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Ussher MH, Taylor AH, Faulkner GEJ.
Exercise interventions for smoking cessation.
Cochrane Database of Systematic Reviews 2014, Issue 8. Art. No.: CD002295.
DOI: 10.1002/14651858.CD002295.pub5.

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[Intervention Review]

Exercise interventions for smoking cessation

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Editorial group: Cochrane Tobacco Addiction Group.
Publication status and date: New search for studies and content updated (no change to conclusions), published in Issue 8, 2014.

Citation: Ussher MH, Taylor AH, Faulkner GEJ. Exercise interventions for smoking cessation. *Cochrane Database of Systematic Reviews* 2014, Issue 8. Art. No.: CD002295. DOI: 10.1002/14651858.CD002295.pub5.

ABSTRACT

Background

Taking regular exercise may help people give up smoking by moderating nicotine withdrawal and cravings, and by helping to manage weight gain.

Objectives

To determine whether exercise-based interventions alone, or combined with a smoking cessation programme, are more effective than a smoking cessation intervention alone.

Search methods

We searched the Cochrane Tobacco Addiction Group Specialized Register in April 2014, and searched MEDLINE, EMBASE, PsycINFO, and CINAHL Plus in May 2014.

Selection criteria

We included randomized trials which compared an exercise programme alone, or an exercise programme as an adjunct to a cessation programme, with a cessation programme (which we considered the control in this review). Studies were required to recruit smokers or recent quitters and have a follow-up of six months or more. Studies that did not meet the full inclusion criteria because they only assessed the acute effects of exercise on smoking behaviour, or because the outcome was smoking reduction, are summarised but not formally included.

Data collection and analysis

We extracted data on study characteristics and smoking outcomes. Because of differences between studies in the characteristics of the interventions used we summarized the results narratively, making no attempt at meta-analysis. We assessed risk of selection and attrition bias using standard methodological procedures expected by The Cochrane Collaboration.

Main results

We identified 20 trials with a total of 5,870 participants. The largest study was an internet trial with 2,318 participants, and eight trials had fewer than 30 people in each treatment arm. Studies varied in the timing and intensity of the smoking cessation and exercise programmes offered. Only one included study was judged to be at low risk of bias across all domains assessed. Four studies showed significantly higher abstinence rates in a physically active group versus a control group at end of treatment. One of these studies also showed a significant benefit for exercise versus control on abstinence at the three-month follow-up and a benefit for exercise of

borderline significance (p = 0.05) at the 12-month follow-up. Another study reported significantly higher abstinence rates at six month follow-up for a combined exercise and smoking cessation programme compared with brief smoking cessation advice. One study showed significantly higher abstinence rates for the exercise group versus a control group at the three-month follow-up but not at the end of treatment or 12-month follow-up. The other studies showed no significant effect for exercise on abstinence.

Authors' conclusions

Only two of the 20 trials offered evidence for exercise aiding smoking cessation in the long term. All the other trials were too small to reliably exclude an effect of intervention, or included an exercise intervention which may not have been sufficiently intense to achieve the desired level of exercise. Trials are needed with larger sample sizes, sufficiently intense interventions in terms of both exercise intensity and intensity of support being provided, equal contact control conditions, and measures of exercise adherence and change in physical activity in both exercise and comparison groups.

PLAIN LANGUAGE SUMMARY

Do exercise interventions help people quit smoking

Review question

We reviewed the evidence about the effect of exercise programmes in people who want to quit smoking. We looked at whether exercise programmes, either alone or combined with stop smoking programmes, helped more people to quit at six months or longer than stop smoking programmes alone or stop smoking programmes combined with health education.

Background

Specialist clinics and self-help materials regularly recommend exercise to people who want to quit smoking. Taking regular exercise may help people give up smoking by helping with withdrawal and cravings, and by helping to manage weight gain.

Study characteristics

The evidence is current to April 2014. We found 20 trials with a total of 5,870 participants. Nine studies were in women only and one study was in men only. Studies varied in the timing and intensity of programmes offered. We only included studies that measured smoking at six months or longer. In most of the trials, the exercise programmes included group and home-based exercise.

Key results

Since these studies used different types and intensities of exercise programmes, the results were not combined.

In four studies, people who received the exercise programme were significantly more likely to quit smoking at end of treatment than people who only received a stop smoking programme. Only two of the 20 trials offered evidence for exercise helping people to quit smoking in the long term. In one of these studies, the people in the exercise group had significantly higher quit rates at three-month follow-up and at 12 months, the results from this study were borderline significant. In this study, people who received the exercise programme were more than twice as likely to still be quit at 12 months. Another study reported significantly higher quit rates at six month follow-up for a combined exercise and smoking cessation programme compared with brief smoking cessation advice. The other studies did not find an effect of exercise programmes on quit rates but that could have been because they were small studies or because the exercise programmes were not intense enough.

Quality of evidence

The level of evidence for whether exercise programmes help people quit smoking is very low and more research is needed. There are issues with study design, possible risk of bias, and differences between the studies.

SUMMARY OF FINDINGS FOR THE MAIN COMPARISON [Explanation]

Exercise interventions for smoking cessation

Population: People who smoke or people who have recently quit smoking
Intervention: Exercise programmes alone or as adjuncts to smoking cessation programmes
Comparison: Smoking cessation programmes without exercise components

Outcomes	Effects of exercise interventions for smoking cessation	No of Participants (studies)	Quality of the evidence (GRADE)
Smoking cessation at longest follow-up (6+ months)	At longest follow-up, one study detected a difference of borderline significance in favour of the intervention group. Another study reported significantly higher abstinence rates at six month follow-up for a combined exercise and smoking cessation programme compared with brief smoking cessation advice, but not when compared to the full smoking cessation programme. No other studies detected a significant difference between intervention and comparison groups at longest follow-up	5870 (20 studies)	⊕○○○ very low[1]

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

1 Risk of bias unclear or high for all but one included study. High level of clinical heterogeneity precluded meta-analysis. Issues with inadequate sample size in majority of included studies.

BACKGROUND

Cigarette smoking is an important risk factor for cardiovascular disease, cancer and hypertension, and is one of the major causes of premature mortality in industrialized nations (Doll 2004; Peto 1996). Stopping smoking prolongs life and reduces morbidity (USDHHS 1990; Taylor 2002). Many attempts to stop smoking are made unaided (West 1997; Hughes 2004), with a success rate (6 to 12 months prolonged abstinence) of around 3 to 5% (Hughes 2004). Aided quit attempts, particularly through a combination of behavioural counselling and nicotine replacement therapy (NRT), bupropion or varenicline can improve success rates, but these remain low (Cahill 2012; Hughes 2014; Stead 2012). More effective smoking cessation interventions are needed.

