Servier, and Janssen Cilag. These companies manufacture and/or distribute some antidepressant, mood stabilizer, and/or antipsychotic medications. Drs. Bernard, Cyprien, and Georgescu have no conflict of interest. Pr Ninot and Taylor have no conflict of interest.

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<tr>
<td>Allocation concealment (selection bias)</td>
<td>Low risk</td>
<td>Allocation to treatment conditions was unknown to the study staff or investigators prior to assignments</td>
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<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Researchers conducting the follow-ups were aware of group allocation but low risk of bias as self-reports were validated objectively by expired CO</td>
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<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>High risk</td>
<td>Less than half (42%) of those randomised were followed up at 52 weeks. ITT approach. Not clear whether missing data were classified as smoking</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>All outcomes stated in Methods were reported</td>
</tr>
</tbody>
</table>
Country: Switzerland
Randomised: computer-generated

Participants
481, mean age 42, mean CPD 27, sedentary: < 150 mins moderate-intensity physical activity per week and < 60 mins vigorous intensity activity

Interventions
(a) Intervention: moderate-intensity group-based CV activity, 45 mins, weekly for 9 weeks + 15 mins CP for 9 weeks (including NRT prescription)
(b) Control: 9 weeks of 15 mins a week CP (including NRT prescription) + Health Education for equal time as exercise intervention (not exercise)
Exercise started 1 week before quit date

Outcomes
Continuous abstinence
Validation: CO < 10 ppm
Follow-up: 5 weeks, 5 months and 47 weeks after quit date

Notes
Contact time balanced between (a) and (b)
First included in review as Cornuz 2007
Funding: This trial was supported by a grant from the Swiss National Science Foundation (SNSF 3200-067085).
Conflict of interest: None declared

Risk of bias

Random sequence generation (selection bias) Low risk Quote: “Remotely and randomly generated by a computer”, block size 50
Allocation concealment (selection bias) Low risk Quote: “Concealment of allocation was secured by means of sealed envelopes.”
Comment: Not stated whether those delivering the intervention were aware of the possible treatment allocations
Blinding of outcome assessment (detection bias) All outcomes Low risk Outcome assessment was not blinded, but as self-reports of smoking were validated objectively by expired CO risk is considered as low
Incomplete outcome data (attrition bias) All outcomes High risk 62 post-randomisation exclusions: 11 Int and 2 Cont did not attend first group session, 1 Cont pregnant, 20 Int and 28 Cont regular exercisers, or marijuana users. 45% Int and 38% Cont lost to follow-up at 1 year, included as smokers in analysis
Selective reporting (reporting bias) Low risk Smoking outcomes reported as stated in Methods

Ciccolo 2011

Methods
Country: USA
Randomisation: computer-generated list of numbers

Participants
26, 52% female, mean age 37 (36.5), mean CPD 18, exercise ≤ 60 mins/week
Ciccolo 2011 (Continued)

Interventions
(a) Resistance training with equipment: alone, facility, 60 mins, 2 times/week for 12 weeks, 10 exercises, 65% - 75% est max, 10 reps, weeks 1 - 3: 1 set, weeks 4 - 12: 2 sets, + CP (single 1 - 20-min counselling + nicotine patches, received prior to randomisation)
(b) CP as (a), + health education video, 25 mins, twice/week for 12 weeks
Exercise began on the quit day

Outcomes
7-day PPA, prolonged abstinence (allowing 2-week grace period after quitting)
Validation: CO < 10 ppm
Follow-up: 3, 6 months

Notes
Number of contacts balanced between (a) and (b) but contact time was not
Following 4 x 30-min pre-randomisation sessions (orientation, consent and baseline questionnaires), over a 2-week run-in period, 147 were excluded
Funding: National Cancer Institute (R03 CA132475 to JTC)
Conflict of interest: None declared

Risk of bias

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<td>Low risk</td>
<td>Details of blinding not specified, but as self-reports of smoking were validated objectively by expired CO risk is considered as low</td>
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<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>1 post-randomisation exclusion: developed lung cancer 8% Int and 15% Cont lost to follow-up at 3 months, 38% Int and 54% Cont lost to follow-up at 6 months; all included as smokers in analysis</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as stated in Methods</td>
</tr>
</tbody>
</table>

Hassandra 2017

Methods
Country: Finland
Randomisation: online randomisation tool

Participants
44 participants, 43% female, mean age 39, smoking > 10 CPD, mean BMI 26 kg/m²

Interventions
All participants received 3 weekly, group smoking-cessation counselling sessions before setting a quit date and before being randomised to intervention or control. Those who missed a group session were offered an individual session. Within 3 to 7 days after their quit day, all participants had a 4th session of group training on relapse prevention and formed action plans to cope with cravings. In addition the intervention group downloaded an app to their mobile phone and were given instructions on how to use it. The app gave messages about which physical activities to do to help them reduce cravings and how to do the activities. The app also gave general messages about smoking cessation Cessation programme began before quit date. Exercise began after quit date
**Hassandra 2017 (Continued)**

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>7-day PP self-reported abstinence at 3 days and 1, 2, 3, 4, 12, and 24 weeks (6 months after starting cessation programme) after the quit date</th>
</tr>
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<tbody>
<tr>
<td>Notes</td>
<td>Small sample, as feasibility study. Low usage of app. The intervention group had more smoking cessation support than the control, as the app included general messages about smoking cessation and motivation, as well as messages about exercise. Self-reports of abstinence were not validated. Funding: The study was funded by the Finnish National Institute for Health and Welfare (Terveyden ja Hyvinvoinnin Laitos) Conflict of interest: None declared</td>
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<td>Allocation to treatment conditions was unknown to the study staff or investigators prior to assignments</td>
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<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Follow-ups were conducted by online questionnaire, risk of differential misreport judged to be low</td>
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<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>77% of those randomised were followed up at 6 months. Used an ITT approach, with those lost to follow-up counted as having relapsed to smoking</td>
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<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Outcomes stated in protocol were reported</td>
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**Hill 1985**

<table>
<thead>
<tr>
<th>Methods</th>
<th>Country: Canada Randomised</th>
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<tr>
<td>Participants</td>
<td>26 women, 10 men, mean age 40, mean CPD 32</td>
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<tr>
<td>Interventions</td>
<td>(a) Intervention: CV activity: various, group, facility, 30 mins, twice weekly for 5 weeks + home activity + CP twice weekly for 5 weeks (b) Control, CP alone Exercise began on quit date</td>
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<tr>
<td>Outcomes</td>
<td>7-day PPA Validation: CO Follow-up: 1, 3, 6 months</td>
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<tr>
<td>Notes</td>
<td>Contact time not balanced Funding: Information not provided. Conflict of interest: Information not provided</td>
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**Risk of bias**
Hill 1985 (Continued)

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<tr>
<td>Allocation concealment (selection bias)</td>
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<td>No details given</td>
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<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>High risk</td>
<td>Self-reported smoking status was not validated objectively</td>
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<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>Low risk</td>
<td>1 participant not attending follow-ups was counted as a smoker</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as stated in Methods</td>
</tr>
</tbody>
</table>

Hill 1993

Methods
Country: USA
Recruitment: community volunteers, smoking at least 30 yrs, not currently walking for exercise
Randomisation: in blocks of 8 to 12, method not described

Participants
82 (43 women, 39 men), mean age 59, mean CPD 28, irregular walkers

Interventions
(a) Intervention 1: Walk: group/individual, facility/home, 15 - 35 mins, 60% - 70% HR reserve, 1 - 3 times/week for 12 weeks (n = 20)
(b) Intervention 2: as (a) + CP 1 - 4 times/week for 12 weeks (n = 18)
(c) Intervention 3: CP as (b) + nicotine gum (n = 22)
(d) Control: CP alone (n = 22)
Exercise began before quit date

Outcomes
5-day PPA
Validation: CO < 10 ppm
Follow-up: 1, 4, 9 months

Notes
(b) compared to (d) for effect of exercise programme
Funding: Information not provided
Conflict of interest: Information not provided

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
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<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Method not stated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Low risk</td>
<td>No details given</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Details of blinding not specified, but as self-reports of smoking were validated objectively by expired CO risk is considered as low</td>
</tr>
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</table>

Exercise interventions for smoking cessation (Review)
### Hill 1993 (Continued)

<table>
<thead>
<tr>
<th>All outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incomplete outcome data</strong> (attrition bias)</td>
</tr>
<tr>
<td>Low risk</td>
</tr>
<tr>
<td>4 individuals dropped out and were excluded from the analysis. The main findings were the same with or without the 4 dropouts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Selective reporting (reporting bias)</strong></td>
</tr>
<tr>
<td>Low risk</td>
</tr>
<tr>
<td>Smoking outcomes reported as stated in Methods</td>
</tr>
</tbody>
</table>

### Kinnunen 2008

<table>
<thead>
<tr>
<th>Country: USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomisation: Method not stated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>263 women, mean age 39, mean CPD 19, exercise &lt; 3 times a week</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Intervention 1: CV equipment, individual, facility, 40 mins, 60% - 80% HR max (twice a week for 5 weeks, then once a week for 14 weeks) + CP (once a week for 19 weeks) + nicotine gum</td>
</tr>
<tr>
<td>(b) Intervention 2: CP and nicotine gum as (a) + health education for same number of sessions as for exercise in (a)</td>
</tr>
<tr>
<td>(c) Control: CP and nicotine gum as (a)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolonged abstinence</td>
</tr>
<tr>
<td>Validation: CO, cotinine</td>
</tr>
<tr>
<td>Follow-up: 1 week, 1, 4, 12 months</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact time balanced between (a) and (b). (b) used as control condition in forest plot (total of 221 women randomised to groups (a) and (b)). 2/34 quit in control (c)</td>
</tr>
<tr>
<td>Funding: Support was provided by NIH/NIDA-12503 grant to Taru Kinnunen and by grants from the Academy of Finland (200075, 103650) to Tellervo Korhonen</td>
</tr>
<tr>
<td>Conflict of interest: Information not provided</td>
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### Risk of bias

<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Random sequence generation (selection bias)</strong></td>
</tr>
<tr>
<td>Unclear risk</td>
</tr>
<tr>
<td>Randomised at baseline visit, method not stated. Recruitment to condition (c) discontinued during trial due to poor early outcomes. Availability of facilities allowed for a greater number of participants to be randomised into the exercise intervention than into the equal-contact condition</td>
</tr>
</tbody>
</table>

| **Allocation concealment (selection bias)** |
| Unclear risk |
| No details reported |

| **Blinding of outcome assessment (detection bias)** |
| Low risk |
| Details of blinding not specified, but as self-reports of smoking were validated objectively by expired CO risk is considered as low |

| **Incomplete outcome data (attrition bias)** |
| High risk |
| Total of only 25 participants followed up in groups (a) and (b) |
| Not an ITT analysis, as 263 women were randomised in groups (a) and (b), but only those considered to have made a quit attempt (92/125 in (a), 56/96 in (b), 34/42 in (c)) were included in the analysis |
### Kinnunen 2008 (Continued)

<table>
<thead>
<tr>
<th>Selective reporting (reporting bias)</th>
<th>Low risk</th>
<th>Smoking outcomes reported as stated in Methods</th>
</tr>
</thead>
</table>

### Maddison 2014

<table>
<thead>
<tr>
<th>Methods</th>
<th>Country: New Zealand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Randomisation: Computer-generated</td>
</tr>
<tr>
<td>Participants</td>
<td>906 participants, 54% female, mean age 38, mean CPD 20, FTCD score 7, &lt; 150 mins of MVPA per week.</td>
</tr>
</tbody>
</table>
| Interventions         | (a) Intervention: PA counselling, 1 face-to-face and 9 telephoned-based sessions over 6 months) + telephoned-based CP for 3 months, with 8 weeks of subsidised nicotine replacement therapy (patches, gum, or lozenge)  
(b) Control: CP only as (a) |
| Exercise began after quit date |
| Outcomes              | Continuous abstinence |
| Validation            | None undertaken due to telephone assessment |
| Follow-up             | 24 weeks after quit date |
| Notes                 | Pragmatic trial comparing intervention with usual care, and time not balanced between (a) and (b)  
Funding: This was an investigator-initiated study funded by a grant from the Health Research Council of New Zealand (09/338R) and a small project grant from the Heart Foundation of New Zealand (1405)  
Conflict of interest: Christopher Bullen has received support for accommodation while a speaker hosted by a manufacturer of smoking cessation drugs but has no other interests to declare. Hayden McRobbie has received honoraria for speaking at research symposia and received benefits in kind and travel support from and has provided consultancy to the manufacturers of smoking-cessation medications, specifically Pfizer, GSK, and J&J |

### Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Computer-generated</td>
</tr>
</tbody>
</table>
| Allocation concealment (selection bias) | Low risk | Concealment of allocation was ensured by means of a central computerised service up to the point of randomisation.  
Study researchers conducting assessments were not blinded to treatment allocation |
| Blinding of outcome assessment (detection bias)  
All outcomes | High risk | Study researchers conducting these assessments were not blinded to treatment allocation and primary outcome of self-reported smoking status was not validated objectively |
| Incomplete outcome data (attrition bias)  
All outcomes | Low risk | ITT analysis  
Follow-up rate lower in intervention group (89%) than in control group (96%) |
### Maddison 2014 (Continued)

<table>
<thead>
<tr>
<th>Selective reporting (reporting bias)</th>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low risk</td>
<td>Smoking outcomes reported as stated in Methods</td>
</tr>
</tbody>
</table>

### Marcus 1991

<table>
<thead>
<tr>
<th>Methods</th>
<th>Country: USA</th>
<th>Randomisation: Method not stated</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Participants</td>
<td>20 women, mean age 39, mean CPD 28, exercise &lt; once a week</td>
</tr>
<tr>
<td></td>
<td>Interventions</td>
<td>(a) CV equipment: group, facility 30 - 45 mins, 70% - 85% HR max, 3 times/week for 15 weeks + CP (twice a week for 4 weeks)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) CP only (twice a week for 4 weeks)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exercise began before quit date</td>
</tr>
<tr>
<td></td>
<td>Outcomes</td>
<td>7-day PPA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Validation: saliva cotinine &lt; 10 ng/ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Follow-up: 1, 3, 12 months</td>
</tr>
<tr>
<td></td>
<td>Notes</td>
<td>Contact time not balanced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Funding: not reported</td>
</tr>
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<td></td>
<td></td>
<td>Conflicts of interest: Not reported</td>
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### Risk of bias

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<tbody>
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<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Method not stated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Blinding of smoking assessments not stated, but as self-reports of smoking were validated objectively by expired CO and saliva cotinine risk is considered as low</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>1 participant did not attend follow-ups and was counted as a smoker</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>All smoking outcomes were reported as stated in Methods</td>
</tr>
</tbody>
</table>

### Marcus 1995

<table>
<thead>
<tr>
<th>Methods</th>
<th>Country: USA</th>
<th>Randomisation: Method not stated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Participants</td>
<td>20 women, mean age 38, mean CPD 23, exercise &lt; once a week</td>
</tr>
</tbody>
</table>
Marcus 1995 (Continued)

Interventions
(a) CV equipment: group, facility, 30 - 40 mins, 60% - 85% HR reserve, (3 times/week for 15 weeks) + CP (once a week for 12 weeks)
(b) CP as (a) + health education 3 times/week for 15 weeks
Exercise began before quit date

Outcomes
7-day PPA
Validation: saliva cotinine < 10 ng/ml
Follow-up: 1, 3, 12 months

Notes
Contact time balanced between (a) and (b)
Funding: not reported
Conflicts of interest: Not reported

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Blinding of smoking assessments not stated, but as self-reports of smoking were validated objectively by expired CO and saliva cotinine risk is considered as low</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>All participants were followed up and included in the analysis for the primary outcome</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as described in Methods</td>
</tr>
</tbody>
</table>

Marcus 1999

Methods
Country: USA
Randomisation: Computer-generated

Participants
281 women, mean age 40, mean CPD 22, exercise < twice a week

Interventions
(a) Intervention: CV equipment: group, facility, 30 - 40 mins, 60% - 85% HR reserve, (3 times/week for 12 weeks) + CP (once a week for 12 weeks)
(b) Control: CP as (a) once/week for 12 weeks + health education 3 times/week for 12 weeks
Exercise began before quit date

Outcomes
Continuous abstinence
Validation: saliva cotinine < 10 ng/ml, CO < 8 ppm.
Follow-up: 3, 12 months

Notes
Contact time balanced between (a) and (b)
Funding: This project was supported in part through grants K07CA01757 and R29CA59660 from the National Cancer Institute, Bethesda, Md, and an R29CA59660 supplementary grant from the Office of Research on Women's Health, National Institutes of Health, Bethesda, Md (Dr Marcus).
Marcus 1999 (Continued)

Conflicts of interest: Not reported

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Quote: “The randomisation code for group assignment was generated by a computer program”</td>
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<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Unclear risk</td>
<td>Blinding of smoking assessments not stated, but as self-reports of smoking were validated objectively by expired CO and saliva cotinine risk is considered as low</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>44% of (a) and 50% of (b) lost at 12 months, included as smokers</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as described in Methods</td>
</tr>
<tr>
<td>Other bias</td>
<td>Low risk</td>
<td>The average weight at baseline was significantly higher in the exercise group than in the control group. Research suggests that women who weigh more are more concerned about their weight and thus may be less motivated to quit smoking</td>
</tr>
</tbody>
</table>

Marcus 2005

Methods

Country: USA
Randomisation: Computer-generated

Participants

217 women, mean age 43, mean CPD 21; exercise ≤ 90 mins/wk

Interventions

(a) Intervention: CV various: group/individual, home/facility, 45 mins, 45% - 59% HR reserve, (facility: once/week for 8 weeks, goal: 165 mins/week) + CP (once a week for 8 weeks), with offer of nicotine patch
(b) Control: CP as (a) once/week for 8 weeks + health education once/week for 8 weeks
Exercise began before quit date

Outcomes

Continuous abstinence
Validation: saliva cotinine < 10 ng/ml, CO < 8 ppm.
Follow-up: 3, 12 months