Effect of exercise on tobacco withdrawal and cravings

Exercise has been proposed as an aid for smoking cessation (Hill 1981). In this review the terms exercise and physical activity (PA) are used interchangeably and refer to both 'lifestyle' physical activities, such as walking, as well as more formal structured activities, such as using a stationary cycle. The severity of 'desire to smoke' reliably predicts relapse in smokers who are trying to stop (Doherty 1995; West 1989) and interventions are required which reduce the desire to smoke. In experimental studies, cardiovascular-type exercise has been shown to have an acute effect on reducing both psychological withdrawal symptoms and desire to smoke in abstinent smokers. This has been shown to be the case for both brief (5 to 10 minute) bouts of moderate intensity exercise among smokers who have been abstinent overnight and for 30 to 40 minute bouts of vigorous intensity among smokers who are trying to quit smoking (Haasova 2013; Haasova 2014; Taylor 2007b; Roberts 2012 - also see the table of acute studies in Appendix 1). The mechanism underlying the observed beneficial effect of exercise on withdrawal and cravings is not clear. Exercise has been shown to have some similarities to smoking in its effects on stimulating the central nervous system (Russell 1983) and on neurobiological processes in the brain (Dishman 2009), including increasing beta-endorphin levels in smokers (Leelarungrayub 2010), and consequently it has been argued that exercise may provide an alternative reinforcer to smoking (Marlatt 1985). This argument is consistent with behavioural theories of choice (Correia 1998) and animal studies have demonstrated that exercise is an effective alternative reinforcer to illicit substances for rats (e.g. Cosgrove 2002), but no studies could be identified which have investigated the role of exercise as an alternative reinforcer to smoking. It seems plausible that the attention to somatic cues during exercise presents a unique strategy for distracting smokers from the cravings and negative cognitions experienced during smoking abstinence, although the findings from one study suggest that distraction is unlikely to play a major role (Daniel 2006). Another possible mechanism is that exercise influences cognitive functioning in smokers; for example, exercise appears to reduce attentional bias to smoking images (Janse van Rensburg 2009a; Oh 2014).

Besides the potential benefits of exercise for moderating psychological withdrawal symptoms and cravings, there is evidence for exercise reducing post-smoking cessation weight gain in the long-term (Farley 2012), and for reducing cravings for sweet foods during the first week of abstinence (Teo 2014). The weight control benefits of exercise may be of particular importance to female smokers (see Linke 2013 for discussion of exercise interventions for female smokers) who report smoking to control weight (USDHHS 2001; Weekley 1992), and report fear of post-cessation weight gain as a motivation for continued smoking (Clark 2004; Sorenson 1992; USDHHS 2001) and for smoking relapse (Gritz 1989; Klesges 1992). Exercise has also been shown to have a positive effect on other factors that may protect against smoking relapse, including perceived coping ability (Steptoe 1989) and self esteem (Spence 2005). In addition, being physically active has many general health benefits (Garber 2011), which have been observed for smokers who have quit (Albrecht 1998; Niaura 1998; Shinton 1997) and for continuing smokers (Colbert 2001; Hedblad 1997; Senti 2001). Moreover, a review suggests that participation in regular physical activity satisfies eight of the principles characterising a tobacco harm reduction strategy (deRuiter 2006). For example, one study observed that physical activity levels were inversely associated with lung carcinoma among current and former smokers (Leitzmann 2009).

Associations between exercise and smoking behaviours

Evidence from a number of large cross-sectional surveys indicates that levels of PA are inversely related to smoking rates (e.g. Boutelle 2000; Boyle 2000; Hu 2002; Picavet 2010; Schuman 2001; Takemura 2000). Among smokers with a depressive disorder attempting to quit, lower physical activity levels at baseline predicted an increased likelihood of relapsing (Bernard 2012). One survey has shown an association between higher levels of cigarette dependence and lower levels of physical activity (Loprinzi 2014). Other evidence from cross-sectional studies suggests that this relationship may be influenced by both gender and mode of PA. For example, when only examining leisure-time PA, heavy smoking has been shown to be inversely related to PA in men but not in women (Schroder 2003). Elsewhere, participation in sport has been negatively associated with smoking in men but not in women (Helmert 1994). Additionally, some earlier studies have shown a weak relationship or no relationship between PA and smoking (Blair 1985; King 1992).

We only found one study (Sasco 2002) which examined the relationship between smoking and exercise in pre-adolescents, and this cross-sectional study reported a positive association between engaging in PA and 'ever smoking'. Among adolescents, cross-

sectional studies have consistently shown that smoking is negatively associated with participation in sport (Escobedo 1993; Peretti-Watel 2003; Rodriguez 2004; Rodriguez 2008) and with overall levels of PA (Coulson 1997; Pate 1996; Verkooijen 2008; Ward 2003). There is some evidence to suggest that this pattern may be different for boys versus girls and some of the evidence is contradictory. For example, a cross-sectional study of adolescents found a negative association between sporting activity and smoking for boys and heavy smoking, but not for girls or for lighter smokers (Peretti-Watel 2002). Another study observed no association between sports participation and smoking levels in males (Davis 1997), while a prospective study found that leisure-time PA was positively associated with initiating smoking for girls but not for boys (Aaron 1995). Two prospective studies found that higher levels of PA reduced the odds of starting smoking for boys and girls both during childhood (Audrain-McGovern 2003) and adulthood (Kujala 2007). One study showed that the negative association between physical activity and smoking is mediated by having a physically active identity (Verkooijen 2008). A detailed review of studies examining associations between smoking and physical activity has been published by Kaczynski 2008.

Smokers trying to quit are likely to be more receptive to an active lifestyle than smokers in general (Doherty 1998; King 1996). An exercise-based smoking cessation intervention has been found to significantly improve cardiovascular disease biomarkers (e.g. inflammatory markers) within three months (Korhonen 2011) and smokers report that they value exercise as a strategy for reducing the risk of developing tobacco-related disease (Haddock 2004). In addition, higher levels of exercise are associated with less depression in smokers (Vickers 2003; Williams 2008). Being physically active has been positively associated with initiating a quit attempt (deRuiter 2008; Gaulthier 2012; Haddock 2000), with confidence to maintain smoking abstinence (King 1996) and with success at stopping smoking (Abrantes 2009; Derby 1994; Paavola 2001; Sedgwick 1988), although one large survey found no association between exercise levels and intention to quit smoking (Nguyen 1998). Other work shows a positive trend between avoiding relapse to smoking and physical health and fitness (Metheny 1998) and a significantly reduced risk of smoking relapse among those who are more physically active (McDermot 2009), including among those with depression (Bernard 2012).