Notes

Contact time balanced between (a) and (b)
Funding: This project was supported in part through grants from the National Cancer Institute (CA77249) and the National Heart, Lung, and Blood Institute (HL64342, HL68422)
Conflicts of interest: Not reported

Risk of bias

<table>
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<th>Support for judgement</th>
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**Marcus 2005** (Continued)

<table>
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<th>Bias</th>
<th>Support for judgement</th>
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<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Quote: &quot;Group assignment was based on a randomisation code generated by a computer software program and was stratified based on participant’s patch usage decision&quot;</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias)</td>
<td>Not stated</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>Blinding of smoking assessments not stated, but as self-reports of smoking were validated objectively by expired CO and saliva cotinine risk is considered as low</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>1- and 6-month follow-up data for smoking behavioural outcomes (in protocol) are not reported, but the end of treatment, 3- and 12-months’ are reported</td>
</tr>
</tbody>
</table>

**Martin 1997**

<table>
<thead>
<tr>
<th>Methods</th>
<th>Country: USA Randomisation: method not stated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>92 women, 113 men, problem drinkers, mean age 42, mean CPD 27, exercise &lt; once a week</td>
</tr>
</tbody>
</table>
| Interventions | (a) Intervention 1: CV activity: various, group/individual, facility/home, 15 - 45 mins, 60% - 75% HR max, (once/week for 4 weeks) + CP: (once/week for 12 weeks)  
(b) Intervention 2: CP as (a) + nicotine gum (does not contribute to this review)  
(c) Control: Different CP (once/week for 8 weeks) and Nicotine Anonymous meetings (3 times/week for 4 weeks)  
Exercise began on quit date |
| Outcomes | 7-day PPA Validation: CO < 10 ppm Follow-up: 7 days, 6, 12 months |
| Notes | Contact time not matched, different cessation programmes  
Funding: not reported  
Conflict of interest: not reported |

**Risk of bias**

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
</tr>
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<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias)</td>
<td>Low risk</td>
</tr>
</tbody>
</table>

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### Martin 1997 (Continued)

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incomplete outcome data</td>
<td>Unclear risk</td>
<td>Numbers lost to follow-up not reported, but all participants included in denominators</td>
</tr>
<tr>
<td>(attrition bias)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as stated in Methods.</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

### McKay 2008

**Methods**

Country: USA  
Randomisation: Computer-generated online

**Participants**

2318, 78% ≥ 30 years of age, 83% > 10 CPD

**Interventions**

(a) Web-based, multi-step programme designed to encourage physical activity with a motivational component (e.g. exploring benefits and barriers) and a behavioural action plan (e.g. weekly schedules), plus access to a peer support forum  
(b) Web-based, multi-step programme introducing users to the key concepts and strategies of a behavioural quit-smoking programme, including a peer support forum and 'ask the expert' tool  
Did not state when exercise began relative to the quit date

**Outcomes**

7-day PPA  
Validation: No biochemical validation as outcomes reported online or by telephone  
Follow-up: 3, 6 months

**Notes**

Exercise condition (a) intended to be an attention placebo control condition  
Funding: This research was supported by grant R01-CA79946 from the National Cancer Institute  
Conflict of interest: None declared

### Risk of bias

<table>
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<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation</td>
<td>Low risk</td>
<td>Randomly generated by a computer through the Internet</td>
</tr>
<tr>
<td>(selection bias)</td>
<td></td>
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<tr>
<td>Allocation concealment</td>
<td>Unclear risk</td>
<td>No detail given</td>
</tr>
<tr>
<td>(selection bias)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blinding of outcome assessment</td>
<td>High risk</td>
<td>Not stated if researchers conducting assessments (by telephone) were aware of treatment allocation and self-reports of smoking status were not validated objectively</td>
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<tr>
<td>(detection bias)</td>
<td></td>
<td></td>
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<tr>
<td>All outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incomplete outcome data</td>
<td>High risk</td>
<td>60.2% Int and 61.3% Cont lost to follow-up at 6 months, counted as smokers in analysis</td>
</tr>
<tr>
<td>(attrition bias)</td>
<td></td>
<td></td>
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<tr>
<td>All outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selective reporting (reporting</td>
<td>Low risk</td>
<td>Smoking outcomes reported as stated in Methods.</td>
</tr>
<tr>
<td>bias)</td>
<td></td>
<td></td>
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</tbody>
</table>
Patten 2017

Methods
Country: USA
Randomisation: Method not stated

Participants
30 women, mean age 38, 90% white ethnicity, smoking ≥ 10 CPD for at least the past year, FTCD score 4.5, not currently achieving moderate-intensity exercise for at least 30 mins on at least 5 days/week or vigorous exercise for at least 20 mins on at least 3 days/week, currently moderate-severe depressed defined by a clinical cut-off score of > 16 on 10-item Center for Epidemiological Studies Depression Scale, 37% (11/30) had a current psychiatric diagnosis

Interventions
(a) Exercise intervention: 30-40 mins supervised moderate-vigorous intensity exercise, thrice weekly for 12 weeks (gradual progression from moderate to vigorous exercise across weeks, individually-based at facility, various CV exercise equipment) + CP (15-20 mins, once a week for 12 weeks, including 8 weeks nicotine patches)
(b) Control: health education (individually-based, 30-40 mins thrice weekly for 12 weeks) + CP (as for (a))

Exercise and CP began before quit date. The target quit date was the first session of week 3

Outcomes
7-day PPA
Validation: saliva cotinine < 10 ng/ml
Follow-up: end of treatment, and 6 months after quit date

Notes
Control group balanced with exercise group for contact time. To save time, the exercise counselling was delivered while the participant was exercising. Limitations: no record of exercise outside of supervised exercise, over half of participants were taking antidepressant medication limiting the potential of the exercise intervention to aid cessation. Overly conservative cut-off for the depression scale (Center for Epidemiological Studies Depression Scale-10)?

Funding: Study was supported by CTSA grant number UL1 TR00135 from the National Center for Advancing Translational Sciences (NCATS), a component of the National Institutes of Health (NIH). Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH. Funding for this study was also provided by a Mayo Clinic NIH-relief award, and a small grant award from the Department of Psychiatry and Psychology

Declared COIs: None declared

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Not reported</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Low risk</td>
<td>Allocation to treatment conditions was unknown to the study staff or investigators prior to assignments</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Study co-ordinator blinded to allocation group conducted all follow-ups; biochemical validation used</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>87% were followed up at 6 months (same rate in 2 groups). Using an ITT approach, missing data were classified as smoking</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>All outcomes stated in Methods were reported</td>
</tr>
</tbody>
</table>
### Prapavessis 2007

**Methods**  
Country: New Zealand  
Randomisation: Computer-generated

**Participants**  
142 women, mean age 38, exercise < twice a week. (following preliminary programme, 21 pretreatment dropouts)

**Interventions**  
Phase 1 (6 weeks): 142 randomised supervised exercise programme or a supervised cognitive behavioural smoking cessation programme  
Phase 2 (12 weeks): 121 who made a quit attempt re-randomised to 1 of 4 conditions:  
(a) Intervention 1: CV activity: various, group/facility, 45 mins, 60% - 75% HR reserve, (3 times/week for 12 weeks) + CP (3 times/week for 12 weeks)  
(b) Intervention 2: exercise as (a) plus nicotine patches  
(c) Intervention 3: Cognitive behavioural cessation programme 3 times/week for 12 weeks  
(d) Intervention 4: as (c) plus nicotine patches  
Exercise began before quit date

**Outcomes**  
Continuous abstinence  
Validation: saliva cotinine < 10 ng/ml, CO < 10 ppm  
Follow-up: 6 weeks, 3, 12 months

**Notes**  
Contact time balanced between a, b, c and d  
Funding: National Heart Foundation of New Zealand funded this project (Project # 905) and GlaxoSmithKlein (GSK) provided the transdermal nicotine patches for the study  
Conflict of interest: Not reported

### Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
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<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Computer-generated randomisation.</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
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<tr>
<td>Blinding of outcome assessment (detection bias)</td>
<td>Low risk</td>
<td>Details of blinding not specified, but as self-reports of smoking were validated objectively by expired CO and saliva cotinine, risk is considered as low</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>High risk</td>
<td>21 pretreatment dropouts excluded from analysis. Loss to follow-up higher in (a)+(b), 40%, than in (c)+(d), 23% (P = 0.05). Not stated whether those lost to follow-up were counted as smokers</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as stated in Methods</td>
</tr>
</tbody>
</table>

### Prapavessis 2016

**Methods**  
Country: Canada  
Randomisation: Computer-generated
Participants
413 women, average age 42.31, 16.76 CPD at baseline, FTCD score 5.4, engaged in ≤ 2 x 30-min bouts of moderate or vigorous physical activity a week over the past 6 months

Interventions
All participants completed a 14-week structured exercise programme with NRT. Supervised group exercise; 3 sessions/wk (45 mins duration) for 8 weeks, 2 sessions weeks 9 - 11 and 1 session during weeks 12 - 14. Workload progressively increased to 70% - 75% maximum HR over the 14 weeks. NRT started after 4 weeks of exercising. Then randomised to 1 of 4 conditions (a) exercise maintenance + smoking cessation maintenance, b) exercise maintenance + contact control, (c) smoking cessation maintenance + contact control, or (d) contact control
(a) and (c): Received Forever Free booklets at end of 14 weeks
(a) and (b): 5 x 25-min weekly CBT sessions in a group format teaching self-regulatory skills for exercise maintenance. After 14 weeks, received 7 x 15-min bi-weekly (for the first month, monthly (for next 2 months) and then bi-monthly (for last 8 months) telephone counselling sessions
(c) and (d): Messages reinforcing women’s health issues were communicated. After week 14, messages reinforcing the Forever Free booklets (c) and/or women’s health issues (d) were communicated.
Exercise began 4 weeks before quit date; NRT began on quit date; relapse prevention support began following randomisation and after 14-week exercise programme

Outcomes
Continuous abstinence
Validation: CO < 6 ppm
Follow-up: end of treatment, 26, 56 weeks

Notes
Relapse prevention intervention with randomisation after 14 weeks. Change in physical activity or fitness not reported between baseline and week 14 (end of supervised exercise). High loss to end-of-intervention assessments of smoking status. The trial did not have sufficient power to detect a significant difference in cessation rates at 14 and 26 weeks. Smoking status consistently related to adherence across trial. Staying involved with the exercise, NRT and maintenance components of the intervention was associated with improved cessation rates.
Funding: This was an investigator-initiated study funded by a grant from the Canadian Cancer Society (#019876-PI-HP). The Exercise and Health Psychology Lab (www.ehpl.uwo.ca) where this work was conducted is supported by a Canadian Foundation Innovation infrastructure grant (#312466) award to the PI-HP
Conflict of interest: None declared

Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
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<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Computer-generated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Low risk</td>
<td>The project manager used numbered containers to implement the random allocation sequence, and the sequence was concealed until interventions were assigned</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Research assistants not blinded to treatment allocation, but low risk of bias as self-reports of smoking abstinence were validated with expired CO</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>High risk</td>
<td>ITT reported with participants not reporting end-point data treated as smokers. High risk as only 46% (189/413) completed follow-up at 12 months post-treatment</td>
</tr>
</tbody>
</table>
### Prapavessis 2016 (Continued)

<table>
<thead>
<tr>
<th>Selective reporting (reporting bias)</th>
<th>Low risk</th>
<th>Outcomes fully reported as stated in protocol</th>
</tr>
</thead>
</table>

### Russell 1988

| Methods | Country: USA  
Randomisation: Method not stated |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>42 women, mean age 28, mean CPD 23</td>
</tr>
</tbody>
</table>
| Interventions | (a) Intervention 1: Walk/jog: group/individual, facility/home, 20 - 30 mins, 70% - 80% HR max, (3 times/week for 9 weeks) + CP: (4 times/week for 1 week)  
(b) Intervention 2: CP as (a) + health education (once a week for 9 weeks)  
(c) Control: CP as (a)  
Exercise began after quit date |
| Outcomes | "Quit" (not defined)  
Validation: CO  
Follow-up: 1, 4, 16 months |
| Notes | No difference between groups  
Contact time balanced between (a) and (b)  
Funding: not reported  
Conflict of interest: not reported |

### Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors' judgement</th>
<th>Support for judgement</th>
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<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
</tbody>
</table>
| Blinding of outcome assessment (detection bias)  
All outcomes | Low risk | Details of blinding not stated, but as self-reports of smoking were validated objectively by expired CO risk is considered low |
| Incomplete outcome data (attrition bias)  
All outcomes | Unclear risk | Not stated |
| Selective reporting (reporting bias) | Low risk | Smoking outcomes reported as described in Methods. Outcomes for Beck Depression Inventory were not reported but this was not considered a high-risk omission |

### Smits 2016

| Methods | Country: USA  
Randomisation: generated by study statistician and placed in sealed envelopes |
Participants
136 participants, 52% female, 74% white ethnicity, mean age 44, at least 1 year of smoking at least 10 CPD, mean CPD 17, mean FTND score 5.4, sedentary (moderate-intensity exercise < twice a week for 30 mins or less), elevated anxiety sensitivity (prescreen score of ≥ 20 on the 16-item Anxiety Sensitivity Inventory; ASI-16)

Interventions
(a) Exercise intervention: 35 mins of supervised moderate-vigorous intensity exercise (at 77% - 85% max HR by week 4), thrice-weekly for 15 weeks (individually-based at facility using treadmills) + CP (60 mins CBT weekly for 7 weeks, optional nicotine patches for up to 8 weeks)

(b) Control: wellness education (individually-based, 30 - 40 mins thrice-weekly for 15 weeks) + CP as for (a)

Exercise and CP began before quit date, target quit date in week 6

Outcomes
Prolonged abstinence
Validation: saliva cotinine < 10 ng/ml or CO ≤ 8ppm
Follow-up: end of treatment, and 6 months after quit date

Notes
Exercise and control conditions balanced for contact time. Limitations: The control groups attended significantly more sessions than the exercise group.

Funding: Funded by grants from the National Institute on Drug Abuse: R01DA027533 (awarded to Michael J. Zvolensky and Jasper A. J. Smits; MPI) and K01DA035930 (awarded to Mark B. Powers; PI). Declared COIs: Jasper A. J. Smits and Michael W. Otto receive royalties from Oxford University Press for books on exercise as a treatment for mood and anxiety disorders. Jasper A. J. Smits has served as a paid consultant for Microtransponder for work unrelated to the research reported in this article. Michael J. Zvolensky, David Rosenfield, Mark B. Powers, Kirsten J. Langdon, Bess H. Marcus, Timothy S. Church, Georita M. Frierson, and Lindsey B. Hopkins, Lorra Garey, Brooke Y. Kauffman, Michelle L. Davis, Scarlett O. Baird, and Daniel J. Paulus report no financial relationships with commercial interests

Risk of bias

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<th>Support for judgement</th>
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<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Randomisation was generated by the study statistician and placed in sealed envelopes</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Low risk</td>
<td>At treatment inception, the therapist opened the envelope corresponding to the cohort number. Allocation unknown before assignment</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias)</td>
<td>Low risk</td>
<td>An assessment team blind to study condition conducted exercise assessments (from protocol). Blinding of smoking assessments not stated but this is not a high risk as the primary outcome included objective assessment of smoking status</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>High risk</td>
<td>Using an ITT approach, missing data were classified as missing rather than computing missing data or counting those missing as smokers (generally recommended approach). Only 49% were followed up at 6 months</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Outcomes stated in Methods were reported</td>
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</tbody>
</table>

Taylor 1988

Methods
Country: USA
### Taylor 1988 (Continued)

Randomisation: Method not stated

<table>
<thead>
<tr>
<th>Participants</th>
<th>68 men, post-acute myocardial infarction</th>
</tr>
</thead>
</table>
| Interventions | (a) Intervention 1: CV activity: various, group, facility, 30 - 40 mins, 70% - 85% HR max, (i) (3, 23) (ii) (3, 8) + CP x 1 session;  
(b) Intervention 2: (i, ii) as (a) home: 20 mins, x 5/wk  
(c) Control: Fitness test at end of treatment only  
(d) Intervention 3: Fitness test at baseline and end of treatment, cessation programme as (a) |
| Outcomes | Validation: plasma thiocyanate  
Follow-up: 23 weeks |
| Notes | Contact time not balanced  
Funding: not reported  
Conflicts of interest: not reported |

### Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
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<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias)</td>
<td>Unclear risk</td>
<td>Details of blinding not stated. Self-reports of smoking were validated objectively by plasma thiocyanate risk only in a sub-sample</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>Unclear risk</td>
<td>Not stated</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as described in Methods</td>
</tr>
</tbody>
</table>

### Ussher 2003

Methods  
Country: UK  
Randomisation: Computer-generated

<table>
<thead>
<tr>
<th>Participants</th>
<th>188 women, 111 men, mean age: 43, mean CPD: 22; &lt; 5 days of 30 mins moderate-intensity exercise a week</th>
</tr>
</thead>
</table>
| Interventions | (a) Intervention: Exercise counselling (once a week for 7 weeks) + CP (once a week for 7 weeks)  
(b) Control: Cessation programme as (a) once/week for 7 weeks + brief health education once/week for 7 weeks  
Exercise began before quit date |
| Outcomes | Continuous abstinence  
Validation: CO < 10 ppm  
Follow-up: 6 weeks, 12 months |
**Ussher 2003 (Continued)**

**Notes**
Contact time balanced between (a) and (b)

Funding: This study was supported through grant CE1198/0101 from the Cancer Research Campaign (now Cancer Research UK) to the authors

Conflicts of interest: Not reported

**Risk of bias**

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Computer-generated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>High risk</td>
<td>Personnel used a list of random numbers</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Researchers conducting assessments were aware of treatment allocation. As self-reports of smoking were validated objectively by expired CO, risk is considered low</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>27 participants could not be contacted at the 12-month follow-up and were counted as smokers, with similar follow-up for the 2 groups</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as described in Methods</td>
</tr>
</tbody>
</table>