Overall, from the above evidence one might hypothesize that pursuing regular exercise during an attempt to stop smoking could act both to reduce nicotine withdrawal symptoms and cravings and to increase rates of smoking cessation. In practice, exercise has for many years been routinely recommended as an aid to smoking cessation by specialist smoking clinics (e.g. Everson 2010; Hurt 1992), by pharmaceutical companies (e.g. Boots 1998), in self-help guides (Ashelman 2000; Marcus 2004), by physical therapists (Pignataro 2012), and in national guidelines (e.g. Quit 1994; Woodhouse 1990; USDHHS 2008), and many smokers are likely to view physical activity as an aid to quitting (Everson-Hock 2010a). In the short term, most smokers are unlikely to spontaneously increase their levels of PA after quitting (Allen 2004; Hall 1989; Vander Weg 2001), and the present review examines studies which have evaluated exercise interventions as an aid to smoking cessation.

The objective of the main review is to evaluate studies on the effect of exercise on smoking cessation after at least six months. Two secondary questions are also addressed: the acute effects of exercise on smoking related outcomes, and, for this update of the review, the effects of physical activity on levels of cigarette consumption. Evidence for the acute effects of exercise on cigarette cravings and withdrawal provides the main rationale for promoting exercise for smoking cessation; therefore we consider it important to present these studies. The effect of a physical activity intervention on levels of cigarette consumption is important as there is increasing interest in the effectiveness of interventions (pharmacological and behavioural) targeting smoking harm reduction (NICE 2013). While smoking cessation is the ultimate goal of interventions, there is evidence that cessation can be induced through smoking reduction, among both smokers who wish to quit and those who do not. Exercise interventions that seek to reduce cigarette consumption, whether it be to implicitly or explicitly lead to a quit attempt, are therefore reviewed.

OBJECTIVES

The primary objective was to establish whether exercise-based interventions alone, or combined with a smoking cessation programme, are more effective than a smoking cessation intervention alone.

METHODS

Criteria for considering studies for this review

Types of studies

Randomized controlled trials.

Types of participants

Smokers wishing to quit or recent quitters.

Types of interventions

Programmes aimed at increasing physical activity, either alone or as an adjunct to a smoking cessation intervention, compared with

a smoking cessation programme alone. Interventions which included exercise in a multiple component smoking cessation programme were excluded since the specific effects of exercise on smoking abstinence could not be addressed. Multiple risk factor interventions where smoking cessation was one of a number of health-related outcomes were excluded for the same reason.

Types of outcome measures

Smoking cessation at the longest follow-up reported. Trials with less than six months' follow-up were not included (i.e. a study was included if follow-up was at least six months post-baseline, six months post-quit or six months post-treatment).

Search methods for identification of studies

We searched the Specialized Register of the Cochrane Tobacco Addiction Group for studies including the terms 'exercise' or 'physical activity' in the title, abstract or keyword fields. At the time of the search in April 2014 the Register included the results of searches of the Cochrane Central Register of Controlled trials (CENTRAL), issue 3, 2014; MEDLINE (via OVID) to update 20140321; EMBASE (via OVID) to week 201413; and PsycINFO (via OVID) to update 20140317. See the Tobacco Addiction Group Module in the Cochrane Library for full search strategies and list of other resources searched. We also searched MEDLINE, PubMed, EMBASE, PsycINFO, and CINAHL Plus, using the terms 'smoking', 'smoking cessation', 'exercise', 'physical activity', and 'intervention' (searches completed May 2014). We also carried out a hand search of reference lists and conference abstracts, conducted additional searches on key authors, and contacted key authors.

Data collection and analysis

We extracted the following data from each study report: study design; recruitment and randomisation method; subject characteristics including age, gender, smoking behaviour, and exercise levels at entry; sample size; description of exercise and smoking cessation programmes (including number of sessions and duration); rates of exercise adherence; control conditions; length of follow-up; definition of cessation; and method of validation. The primary outcome was quitting at longest follow-up using the strictest definition of abstinence reported in the study. Data on change in cigarette consumption was also extracted.

Due to the differences in study design and intervention, we did not conduct a meta-analysis. For each study the risk ratio for quitting at longest follow-up ((number of events in intervention condition/intervention denominator)/ (number of events in control condition/control denominator)) and the 95% confidence interval were displayed graphically. Where the event is defined as smoking cessation, an RR greater than one indicates that more people successfully quit in the treatment group than in the control group.

Unless noted otherwise, quit rates are calculated based on numbers randomised to an intervention or control, and exclude any deaths or untraceable moves. We regard participants who dropped out or were lost to follow-up as continuing to smoke. We have where possible conducted intention-to-treat analyses (i.e., all participants initially assigned to intervention or control are included in their original groups).

Included studies were assessed for risk of selection bias (random sequence generation and allocation concealment) and attrition bias (incomplete follow-up) in accordance with Cochrane guidelines.

RESULTS

Description of studies

The searches identified 20 studies which met the inclusion criteria, with a total of 5,870 participants, the largest study being an internet trial with 2,318 participants (McKay 2008). Eight trials had fewer than 30 individuals in each treatment arm (Bock 2012; Ciccolo 2011; Hill 1985; Hill 1993; Marcus 1991; Marcus 1995; Russell 1988; Taylor 1988). Five studies have been added since the last version of this review (Abrantes 2014; Bock 2012; Horn 2011; Maddison 2014; Whiteley 2012). Full details for each study are given in the Characteristics of included studies table. Ten studies had more than one associated publication or abstract (Bize 2010; Horn 2011; Kinnunen 2008; Maddison 2014; Marcus 1999; Marcus 2005; Martin 1997; Prapavessis 2007; Ussher 2003; Whiteley 2012) and these are listed under the study identifier in the reference section. Nine trials were limited to women (Bock 2012; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Prapavessis 2007; Russell 1988; Whiteley 2012) and one was limited to men (Taylor 1988).

In all but two of the studies (McKay 2008; Taylor 1988), a multisession cognitive behavioural smoking cessation programme was provided for intervention and control conditions. In ten studies this was described as beginning prior to quit day (Abrantes 2014; Bock 2012; Hill 1993; Kinnunen 2008; Maddison 2014; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003; Whiteley 2012). One study provided only a single session cessation programme and participants were post-acute myocardial infarction (AMI) patients, with the intervention being for relapse prevention (Taylor 1988). One study delivered a smoking cessation programme via the Internet and this was only available for the non-exercise condition (McKay 2008). Six studies included nicotine patches as part of the smoking cessation programme (Abrantes 2014; Ciccolo 2011; Marcus 2005; Prapavessis 2007; Ussher 2003; Whiteley 2012), one study used nicotine gum (Kinnunen 2008), three promoted nicotine replacement therapy in general (Bize 2010; Maddison 2014; McKay 2008), and one advocated smoking cessation medicines in general (Bock 2012).