**Ussher 2015**

**Methods**
Country: UK

Randomisation: Computer-generated

**Participants**
789 pregnant women, mean age 28, white ethnicity 78%, median CPD before pregnancy 20, median CPD at randomisation 10, median FTCD score 4, 70% self-report ≥ 150 mins/week of moderate-vigorous physical activity

**Interventions**
(a) Exercise intervention: Up to 30 mins of supervised moderate-intensity exercise 14 sessions over 8 weeks, twice a week for 6 weeks, then weekly for 2 weeks + CP weekly for 6 weeks

(b) Control: CP as (a)

Exercise and CP began 1 week before quit date

**Outcomes**
Continuous abstinence

Validation: saliva cotinine < 10 ng/ml or CO < 8 ppm or both

Follow-up: to end of pregnancy (variable), and 6 months postpartum

**Notes**
Funding: This study was funded by the NIHR health technology assessment programme (grant 07.01.14).

Conflicts of interest: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; in the past three years PA has done one day of consultancy for Pfizer concerning general smoking cessation advice and not about particular products, and
RW has undertaken research and consultancy for companies (Pfizer and GlaxoSmithKline) that develop and manufacture smoking cessation drugs in the past three years; in the past three years TC has been paid for speaking at two educational events that were part or wholly sponsored by a company (Pierre Fabre Laboratories, France) that manufactures nicotine replacement therapy; RW is an unpaid trustee of the stop smoking charity QUIT and an unpaid director of the National Centre for Smoking Cessation and Training; no other relationships or activities that could appear to have influenced the submitted work.

### Risk of bias

<table>
<thead>
<tr>
<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Computer-generated</td>
</tr>
<tr>
<td>Allocation concealment (selection bias)</td>
<td>Low risk</td>
<td>Allocation to treatment conditions was unknown to the study staff or investigators prior to assignments</td>
</tr>
<tr>
<td>Blinding of outcome assessment (detection bias) All outcomes</td>
<td>Low risk</td>
<td>Researcher blinded to allocation group conducted all follow-ups, but not always possible. As the primary outcome, at end of pregnancy, was based on objective assessment using expired CO or saliva cotinine or both, we considered there was low risk of the results being altered</td>
</tr>
<tr>
<td>Incomplete outcome data (attrition bias) All outcomes</td>
<td>Low risk</td>
<td>89% of those randomised were followed up at end of pregnancy and the follow-up rate was similar for the 2 groups. Using an ITT approach, missing data were classified as smoking</td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>All outcomes stated in protocol were reported</td>
</tr>
</tbody>
</table>

### Ussher 2015 (Continued)

**Methods**

- **Country:** USA
- **Randomisation:** Computer-generated

**Participants**

- 330 women, mean age 44, mean CPD 17, FTND score 5.0, < 20 mins of vigorous activity twice a week

**Interventions**

- (a) Intervention: 12 weeks YMCA membership, 4 individual personal training sessions over 12 weeks (aerobic and resistance exercise) plus group-based CP (once a week for 12 weeks)
- (b) Control: 4 wellness sessions over 12 weeks) plus CP as (a)

Interventions began before quit date

**Outcomes**

- Continuous abstinence
- **Validation:** Saliva cotinine < 10 mg/mL
- **Follow-up:** end of treatment, and 3, 6 months and 12 months post-treatment

**Notes**

- Contact time balanced between (a) and (b)
- **Funding:** This research was supported by the National Institute on Drug Abuse at the NIH (Grant DA021729)
- **Conflicts of interest:** None declared

### Whiteley 2012

**Methods**

- **Country:** USA
- **Randomisation:** Computer-generated

**Participants**

- 330 women, mean age 44, mean CPD 17, FTND score 5.0, < 20 mins of vigorous activity twice a week

**Interventions**

- (a) Intervention: 12 weeks YMCA membership, 4 individual personal training sessions over 12 weeks (aerobic and resistance exercise) plus group-based CP (once a week for 12 weeks)
- (b) Control: 4 wellness sessions over 12 weeks) plus CP as (a)

Interventions began before quit date

**Outcomes**

- Continuous abstinence
- **Validation:** Saliva cotinine < 10 mg/mL
- **Follow-up:** end of treatment, and 3, 6 months and 12 months post-treatment

**Notes**

- Contact time balanced between (a) and (b)
- **Funding:** This research was supported by the National Institute on Drug Abuse at the NIH (Grant DA021729)
- **Conflicts of interest:** None declared
### Risk of bias

<table>
<thead>
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<th>Bias</th>
<th>Authors’ judgement</th>
<th>Support for judgement</th>
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<tbody>
<tr>
<td>Random sequence generation (selection bias)</td>
<td>Low risk</td>
<td>Computer-generated</td>
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<tr>
<td>Allocation concealment (selection bias)</td>
<td>Unclear risk</td>
<td>Not specified</td>
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<tr>
<td>Blinding of outcome assessment (detection bias)</td>
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<td>Low risk</td>
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<tr>
<td>Incomplete outcome data (attrition bias)</td>
<td>All outcomes</td>
<td>Low risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selective reporting (reporting bias)</td>
<td>Low risk</td>
<td>Smoking outcomes reported as described in Methods</td>
</tr>
</tbody>
</table>

BMI: body mass index; CBT: cognitive behavioural therapy; CO: carbon monoxide; CONT: control; CP: cessation programme; CPD: cigarettes per day; CV: cardiovascular; Fagerström Test for Cigarette Dependence; FTND: Fagerström Test for Nicotine Dependence; FTQ: Fagerström Tolerance Questionnaire; HR: heart rate; INT: intervention; ITT: intention to treat; MVPA: moderate to vigorous physical activity; NRT: nicotine replacement therapy; PP(A): point prevalence (abstinence); ppm: parts per million