Sixteen of the studies recruiting current smokers set a quit date, and one set a quit date for the non-exercise condition but did not specify whether the exercise group set a quit date (McKay 2008). The exercise programme began before the quit date in 12 studies (Abrantes 2014; Bize 2010; Bock 2012; Hill 1993; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003; Whiteley 2012), on the quit date in three (Ciccolo 2011; Hill 1985; Martin 1997), and after the quit date in three (Maddison 2014; Russell 1988; Taylor 1988). Two studies did not state the timing of the exercise programme relative to quit date (Horn 2011; McKay 2008). Two studies involved exercise programmes lasting for less than six weeks (Hill 1985; Martin 1997) and the length of one programme was not given (McKay 2008). Most of the trials employed supervised, group-based cardiovascular-type exercise supplemented by a home-based programme. Five studies did not provide a home programme (Bock 2012; Ciccolo 2011; Marcus 1991; Marcus 1995; Marcus 1999), one study used only brief one-to-one counselling towards pursuing home-based exercise (Ussher 2003), one focused on telephone-based physical activity counselling (Maddison 2014), and one provided a web-based program designed to encourage engagement in a personalized fitness program, although specific detail was not provided regarding the type of exercise promoted (McKay 2008). Ciccolo 2011 focused exclusively on an individual programme of resistance exercise (i.e. weight training) and Bock 2012 delivered a yoga intervention.

Excluded studies

The literature search revealed a number of trials which did not satisfy the inclusion criteria (see Characteristics of excluded studies table), but had exercise as an independent variable and smoking cessation behaviour as a dependent variable. These studies mainly fell into four categories:

(a) Multiple independent and dependent variables: a number of studies were identified in which exercise was one element in a multiple risk factor intervention, with smoking cessation behaviour as one of a number of health-related outcomes. The specific effects of exercise on smoking cessation could not be determined due to possible interaction and confounding between the independent variables. For example, it is not possible to separate the effects on smoking cessation due to a change in diet versus a change in exercise.

(b) Multiple independent variables and a single dependent variable: these studies included multiple smoking cessation elements one of which was exercise. In these studies the specific effects of exercise on smoking abstinence were not addressed.

(c) Single independent variable and multiple dependent variables: in these studies exercise was encouraged without a smoking cessation programme, and changes in various health and behavioural indices including smoking cessation were examined. None of these studies found a significant effect on smoking abstinence for the active condition. However, as these studies did not record the number of smokers who were trying to stop, it is difficult to evaluate their success.

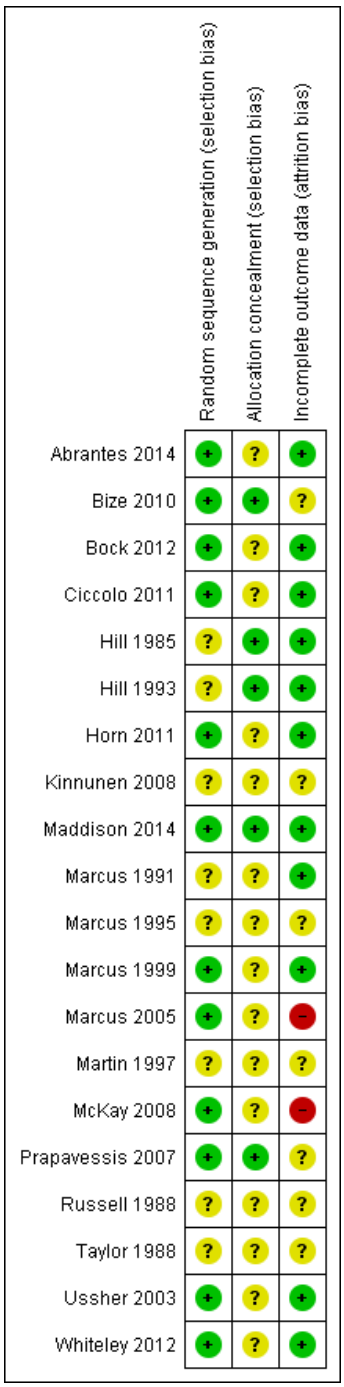
(d) Acute studies: These experimental studies assessed the acute impact of an exercise intervention on withdrawal symptoms and desire to smoke, mostly following temporary abstinence. Details and findings of these studies are shown in Appendix 1 and summarised in the Discussion.

(e) Did not meet other inclusion criteria: These studies either had a follow-up of less than six months, did not include all smokers who wish to quit at the outset, did not include a non-exercise control group or did not have smoking abstinence as an outcome. Studies which reported change in cigarette consumption are included in Appendix 2.

Risk of bias in included studies

Only one of the 20 studies was at low risk of bias across all domains (Figure 1). All other studies were rated at unclear risk in at least one domain due to insufficient detail in the study report. Eleven studies described the randomization method in detail (Abrantes 2014; Bize 2010; Bock 2012; Ciccolo 2011; Marcus 1999; Maddison 2014; Marcus 2005; McKay 2008; Prapavessis 2007; Ussher 2003; Whiteley 2012). The strictest measure of abstinence was continuous in eight studies, prolonged abstinence in two, point prevalence in eight, and was not specified in two.

Figure 1. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.



Thirteen studies stated that those lost to follow-up were counted as having relapsed to smoking (Abrantes 2014; Bize 2010; Bock 2012; Ciccolo 2011; Horn 2011; Hill 1985; Maddison 2014; Marcus 1991; Marcus 1999; Marcus 2005; McKay 2008; Ussher 2003; Whiteley 2012). Post-randomization dropouts were excluded from the denominator in six studies (Bize 2010; Ciccolo 2011; Hill 1993; Kinnunen 2008; Prapavessis 2007; Taylor 1988). Two studies were judged to be at high risk of attrition bias as less than half of the participants were followed up (Marcus 2005; McKay 2008).

Effects of interventions

See: **Summary of findings for the main comparison**

We defined the efficacy of the intervention in terms of the risk ratio (RR) for quitting in the treatment group versus the controls. The RRs with 95% confidence intervals (CI) for cessation at longest follow-up for each study are shown in Analysis 1.1. Four studies showed significantly higher abstinence rates in a physically active group versus a control group at end of treatment (Bock 2012; Marcus 1991; Marcus 1999; Martin 1997). One of these studies also showed a benefit for exercise versus control on abstinence at the three-month follow-up and a benefit for exercise of borderline significance at the 12-month follow-up point (Marcus 1999). The latter study showed a difference in abstinence rates for the exercise condition compared with the control of 11.9% versus 5.4% (p = 0.05, RR 2.19, 95% CI 0.97 to 4.96) at the 12-month follow-up. One study observed significantly higher cessation rates for a condition combining exercise with a cessation programme compared with a brief advice only control group at three and six month follow-ups (at six months: p = 0.013, RR 2.81, 95% CI 1.44 to 5.49), but the differences were not significant when comparing the exercise condition with a cessation programme plus brief advice (Horn 2011). In this study, abstinence was not biochemically validated at six months. One study showed significantly higher abstinence rates for the exercise group versus a control group at the three-month follow-up but not at the end of treatment or 12-month follow-up (Marcus 2005). The latter study also found that those with higher levels of exercise adherence were significantly more likely to achieve smoking abstinence at the end of treatment. The other studies showed no significant effect for exercise on abstinence. Several of the studies showed a trend for higher rates of abstinence in the exercise condition compared with the controls (Abrantes 2014; Ciccolo 2011; Hill 1985; Kinnunen 2008; Marcus 1995; Prapavessis 2007; Whiteley 2012). Only seven studies had a sufficiently large sample size to have a good prospect of detecting a significant difference between the treatment and control conditions (Bize 2010; Maddison 2014; Marcus 1999; Marcus 2005; Martin 1997; McKay 2008; Ussher 2003). One of the studies 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, not included in Analysis 1.1).

In addition to comparing the exercise condition with a control group, four of the studies examined the effectiveness of exercise versus nicotine replacement therapy (NRT) (Hill 1993; Kinnunen 2008; Martin 1997; Prapavessis 2007). In one study at end of treatment and at 12-month follow-up abstinence rates were significantly higher in the exercise-plus-patch group than in the exercise-only group (Prapavessis 2007). The other studies observed no significant differences.

DISCUSSION

The evidence on the effectiveness of exercise interventions for smoking cessation is very limited (Summary of findings for the main comparison). Four of the 20 studies found an effect in favour of the intervention at end of treatment, one study detected a borderline significant difference in favour of the intervention at 12 months, and one study detected a significant difference at six months when evaluating an exercise programme as an adjunct to brief advice, but not when comparing the exercise programme to a more intensive smoking cessation programme. Key limitations to the body of evidence include clinical heterogeneity, unclear risk of bias, issues with generalisabilty to other population groups, and issues with study design and outcome measures. These are explored in more detail below.

Cessation programmes

In one study the effect of the treatment may have been compromised by the smoking cessation programme being limited to a single counselling session (Taylor 1988). In this study the interventions were not intended to initiate smoking abstinence but rather to maintain abstinence in smokers following acute myocardial infarction (AMI). Thus the results, which did not show any benefit for exercise, cannot easily be generalized beyond abstaining post-AMI smokers. This trial also compared the combined effect on smoking abstinence of four different exercise interventions with the combined effect of two different control interventions; therefore it was not possible to relate outcomes for smoking cessation to specific interventions. This study is further limited by providing smoking cessation counselling for only one of the two control conditions.

The results of one of the studies, showing a positive effect for exercise on smoking abstinence at end of treatment, may have been confounded by the exercise group receiving a different cessation programme than the control group (Martin 1997). In two studies

showing a significant benefit of exercise versus control at end of treatment the exercise condition received more staff contact time than the control (Marcus 1991; Martin 1997), leading to the question of whether the outcomes for abstinence were due to exercise alone or due to additional social support.

It has been recommended that a smoking cessation programme should start before the quit date and continue into the period of abstinence (Raw 1998). Yet almost half of the trials did not do this (Ciccolo 2011; Hill 1985; Maddison 2014; Marcus 1991; Marcus 1995; Martin 1997; McKay 2008; Russell 1988; Taylor 1988). With the provision of more extensive cessation programmes the impact of the interventions may have been more pronounced. Furthermore, only one of the studies (Ussher 2003) described an intervention in which the smoking cessation and exercise components were integrated in such a way as to reinforce exercise as a coping strategy for smoking cessation (Marlatt 1985; Taylor 2010). For example, the potential for exercise to be used to reduce cigarette cravings and withdrawal symptoms (Taylor 2007b) was not made explicit in the majority of studies.

Target populations

Demographic factors, such as age, gender, weight, fitness level, socioeconomic status and occupation could influence outcomes for both smoking cessation (Jarvis 1997; Vangeli 2011) and exercise behaviour (Caspersen 1994; Pate 1995). Of the nine trials which recruited men and women, four compared outcomes by gender. Of these studies, Abrantes 2014, Hill 1993, and Ussher 2003 reported no gender differences, and Horn 2011 observed significantly higher abstinence rates for males, but not for females, at three and six month follow-ups, in a teenage population. None of the studies considered outcomes relative to occupation, socioeconomic status or age. It is possible that the relationship between demographic variables and outcomes was not explored in some of the studies because of small sample sizes. All but four of the studies were North American. Thirteen studies recorded ethnic status, and all reported a predominantly white sample. Researchers must consider whether these results can be generalized to other national and ethnic populations (Caspersen 1994; King 1997; Mackay 1996). One trial recruited post-acute myocardial infarction (AMI) patients, another targeted teenage smokers (aged 14 to 19 years), and the remaining trials recruited from the general population of smokers. Trials are needed among other populations of smokers who might especially benefit from an exercise intervention. Given the high prevalence of smoking among those with mental illness, and the established benefits of regular physical activity for mental health (Stathopoulou 2006), research is needed to examine the role that physical activity may play as an aid to quitting. Those with serious mental illness are likely to be receptive to exercise as an aid to cessation (Arbour-Nicitopoulos 2011; Arbour-Nicitopoulos 2011b; Faulkner 2007) and an exercise intervention has been successfully piloted among women smokers with depression (Bernard 2013; Vickers 2009). Horn 2011 showed that teenage smokers are likely to benefit from an exercise intervention. An excluded study explored a sport-based intervention for smoking prevention in pre-adolescents (Trigwell 2014). Obese quitters may have a particular need for weight control interventions, such as exercise (Lycett 2011), and we have yet to see a trial of exercise focusing on this population. Additionally, a non-pharmaceutical intervention such as exercise is likely to appeal to pregnant smokers (Ussher 2004; Ussher 2007) and a recently completed trial is assessing the effects of an exercise intervention in this population (Ussher 2008; Ussher 2012).

Seven studies did not present the participants' level of exercise at baseline (Abrantes 2014; Bock 2012; Ciccolo 2011; Hill 1985; McKay 2008; Russell 1988; Taylor 1988). All the remaining studies, except Horn 2011, reported that they had recruited fairly sedentary smokers. A substantial proportion of smokers may be physically active (deRuiter 2008; Emmons 1994; Prochaska 1992; Ward 2003; Scioli 2009) and there is some evidence that regular exercisers may be more successful at quitting (Abrantes 2009; Derby 1994; Paavola 2001; Sedgwick 1988), yet it is not clear whether exercise interventions are effective as an aid to smoking cessation for a more active population.