### Characteristics of excluded studies [ordered by study ID]

<table>
<thead>
<tr>
<th>Study</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrantes 2017</td>
<td>Acute study</td>
</tr>
<tr>
<td>Abrantes 2018</td>
<td>Acute study</td>
</tr>
<tr>
<td>Aggarwal 2017</td>
<td>Multiple component yoga intervention</td>
</tr>
<tr>
<td>Al-Chalabi 2008</td>
<td>Follow-up less than 6 months and combined isometric exercise and body-scanning interventions; it was not possible to assess the specific effects of exercise</td>
</tr>
<tr>
<td>Al-Eisa 2016</td>
<td>Non-randomised study</td>
</tr>
<tr>
<td>Allen 2018a</td>
<td>Quit attempts rather than cessation as outcome</td>
</tr>
<tr>
<td>Allen 2018b</td>
<td>Acute study</td>
</tr>
<tr>
<td>Angeli 2018</td>
<td>Acute study</td>
</tr>
<tr>
<td>Arbour-Nicitopoulos 2011</td>
<td>Acute study.</td>
</tr>
<tr>
<td>Audrain-McGovern 2015</td>
<td>Acute study</td>
</tr>
<tr>
<td>Bernard 2013</td>
<td>Did not assess smoking abstinence.</td>
</tr>
<tr>
<td>Blank 2017</td>
<td>Follow-up less than 6 months</td>
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<tr>
<td>Study</td>
<td>Reason for exclusion</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bock 2012</td>
<td>Multiple component yoga programme</td>
</tr>
<tr>
<td>Caliani 2004</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Chaney 2008</td>
<td>Follow-up was less than 6 months</td>
</tr>
<tr>
<td>Cinciripini 1996</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Clark 2005</td>
<td>A non-exercise control group was not included</td>
</tr>
<tr>
<td>Conklin 2017</td>
<td>Acute study</td>
</tr>
<tr>
<td>Cooke 2016</td>
<td>Acute study</td>
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<tr>
<td>Copeland 2006</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Daley 2004</td>
<td>Acute study</td>
</tr>
<tr>
<td>Daniel 2004</td>
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<tr>
<td>Daniel 2006</td>
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<td>De Jesus 2014</td>
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<tr>
<td>De Jesus 2018a</td>
<td>Acute study</td>
</tr>
<tr>
<td>De Jesus 2018b</td>
<td>Follow-up was less than 6 months</td>
</tr>
<tr>
<td>Elibero 2011</td>
<td>Acute study</td>
</tr>
<tr>
<td>Everson 2006</td>
<td>Acute study</td>
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<tr>
<td>Everson 2008</td>
<td>Acute study</td>
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<tr>
<td>Faulkner 2010</td>
<td>Acute study</td>
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<td>Fong 2014</td>
<td>Acute study</td>
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<tr>
<td>Fortmann 1995</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
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<tr>
<td>Garcia 2019</td>
<td>Multi-component intervention</td>
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<tr>
<td>Gorini 2012</td>
<td>Not all participants wished to quit</td>
</tr>
<tr>
<td>Grove 1993</td>
<td>The outcome was withdrawal symptoms rather than smoking abstinence</td>
</tr>
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<td>Grove 2006</td>
<td>Had sleep disturbance as the main outcome, rather than smoking abstinence</td>
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<td>Haasova 2011</td>
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<td>Reason for exclusion</td>
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<td>------------------------------</td>
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<td>Harper 2012</td>
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<tr>
<td>Harper 2013</td>
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<tr>
<td>Hassandra 2012</td>
<td>Lack of a control group</td>
</tr>
<tr>
<td>Hatzigeorgiadis 2016</td>
<td>Acute study</td>
</tr>
<tr>
<td>Ho 2014</td>
<td>Acute study</td>
</tr>
<tr>
<td>Horn 2011</td>
<td>Included smokers not wishing to quit</td>
</tr>
<tr>
<td>Hurt 1994</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Hwang 2012</td>
<td>A non-exercise control group was not included. Also follow-up was less than 6 months.</td>
</tr>
<tr>
<td>Janse van Rensburg 2008</td>
<td>Acute study</td>
</tr>
<tr>
<td>Janse van Rensburg 2009a</td>
<td>Acute study</td>
</tr>
<tr>
<td>Janse van Rensburg 2009b</td>
<td>Acute study</td>
</tr>
<tr>
<td>Janse van Rensburg 2010</td>
<td>Acute study</td>
</tr>
<tr>
<td>Janse van Rensburg 2012</td>
<td>Acute study</td>
</tr>
<tr>
<td>Janse van Rensburg 2013</td>
<td>Acute study</td>
</tr>
<tr>
<td>Jones 2001</td>
<td>Included an exercise programme in a self-help manual as part of a multiple-component programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Jonsdottir 2001</td>
<td>A quasi-experimental study comparing a smoking cessation programme plus weekly group exercise with the smoking cessation programme only. Participants were not randomly allocated to the groups</td>
</tr>
<tr>
<td>Katomeri 2007</td>
<td>Acute study</td>
</tr>
<tr>
<td>Kinnunen 2013</td>
<td>Did not include a non-exercise condition</td>
</tr>
<tr>
<td>Kovelis 2012</td>
<td>Did not assess smoking abstinence.</td>
</tr>
<tr>
<td>Kurti 2014a</td>
<td>Acute study</td>
</tr>
<tr>
<td>Kurti 2014b</td>
<td>Acute study</td>
</tr>
<tr>
<td>Leelarungrayub 2010</td>
<td>Did not include smoking abstinence as an outcome</td>
</tr>
<tr>
<td>Linke 2012</td>
<td>Assessment of smoking abstinence less than 6 months</td>
</tr>
<tr>
<td>Loprinzi 2015</td>
<td>Cohort study</td>
</tr>
<tr>
<td>Luo 2019</td>
<td>Cohort study</td>
</tr>
<tr>
<td>Mantoani 2014</td>
<td>Lack of a control group</td>
</tr>
<tr>
<td>Study</td>
<td>Reason for exclusion</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>McClure 2009</td>
<td>Included exercise counselling as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>McClure 2011</td>
<td>Included exercise counselling as part of a multiple risk factor intervention. It was therefore not possible to examine the specific effects of exercise on smoking cessation.</td>
</tr>
<tr>
<td>McIver 2004</td>
<td>There was no control group</td>
</tr>
<tr>
<td>Mikhail 1983</td>
<td>Acute study</td>
</tr>
<tr>
<td>Nair 2017</td>
<td>Follow-up was less than 6 months</td>
</tr>
<tr>
<td>Nguyen 2012</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Oenema 2008</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Oh 2014</td>
<td>Acute study</td>
</tr>
<tr>
<td>Ortega Sanchez-Pinilla 2006</td>
<td>Retrospective study</td>
</tr>
<tr>
<td>Pomerleau 1987</td>
<td>Acute study</td>
</tr>
<tr>
<td>Prapavessis 2014</td>
<td>Acute study</td>
</tr>
<tr>
<td>Priebe 2017</td>
<td>Not an RCT</td>
</tr>
<tr>
<td>Prochaska 2008</td>
<td>Included exercise counselling as part of a multiple-component relapse-prevention programme. It was therefore not possible to examine the specific effects of exercise. Also, follow-up was less than 6 months</td>
</tr>
<tr>
<td>Ramsay 2004</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Reeser 1983</td>
<td>Acute study</td>
</tr>
<tr>
<td>Reid 2014</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Roberts 2015</td>
<td>Acute study</td>
</tr>
<tr>
<td>Saltychev 2012</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Scerbo 2010</td>
<td>Acute study</td>
</tr>
<tr>
<td>Schneider 2015</td>
<td>Acute study</td>
</tr>
<tr>
<td>Spring 2004</td>
<td>Combined an exercise programme with a dietary intervention. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Taylor 2005</td>
<td>Acute study</td>
</tr>
<tr>
<td>Taylor 2006a</td>
<td>Acute study</td>
</tr>
<tr>
<td>Study</td>
<td>Reason for exclusion</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Taylor 2006b</td>
<td>Acute study</td>
</tr>
<tr>
<td>Taylor 2014</td>
<td>Assessment of smoking abstinence less than 6 months.</td>
</tr>
<tr>
<td>Thayer 1993</td>
<td>Acute study</td>
</tr>
<tr>
<td>Toobert 2011</td>
<td>Included an exercise programme as part of a multiple-component smoking-cessation programme. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Treviño 2014</td>
<td>Not an RCT</td>
</tr>
<tr>
<td>Trigwell 2014</td>
<td>Non-randomised study</td>
</tr>
<tr>
<td>Tritter 2015</td>
<td>Acute study</td>
</tr>
<tr>
<td>Ussher 2001</td>
<td>Acute study</td>
</tr>
<tr>
<td>Ussher 2006</td>
<td>Acute study</td>
</tr>
<tr>
<td>Ussher 2008</td>
<td>Did not include a control group</td>
</tr>
<tr>
<td>Ussher 2009</td>
<td>Acute study</td>
</tr>
<tr>
<td>Vander Weg 2008</td>
<td>Included an exercise programme as part of a multiple-component programme for smoking cessation and management of weight and blood pressure. It was therefore not possible to examine the specific effects of exercise</td>
</tr>
<tr>
<td>Vickers 2005</td>
<td>The follow-up was less than 6 months</td>
</tr>
<tr>
<td>Vickers 2009</td>
<td>Follow-up was less than 6 months.</td>
</tr>
<tr>
<td>Whiteley 2007</td>
<td>Did not include a control group</td>
</tr>
<tr>
<td>Williams 2010</td>
<td>Follow-up was less than 6 months.</td>
</tr>
<tr>
<td>Williams 2011</td>
<td>Acute study</td>
</tr>
<tr>
<td>Ybarra 2013</td>
<td>Assessment of smoking abstinence less than 6 months.</td>
</tr>
<tr>
<td>Zwick 2006</td>
<td>Unable to obtain details of study from authors</td>
</tr>
</tbody>
</table>

**Characteristics of ongoing studies [ordered by study ID]**

**Ciccolo 2014**

<table>
<thead>
<tr>
<th>Trial name or title</th>
<th>Resistance training as an aid to smoking cessation treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>RCT</td>
</tr>
<tr>
<td>Participants</td>
<td>N = 206</td>
</tr>
<tr>
<td>Interventions</td>
<td>Resistance training vs contact control</td>
</tr>
</tbody>
</table>
### Ciccolo 2014 (Continued)

**Outcomes**
Smoking cessation, Follow-up assessments will occur at the end of the 12-weeks intervention, and at a 6-month and 12-month (post-randomisation) visit

**Starting date**
Study start date: 2013; estimated study completion date: March 2019

**Contact information**
Dr Joe Ciccolo, ciccolo@tc.columbia.edu

**Notes**
ClinicalTrials.gov Identifier: NCT01951456

### NCT00921388

<table>
<thead>
<tr>
<th>Trial name or title</th>
<th>Exercise for smoking cessation in postmenopausal women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>RCT</td>
</tr>
<tr>
<td>Participants</td>
<td>N = 364</td>
</tr>
<tr>
<td>Interventions</td>
<td>All participants receive smoking cessation counselling and varenicline, plus either (i) 1-hour exercise sessions twice a week for 8 weeks, then once a week for 8 weeks, then once every other week for 4 weeks, or (ii) participants in the control group receive a relaxation programme that controls for contact time</td>
</tr>
<tr>
<td>Outcomes</td>
<td>Smoking abstinence at weeks 12 and 64</td>
</tr>
<tr>
<td>Starting date</td>
<td>Start date: March 2009; study completion Aug 2017; publication in preparation</td>
</tr>
<tr>
<td>Contact information</td>
<td>Cheryl A Oncken</td>
</tr>
<tr>
<td>Notes</td>
<td>ClinicalTrials.gov Identifier: NCT00921388</td>
</tr>
</tbody>
</table>

### NCT02086149

<table>
<thead>
<tr>
<th>Trial name or title</th>
<th>Exercise for depressed smokers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>RCT</td>
</tr>
<tr>
<td>Participants</td>
<td>N = 250</td>
</tr>
</tbody>
</table>
| Interventions       | (a) 12-week moderate-intensity behavioural exercise intervention. Weekly sessions with an exercise physiologist who will also assign weekly exercise goals. 2-month course of the nicotine patch initiated during week 5  
(b) 12-week health education control. Weekly sessions about 12 different topics related to the health effects of smoking, led by an expert in smoking cessation |
| Outcomes            | Smoking cessation at 12 months, verified biochemically (saliva cotinine) |
| Starting date       | February 2014, estimated completion date: Feb 2019    |
| Contact information | Dr Ana Abrantes, ana.abrantes@brown.edu               |
| Notes               | ClinicalTrials.gov Identifier: NCT02086149           |
### Pavey 2015