Weight gain

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. Marcus 1999 did not find any significant differences in weight change between the treatment conditions 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 (Horn 2011 (BMI); Marcus 1991; Marcus 1995; Marcus 2005; Ussher 2003; Whiteley 2012), at three- and six-month follow-ups (Ciccolo 2011), or at 12 months post-cessation (Bize 2010; Ussher 2003). The studies by Ciccolo 2011, Marcus 1991, Marcus 1995, and Whiteley 2012 were too small to have a realistic chance of detecting significant differences. The studies by Bize 2010, Marcus 2005, Ussher 2003, and Whiteley 2012 included nicotine replacement therapy (NRT) and post-cessation weight gain is likely to be less pronounced when using NRT (Jorenby 1996). Therefore, the potential for exercise to moderate weight gain was 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 determined.

When pooling the studies, Farley 2012 found no evidence for exercise moderating weight gain at end of treatment, but reported a benefit at 12 months follow-up when combining three studies (Bize 2010; Marcus 1999; Ussher 2003). The authors concluded that 'More studies are needed to clarify whether this is an effect of treatment or a chance finding'. An earlier publication conducted a meta-analysis with 10 studies of weight management interventions during smoking cessation, including five of the studies included in the current review (Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Ussher 2003), and observed a significant benefit for the intervention in the short-term (< three months), but not in the long-term (> six months) (Spring 2009).

Nicotine replacement therapy

Prapavessis 2007 provides some indication that combining nicotine patches and exercise enhances abstinence compared with exercise alone, as would be expected given the established efficacy of NRT (Stead 2012). Future studies need to establish whether exercise offers additional benefits to those provided by NRT, and other smoking cessation medications, alone. It is feasible that exercise could address psychosocial and physical needs that are not currently met by NRT-based programmes.

Exercise programmes

For those beginning exercise either on or after the quit date (Ciccolo 2011; Hill 1985; Maddison 2014; Martin 1997; Russell 1988) success rates may have been hampered by the demand to cope simultaneously with two major changes in health behaviour (Emmons 1994; King 1996; Patten 2001). 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 (Taylor 2007b). In practice, when the exercise programme begins may depend on individual capabilities and preferences (Everson-Hock 2010b).

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. Most of the trials employed supervised, group-based exercise supplemented by a home-based programme. Where home programmes were not provided (Bock 2012; Ciccolo 2011; Marcus 1991; Marcus 1995; Marcus 1999) it is possible that the participants' high level of dependence on supervised exercise reduced their level of post-intervention activity. An excluded study compared facility and home-based exercise and found no group differences in smoking abstinence at 12 months (Kinnunen 2013).

Those adequately powered trials not showing a consistent effect of exercise on smoking abstinence (Bize 2010; Maddison 2014; Marcus 2005; McKay 2008; Ussher 2003) had interventions of a low intensity, in that they promoted moderate intensity rather than vigorous intensity exercise. In one case they relied solely on fairly brief exercise counselling (Ussher 2003), another focused on telephone-based counselling (Maddison 2014), in two other studies supervised exercise was only provided once per week (Bize 2010; Marcus 2005), and the remaining study relied on a web-based programme (McKay 2008). In these studies the exercise intervention may have been insufficiently intense to benefit smoking abstinence. Further studies are required to establish the optimum intensity of exercise intervention required as an aid to smoking cessation. Intensity here refers to both the exercise intensity per se (i.e. light, moderate or vigorous) and the extensiveness of the support being provided (e.g. number of supervised exercise sessions). The findings from Marcus 2005 suggest that abstaining smokers may need to accumulate at least 110 minutes of activity per 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 recent pilot study showed promising findings for an intervention involving moderate intensity exercise supervised on three days a week over eight weeks (Williams 2010) and this needs to be tested in a larger trial.

Only three of the studies provided any post-intervention exercise programming (Hill 1993; Maddison 2014; Ussher 2003), and this may have reduced post-intervention exercise adherence (King 1989). However, it is not possible to draw any conclusions about whether various aspects of the intervention affected levels of exercise adherence after the formal supervised programme ended because none of the studies reported rates of adherence for this period.

Ciccolo 2011 promoted resistance exercise, Whiteley 2012 covered both aerobic and resistance exercise, and yoga classes were provided by Bock 2012. The remaining studies focused on cardiovascular-type exercise. More studies are required 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).

Exercise adherence issues

During the treatment period a range of cognitive-behavioural methods were employed to improve adherence to the exercise programme. All but seven of the studies used group-based exercise (Ciccolo 2011; Horn 2011; Kinnunen 2008; Maddison 2014; McKay 2008; Ussher 2003; Whiteley 2012). Only five studies did not provide full supervision of facility-based exercise (Horn 2011; Kinnunen 2008; Maddison 2014; McKay 2008; Ussher 2003). All the studies included goal setting, nine used self-monitoring (Abrantes 2014; Horn 2011; Hill 1985; Kinnunen 2008; Maddison 2014; Martin 1997; Russell 1988; Taylor 1988; Whiteley 2012), one used reinforcement (Martin 1997), Hill 1993 used telephone follow-up in the case of non-attendance, Taylor 1988 used remote monitoring of heart rate, and two studies provided pedometers (Horn 2011; Maddison 2014). Two trials employed exercise counselling, including a broad range of cognitive-behavioural techniques (Maddison 2014; Ussher 2003).

Four studies did not report overall activity levels for the treatment group during the treatment period (Bock 2012; Ciccolo 2011; Hill 1993; McKay 2008). Where supervised exercise was offered, attendance at these sessions was high. Where the emphasis was on home-based exercise (Bize 2010; Horn 2011; Maddison 2014; Marcus 2005; McKay 2008; Ussher 2003) only a minority of the participants achieved the criterion level of exercise. For example, in one study combining home-based exercise with one supervised session of exercise per week, 50% of those in the exercise group were still classed as sedentary at the end of treatment (Bize 2010). One study reported greater attrition for the exercise group compared with the controls (Marcus 1999 - see Borrelli 2002). Two studies reported lower attendance for the exercise intervention compared with the health education programme (Kinnunen 2008; Whiteley 2012). The one internet-based trial observed very similar levels of physical activity for the two groups at the six-month follow-up (McKay 2008). Future studies need to consider other methods for increasing 'home-based' physical activity. For example, pedometers have been used to increase participation in a walking-based intervention during smoking cessation (Prochaska 2008). However, when using a pedometer and counselling-based intervention Horn 2011 observed no effect on physical activity levels in teens, while Maddison 2014 used a similar intervention and found a significant increase in leisure time physical activity for the exercise group versus control group, but no effect on overall physical activity.

Fitness measures

Although many of the studies reported fitness measures for the control group during the treatment period (Abrantes 2014; Ciccolo 2011; Hill 1985; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Prapavessis 2007; Russell 1988; Taylor 1988; Whiteley 2012), less than half of them reported physical activity (PA) levels for the control group at this time (Abrantes 2014; Bize 2010; Hill 1985; Horn 2011; Kinnunen 2008; Maddison 2014; Ussher 2003; Whiteley 2012). Therefore, in the majority of the studies the relative increase in PA in the treatment group versus any spontaneous increase in activity in the control group could not be accurately monitored. During the follow-up period none of the studies described using cognitive-behavioural techniques to encourage regular exercise, although Maddison 2014 offered physical activity consultations up until the end of a six month intervention. Only three of the studies assessed fitness during the follow-up period (Ciccolo 2011; Prapavessis 2007; Russell 1988) and only two studies reported levels of activity at 12-month follow-up (Bize 2010; Ussher 2003). Therefore, for the vast majority of studies it was not possible to relate long-term smoking abstinence to exercise behaviour.

Fitness measures are useful as a confirmation of exercise adherence. However, the significance of changes in fitness in the context of smoking cessation is debatable. Since exercise has been shown to benefit psychological and general health without increases in fitness (Pate 1995; Taylor 2008) it is possible that exercise could aid smoking cessation independently of changes in physical capacity. A number of the trials reported a significant increase in fitness levels at the end of the treatment period within the active exercise condition (Marcus 1991; Marcus 1995; Marcus 1999 (see also Albrecht 1998); Marcus 2005; Prapavessis 2007). Four studies showed an increase in fitness for the intervention conditions compared with the controls at end of treatment (Marcus 1999; Prapavessis 2007; Taylor 1988; Whiteley 2012); others showed no differences at end of treatment (Abrantes 2014; Kinnunen 2008), at a four-month follow-up (Russell 1988), or a 12-month follow-up (Prapavessis 2007).

Psychological measures

The majority of the studies used psychological measures at baseline and eleven trials reported changes in these measures (Abrantes 2014; Bock 2012; Kinnunen 2008; Maddison 2014; Marcus 1999; Marcus 2005; Martin 1997; Prapavessis 2007; Russell 1988; Ussher 2003; Whiteley 2012). Russell 1988 found a significant increase in Profile of Mood States (POMs) tension-anxiety scores for the active group compared with the controls at four months follow-up. These findings are not consistent with the general consensus that exercise reduces mood disturbance, stress, and anxiety (Stathopoulou 2006; Taylor 2000; Taylor 2008). The reported effect on psychological outcomes may have been caused by extraneous variables which could not be controlled for with a small sample size. Martin 1997 found no significant treatment differences on mood (POMs) or depression (Beck Depression Inventory) when comparing measures taken at baseline and seven days post-quit; these findings may have been influenced by the sample including a large number of individuals with a history of major depression. Prapavessis 2007 showed that reports of self efficacy for stopping smoking were higher in a cognitive-behavioural support condition compared with an exercise-only condition. Marcus 1999 did not find a significant change in reports of tobacco withdrawal symptoms and cigarette cravings for exercise versus controls across the treatment period. Kinnunen 2008 did not find any difference in reports of withdrawal symptoms for the exercise group versus the controls at one week post-cessation. Bize 2010 found no significant differences in reports of withdrawal symptoms, depression, urges to smoke, or perceived stress for the exercise group versus the control group. Marcus 2005 observed that, among 40 women who were abstinent at the end of treatment, those who increased their fitness were more likely to report decreases in depressive symptoms (see Williams 2008). Ussher 2003 observed a reduction in some withdrawal symptoms for exercise versus controls up to three weeks post-cessation. Bock 2012 observed no effects of a yoga intervention on anxiety, depression, or temptations to smoke. Maddison 2014 found no group differences in tobacco withdrawal symptoms. Abrantes 2014 reported significantly lower

somatic withdrawal symptoms and sleep disturbance for the exercise versus control group; there were no group differences for craving, mood disturbance, or positive affect. Abrantes 2014 was the only study which examined the effect of exercise on sleep disturbance, and this may be a worthwhile objective. For example, Grove 2006 observed that, compared with controls, regular participation in exercise, during the period of tobacco withdrawal, did not affect the ability to stay asleep but exercisers reported significantly less difficulty falling asleep. It would also be valuable if affective changes after exercise were assessed among different subgroups of smokers. For example, one study observed that, among women smokers with increased concern about weight gain, engagement in exercise was associated with less of an increase in negative affect following smoking cessation (Schneider 2007).

Acute effect of exercise on tobacco withdrawal and cravings

Appendix 1 presents a summary of 41 studies we identified which have assessed the acute effects of exercise on smoking outcomes. Since the previous version of this review a further 14 studies have been added. Three studies focused on outcomes related to smoking intake (Kurti 2014; Mikhail 1983; Reeser 1983). The remaining 38 studies included outcomes related to tobacco withdrawal/mood and/or tobacco cravings. Six studies assessed outcomes during an attempt to quit smoking (Abrantes 2014; Arbour-Nicitopoulos 2011; Bock 1999; Harper 2012; Harper 2013; Williams 2011). Of these studies, compared with a passive control group, two reported a significant reduction in mood related withdrawal symptoms and cigarette cravings (Abrantes 2014; Bock 1999), and one showed that exercise increased energy and reduced tiredness but had no effect on cravings (Williams 2011). In addition, two single-group studies observed a significant post-exercise reduction in withdrawal and cravings (Harper 2012; Harper 2013). Just one of the studies involving a quit attempt found no effect of exercise on cravings or withdrawal symptoms and this was among those with serious mental illness (Arbour-Nicitopoulos 2011). We found 32 studies that examined the acute effects of exercise on withdrawal symptoms and/or cravings among temporarily abstinent smokers and all but six of these studies (Daley 2004; Daniel 2007; Everson 2006; Faulkner 2010; Oh 2014; Pomerleau 1987) observed a significant reduction in cravings and/or withdrawal symptoms compared with a passive control. One of these studies, for the first time, demonstrated a reduction in cravings, for an exercise versus passive group, among pregnant smokers (Prapavessis 2014). Previous reviews of 14 or 15 studies (Haasova 2013; Roberts 2012; Taylor 2007b) provide a more detailed discussion but this section highlights some findings from more recent studies which have shown an acute benefit of exercise during temporary smoking abstinence. These studies showed that, compared with a passive condition, after periods of up to 24 hours without smoking, smokers have lower cravings, withdrawal symptoms and negative affect during and for up to 30 minutes post-exercise. The effects are evident for moderate and vigorous intensity exercise, for Hatha Yoga, and for durations from five minutes of seated isometric exercise to 20 to 30 minutes of cardiovascular activity. Encouragingly, findings suggest relatively convenient forms of physical activity (e.g. 10 to 15 minutes of brisk walking) can be effective.