**Trial name or title**  
Assessing the effectiveness of High Intensity Interval Training (HIIT) for smoking cessation in women

**Methods**  
RCT

**Participants**  
Women aged 18 - 55 years who smoke ≥ 5 CPD, and want to quit smoking

**Interventions**  
All participants will receive usual care for quitting smoking.  
Group 1 will complete 2 gym-based supervised HIIT sessions/week and 1 home-based HIIT session/week. At each training session participants will be asked to complete 4 x 4-min intervals at approximately 90% of maximum heart rate interspersed with 3-min recovery periods  
Group 2 participants will receive a resource pack and pedometer, and will be asked to use the 10,000 steps log book to record steps and other physical activities. The aim will be to increase daily steps to 10,000 steps/day

**Outcomes**  
% of participants who have ceased smoking  
Identified using the Russell standard, self-reported abstinence (previous 2 weeks) and CO concentration < 10 ppm 13 and 26 weeks after randomisation  
Secondary outcome: CPD

**Starting date**  
December 2014

**Contact information**  
toby.pavey@qut.edu.au (Dr Toby Pavey)

**Notes**

---

### Smits 2019

**Trial name or title**  
YMCA exercise intervention to augment smoking cessation treatment in adults with high anxiety sensitivity: study protocol for a randomised controlled trial

**Methods**  
"Building upon emerging evidence supporting the efficacy of exercise as an aid for smoking cessation in adults with high AS, we are conducting a trial to examine the efficacy and feasibility of this clinical application when implemented in a community setting. Partnering with the YMCA, this study aims to enroll 150 adults in a standard smoking cessation protocol (i.e. counselling and nicotine replacement therapy) and randomly assign them to either 15 weeks of programmed vigorous-intensity or low-intensity exercise. Smoking abstinence data will be collected up to 6 months following the quit attempt."

**Participants**

**Interventions**

**Outcomes**

**Starting date**

**Contact information**  
Smits JAJ

**Notes**
### Tai-Hing 2016

**Trial name or title**  
Short-bout Handgrip Exercise for Smoking Cessation (SHESC)

**Methods**  
All the participants will be randomised to one of the RCT groups by using sequentially numbered, opaque sealed envelope method. Participants from both groups will be helped to install a phone application (App) in their smart phone which can send reminders of doing exercise or healthy diet. Also, the participants will enter their smoking and craving data by the App by answering the automatic daily questionnaire. Telephone follow-up will be conducted at 2, 6 and 12 months

**Participants**  
Adults who enrolled in smoking cessation service, smoke 10 CPD+ and interested in participating in an exercise/diet programme for smoking cessation

**Interventions**  
Short-bout exercise (intervention) and healthy diet (control)

**Outcomes**  
Primary outcome measures:  
- 4-week self-reported tobacco abstinence at 6-month follow-up  
- Telephone follow-up will be conducted at 2, 6 and 12 months

**Starting date**  
October 2016

**Contact information**  
Tai Hing Lam

**Notes**  
ClinicalTrials.gov ID NCT02844296

---

### Vander Weg 2018

**Trial name or title**  
Community-based physical activity as adjunctive smoking cessation treatment: Rationale, design, and baseline data for the Lifestyle Enhancement Program (LEAP) randomized controlled trial

**Methods**  
2-group, randomised controlled trial. Adult smokers were randomly assigned to treatment conditions

**Participants**  
Participants consist of 392 sedentary smokers (mean (standard deviation) age = 44.6 (10.2) years; 62% female; 31% African-American).

**Interventions**  
Treatment conditions consisted of an individualised physical activity intervention delivered by health fitness instructors in community-based exercise facilities or an equal contact wellness control. All participants received standard cognitive behavioural smoking cessation counselling combined with nicotine replacement therapy

**Outcomes**  
The primary outcomes are 7-day PPA at 7 weeks, 6 and 12 months.  
Secondary outcomes include self-reported physical activity, dietary intake, BMI, waist circumference, percent body fat, and nicotine withdrawal symptoms

**Notes**  
BMI: body mass index; CPD: cigarettes per day; ppm: parts per million

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**Exercise interventions for smoking cessation (Review)**

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## DATA AND ANALYSES

### Comparison 1. Exercise component versus smoking cessation programme only

<table>
<thead>
<tr>
<th>Outcome or subgroup title</th>
<th>No. of studies</th>
<th>No. of participants</th>
<th>Statistical method</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Smoking abstinence at longest follow-up, subgroup by exercise type</td>
<td>21</td>
<td>6607</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>1.08 [0.96, 1.22]</td>
</tr>
<tr>
<td>1.1 Cardiovascular exercise</td>
<td>17</td>
<td>3635</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>1.08 [0.94, 1.24]</td>
</tr>
<tr>
<td>1.2 Resistance training</td>
<td>1</td>
<td>25</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>1.85 [0.19, 17.84]</td>
</tr>
<tr>
<td>1.3 Cardiovascular and resistance</td>
<td>1</td>
<td>330</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>1.81 [0.69, 4.78]</td>
</tr>
<tr>
<td>1.4 Not specified</td>
<td>2</td>
<td>2617</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>1.05 [0.84, 1.32]</td>
</tr>
<tr>
<td>2 Relapse prevention at longest follow-up</td>
<td>2</td>
<td>453</td>
<td>Risk Ratio (M-H, Random, 95% CI)</td>
<td>0.98 [0.65, 1.47]</td>
</tr>
</tbody>
</table>

#### Analysis 1.1. Comparison 1 Exercise component versus smoking cessation programme only, Outcome 1 Smoking abstinence at longest follow-up, subgroup by exercise type.

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Exercise</th>
<th>Control</th>
<th>Risk Ratio M-H, Random, 95% CI</th>
<th>Weight</th>
<th>Risk Ratio M-H, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1.1 Cardiovascular exercise</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abrantes 2014</td>
<td>4/30</td>
<td>1/31</td>
<td></td>
<td>0.31%</td>
<td>4.13 [0.49, 34.89]</td>
</tr>
<tr>
<td>Bernard 2015</td>
<td>7/35</td>
<td>7/35</td>
<td></td>
<td>1.6%</td>
<td>1 [0.39, 2.55]</td>
</tr>
<tr>
<td>Bize 2010</td>
<td>62/229</td>
<td>72/252</td>
<td></td>
<td>16.88%</td>
<td>0.95 [0.71, 1.26]</td>
</tr>
<tr>
<td>Hill 1985</td>
<td>7/18</td>
<td>5/18</td>
<td></td>
<td>1.58%</td>
<td>1 [0.54, 3.6]</td>
</tr>
<tr>
<td>Hill 1993</td>
<td>5/18</td>
<td>7/22</td>
<td></td>
<td>1.51%</td>
<td>0.87 [0.33, 2.29]</td>
</tr>
<tr>
<td>Kinnunen 2008</td>
<td>9/125</td>
<td>7/96</td>
<td></td>
<td>1.55%</td>
<td>0.99 [0.38, 2.56]</td>
</tr>
<tr>
<td>Maddison 2014</td>
<td>78/455</td>
<td>80/451</td>
<td></td>
<td>17.5%</td>
<td>0.97 [0.73, 1.32]</td>
</tr>
<tr>
<td>Marcus 1991</td>
<td>2/10</td>
<td>0/10</td>
<td></td>
<td>0.16%</td>
<td>5 [0.27, 92.62]</td>
</tr>
<tr>
<td>Marcus 1995</td>
<td>3/10</td>
<td>1/10</td>
<td></td>
<td>0.32%</td>
<td>3 [0.37, 24.17]</td>
</tr>
<tr>
<td>Marcus 1999</td>
<td>16/134</td>
<td>8/147</td>
<td></td>
<td>2.11%</td>
<td>2.19 [0.97, 4.96]</td>
</tr>
<tr>
<td>Marcus 2005</td>
<td>1/109</td>
<td>1/108</td>
<td></td>
<td>0.18%</td>
<td>0.99 [0.06, 15.64]</td>
</tr>
<tr>
<td>Martin 1997</td>
<td>19/72</td>
<td>18/70</td>
<td></td>
<td>4.57%</td>
<td>1.03 [0.59, 1.79]</td>
</tr>
<tr>
<td>Patten 2017</td>
<td>4/15</td>
<td>6/15</td>
<td></td>
<td>1.29%</td>
<td>0.67 [0.23, 1.89]</td>
</tr>
<tr>
<td>Prapavessis 2007</td>
<td>12/68</td>
<td>8/53</td>
<td></td>
<td>2.09%</td>
<td>1.17 [0.52, 2.65]</td>
</tr>
<tr>
<td>Smits 2016</td>
<td>23/72</td>
<td>16/64</td>
<td></td>
<td>4.79%</td>
<td>1.28 [0.74, 2.2]</td>
</tr>
<tr>
<td>Taylor 1988</td>
<td>29/42</td>
<td>16/26</td>
<td></td>
<td>10.54%</td>
<td>1.12 [0.78, 1.62]</td>
</tr>
<tr>
<td>Ussher 2015</td>
<td>24/392</td>
<td>16/393</td>
<td></td>
<td>3.69%</td>
<td>1.5 [0.81, 2.79]</td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td><strong>1834</strong></td>
<td><strong>1801</strong></td>
<td></td>
<td><strong>70.7%</strong></td>
<td><strong>1.08 [0.94, 1.24]</strong></td>
</tr>
</tbody>
</table>

Total events: 305 (Exercise), 269 (Control)
Heterogeneity: Tau²=0; Chi²=10.78, df=16(P=0.82); I²=0%
Test for overall effect: Z=1.05(P=0.29)

#### 1.1.2 Resistance training

Favours control | Favours exercise
---|---|
0.02 | 0.1 | 1 | 10 | 50

---

Exercise interventions for smoking cessation (Review)

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<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Exercise</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H, Random, 95% CI</td>
<td></td>
<td>M-H, Random, 95% CI</td>
</tr>
<tr>
<td>Ciccolo 2011</td>
<td>2/13</td>
<td>1/12</td>
<td>0.27%</td>
<td>1.85[0.19,17.84]</td>
<td></td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>13</td>
<td>12</td>
<td>0.27%</td>
<td>1.85[0.19,17.84]</td>
<td></td>
</tr>
<tr>
<td>Total events:</td>
<td>2 (Exercise), 1 (Control)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity:</td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect:</td>
<td>Z=0.53(P=0.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.1.3 Cardiovascular and resistance

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Exercise</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H, Random, 95% CI</td>
<td></td>
<td>M-H, Random, 95% CI</td>
</tr>
<tr>
<td>Whiteley 2012</td>
<td>11/166</td>
<td>6/164</td>
<td>1.49%</td>
<td>1.81[0.69,4.78]</td>
<td></td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>166</td>
<td>164</td>
<td>1.49%</td>
<td>1.81[0.69,4.78]</td>
<td></td>
</tr>
<tr>
<td>Total events:</td>
<td>11 (Exercise), 6 (Control)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity:</td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect:</td>
<td>Z=1.2(P=0.23)</td>
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</tbody>
</table>

1.1.4 Not specified

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Exercise</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H, Random, 95% CI</td>
<td></td>
<td>M-H, Random, 95% CI</td>
</tr>
<tr>
<td>McKay 2008</td>
<td>120/1159</td>
<td>112/1159</td>
<td>23.55%</td>
<td>1.07[0.84,1.37]</td>
<td></td>
</tr>
<tr>
<td>Ussher 2003</td>
<td>19/154</td>
<td>19/145</td>
<td>3.98%</td>
<td>0.94[0.52,1.71]</td>
<td></td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>1313</td>
<td>1304</td>
<td>27.54%</td>
<td>1.05[0.84,1.32]</td>
<td></td>
</tr>
<tr>
<td>Total events:</td>
<td>139 (Exercise), 131 (Control)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity:</td>
<td>Tau=0; Chi²=0.16, df=1(P=0.69); I²=0%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Test for overall effect:</td>
<td>Z=0.44(P=0.66)</td>
<td></td>
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</tr>
</tbody>
</table>

Favours exercise 0.02 0.1 1 10 100 Favours control

Analysis 1.2. Comparison 1 Exercise component versus smoking cessation programme only, Outcome 2 Relapse prevention at longest follow-up.

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Exercise</th>
<th>Control</th>
<th>Risk Ratio</th>
<th>Weight</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N</td>
<td>n/N</td>
<td>M-H, Random, 95% CI</td>
<td></td>
<td>M-H, Random, 95% CI</td>
</tr>
<tr>
<td>Hassandra 2017</td>
<td>9/25</td>
<td>7/19</td>
<td>26.86%</td>
<td>0.98[0.44,2.15]</td>
<td></td>
</tr>
<tr>
<td>Prapavessis 2016</td>
<td>30/214</td>
<td>28/195</td>
<td>73.14%</td>
<td>0.98[0.61,1.57]</td>
<td></td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>239</td>
<td>214</td>
<td>100%</td>
<td>0.98[0.65,1.47]</td>
<td></td>
</tr>
<tr>
<td>Total events:</td>
<td>39 (Exercise), 35 (Control)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity:</td>
<td>Tau=0; Chi²=12.28, df=20(P=0.91); I²=0%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Test for overall effect:</td>
<td>Z=1.28(P=0.2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for subgroup differences: Chi²=1.36, df=1 (P=0.72), I²=0%</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Favours control 0.01 0.1 1 10 100 Favours exercise

WHAT'S NEW

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 June 2019</td>
<td>New search has been performed</td>
<td>6 new studies added, several excluded studies added, all of main text updated, 'Risk of bias' table updated, meta-analysis added.</td>
</tr>
</tbody>
</table>
We have removed the table of acute studies, and instead provide a narrative summary.

**Date** | **Event** | **Description**
--- | --- | ---
8 June 2019 | New citation required but conclusions have not changed | No change to conclusions

**HISTORY**

Review first published: Issue 3, 2000

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 November 2011</td>
<td>New citation required but conclusions have not changed</td>
<td>New citation for update</td>
</tr>
<tr>
<td>26 September 2011</td>
<td>New search has been performed</td>
<td>Two new studies added, several excluded studies added, all of main text updated, several studies added to appendix of acute studies.</td>
</tr>
<tr>
<td>21 July 2008</td>
<td>New search has been performed</td>
<td>Two new studies included, several excluded studies added, background updated, table of acute studies added.</td>
</tr>
<tr>
<td>21 July 2008</td>
<td>New citation required but conclusions have not changed</td>
<td>Change of authorship</td>
</tr>
<tr>
<td>1 July 2008</td>
<td>Amended</td>
<td>Converted to new review format.</td>
</tr>
<tr>
<td>22 May 2005</td>
<td>New search has been performed</td>
<td>Three new studies, no change to conclusions.</td>
</tr>
<tr>
<td>19 May 2002</td>
<td>New search has been performed</td>
<td>Search updated, no new studies.</td>
</tr>
</tbody>
</table>

**CONTRIBUTIONS OF AUTHORS**

The original review was conceived, extracted and written by Michael Ussher (MU), Adrian Taylor (AT), Robert West (RW) and Andrew McEwen (AM).

The idea for the review was conceived by MU, AT and RW. MU was responsible for co-ordinating the review and undertook the search process and data management, including screening search results and retrieved papers, abstracting data from the papers and contacting study authors for additional information.

All review authors made a contribution to the design, search strategy and interpretation of data. The writing of the original review was led by MU with assistance from RW, AT and AM.

The 2005 update was conducted solely by MU.

We updated the 2008 review to include a table of studies examining the acute effects of exercise on cravings and withdrawal symptoms. AT and Guy Faulkner (GF) synthesised this evidence, in both 2008 and 2011.

In both the 2008 and 2011 reviews MU added studies to the main review and these details were checked by GF. In both 2008 and 2011, except for the section 'Acute effect of exercise on tobacco withdrawal and cravings' (which was updated by AT), MU updated the text and other review authors checked it.

In the 2014 review MU added studies to the main review and to the table of acute studies, and revised the text. In 2014 we added a table of studies (Appendix 2) assessing the effect of exercise interventions on cigarette consumption. AT or GF checked all the revisions and additions against the original papers. Both AT and GF checked all the revisions to the main text.
In 2019 Jonathan Livingstone-Banks searched the Cochrane Tobacco Addiction Group register and KA conducted the rest of the searches. MU, AT, GF and KA were involved with independently checking titles, abstracts and full texts for relevant studies, with two review authors checking all the titles retrieved from the searches. MU, AT, GF and KA were involved with extracting study data and a second review author checked the entries. Two review authors independently conducted risk assessments for each study and discussed and resolved any differences. MU and Jamie Hartmann-Boyle (JHB) revised the text, and all review authors checked and commented on the revisions.

**DECLARATIONS OF INTEREST**

MU: was involved in the conduct of four of the included studies (Ciccolo 2011; Patten 2017; Ussher 2003; Ussher 2015).

AT: was involved with three of the included trials (Bernard 2015; Ussher 2003; Ussher 2015).

GF: was involved with one of the included trials (Prapavessis 2016).

JHB: none declared.

KA: none declared.

**SOURCES OF SUPPORT**

Internal sources
- St George’s, University of London, UK.
- University of Exeter, UK.
- University of Toronto, Canada.
- University of Stirling, UK.

External sources
- National Institute for Health Research (NIHR) Cochrane Incentive Award, UK.

**DIFFERENCES BETWEEN PROTOCOL AND REVIEW**

For the 2019 review we removed the table of studies assessing the acute effect of exercise on tobacco withdrawal and cravings, as these studies are not central to the review and are presented in other reviews.

**INDEX TERMS**

**Medical Subject Headings (MeSH)**

Cognitive Behavioral Therapy; Exercise; Randomized Controlled Trials as Topic; Recurrence; Smoking [psychology] [*therapy]; Smoking Cessation [*methods]; Weight Gain

**MeSH check words**

Humans