Haasova 2013 and Roberts 2012 have quantified the effects of a single bout of exercise on reducing strength of desire to smoke using 15 studies; the pooled estimates for treatment effect (non-standardised mean difference) were -1.91 and -2.41, respectively, with a high degree of between-study heterogeneity. There has been a tendency for studies with shorter bouts of exercise to show a less sustained effect on reducing cravings and withdrawal and further research is needed to understand how the dose of exercise impacts on the duration of acute effects. However, even brief bouts of exercise, with a brief effect, may be useful to cope with a temporary spike in cravings.

Several mechanisms have been tested among these studies for how exercise reduces cravings. Distraction (Daniel 2006) does not appear to explain the effects. Exercise expectancy was modestly associated with psychological symptoms, but not with cigarette cravings, in one study (Harper 2013) and did not explain any of the effects in another study (Daniel 2007). In two studies changes in cortisol concentration were unrelated to changes in cravings (Janse Van Rensburg 2013; Scerbo 2010). This suggests that cortisol changes do not mediate the effects of exercise on cravings. Taylor 2006a reported that reductions in urges to smoke in response to exercise were mediated by reductions in tension. Three studies involving functional Magnetic Resonance Imagery (fMRI) scanning suggested that parts of the brain that are typically activated by smoking cues (images) were less activated following moderate intensity exercise (Janse van Rensburg 2009b; Janse van Rensburg 2010; Janse Van Rensburg 2012). Finally, two studies (Janse van Rensburg 2009a; Oh 2014) reported that after exercise, compared with rest, abstinent smokers had less attentional bias (gaze or dwell time, measured using eye-tracker technology) towards smoking images, compared with neutral images presented simultaneously. Shifts in attentional bias away from smoking-related cues, after exercise, are in line with other studies in which participants report improvements in concentration (as a withdrawal symptom) after exercise (e.g. Daniel 2006; Ussher 2001; Ussher 2006). Further work is needed to understand how different types of exercise (e.g. isometric, resistance, cardiovascular) influence symptoms known to cause relapse among actual quitters, and among those using pharmaceutical aids to cessation, in which case symptoms may be lower at the outset. In addition to studies focusing on self-reported cravings, seven studies (Faulkner 2010; Katomeri 2007; Kurti 2014; Mikhail 1983; Reeser 1983; Taylor 2007a; Thayer 1993;) reported that a bout of exercise delayed ad libitum smoking, or favourably influenced smoking topography, although three other studies observed no significant effect on ad libitum smoking or smoking topography (De Jesus 2014; Fong 2014; Schneider

2014). Overall, given this experimental evidence further research is needed to understand how best to promote the use of acute bouts of physical activity, in contrast to longer scheduled bouts of exercise, as a momentary aid to smoking cessation.

Effects of exercise interventions on smoking reduction

In this update of the review, for the first time, we include a review of studies that assessed the effect of a PA intervention on levels of cigarette consumption. This is the first review we are aware of on this topic. This issue is important as many smokers say that they wish to reduce cigarette consumption before quitting, reduction for those who want to quit has been shown to be as effective for smoking cessation as abrupt approaches (Lindson 2010), and reduction approaches are recommended in national guidelines (NICE 2013). The NICE 2013 review that informed the guidelines did not explicitly search for 'exercise' studies that may have aided reduction, and none were reported. This section of the review includes any studies, irrespective of study design, which report the effects of a PA intervention on rates of cigarette consumption. The ultimate aim of the majority of these studies was quitting; therefore, we also report outcomes for attempts to quit and for smoking abstinence and state whether these were primary or secondary outcomes. A table of studies assessing the effect of physical activity on levels of cigarette consumption is presented in Appendix 2. Our searches identified 14 studies and five of these are also included in the main review of smoking cessation studies (Hill 1985; Taylor 1988; Horn 2011 (smoking reduction reported in Horn 2013); Prapavessis 2007; Maddison 2014). Two studies were published in the 1980s and the remainder were reported since 2007.

In the majority of studies smoking cessation was defined as the primary outcome and smoking reduction as a secondary outcome (Hill 1985; Horn 2013; Maddison 2014; Prapavessis 2007; Taylor 1988; Taylor 2014; Ussher 2012; Whiteley 2007; Ybarra 2013). Two studies defined smoking reduction as the sole primary outcome (Bernard 2013b; Leelarungrayub 2010). Changes in PA levels were primary and smoking levels were secondary in one study (Kovelis 2012). McClure 2011 defined mental and physical well-being as the main outcome and cigarette consumption as secondary. Finally, one study identified both smoking abstinence and cigarette consumption as primary outcomes (Gorini 2012).

All ten studies with smoking cessation as an outcome provided a smoking cessation intervention; in addition, McClure 2011 provided a smoking cessation intervention but did not assess rates of smoking abstinence. In most of these cessation studies the participants wished to quit smoking immediately and smoking reduction was measured 'incidentally' without a specific goal to reduce. In one study the participants wished to reduce but not quit immediately; PA was used to assist reduction and inducing quit attempts was a research goal but this was not an explicit goal for the participants (Taylor 2014). In one case participants were seriously thinking about quitting in the next 30 days and exercise was used to prepare for and aid a quit attempt (Ybarra 2013). McClure 2011 reported that 71% of participants were in the preparation or contemplation stage of change for quitting smoking, and the level of intention to quit was not stated in one study (Taylor 1988). Among the three non-smoking cessation studies, in one study participants' intention to quit was not stated and the aim was solely to reduce smoking levels as a harm reduction strategy among individuals with schizophrenia (Bernard 2013b) and in the studies by Leelarungrayub 2010 and Kovelis 2012 intention to quit was not reported, nor were participants advised to reduce their smoking (i.e. smoking reduction was assessed incidentally following a PA programme). Only one study encouraged specific strategies for smoking reduction, and in this case four strategies (hierarchical reduction, smoke free periods, scheduled reduction, planned reduction) were offered to smokers (Taylor 2014).

Twelve of the 14 studies were RCTs and the remaining two had a single group within-subjects design (Bernard 2013b; Whiteley 2007). Seven had a sample of less than 60 participants (Bernard 2013b; Hill 1985; Horn 2013; Kovelis 2012; McClure 2011; Taylor 1988; Whiteley 2007). No studies reported power calculations related to examining the effect on smoking reduction, and among the smoking cessation studies only three had large enough samples to have a realistic chance of detecting an effect on smoking cessation (Gorini 2012; Maddison 2014; Ussher 2012). Five studies were identified as pilot or feasibility studies (Bernard 2013b; McClure 2011; Taylor 2014; Whiteley 2007; Ybarra 2013).

The large majority of studies were based in North America. Four studies targeted more sedentary smokers (Maddison 2014; McClure 2011; Prapavessis 2007; Whiteley 2007), and all but two studies (Taylor 1988; Horn 2013) reported that participants were smoking a mean or median of at least 10 cigarettes a day at baseline. Most studies targeted smokers in general, while five targeted the following specific populations: post-acute myocardial infarction (Taylor 1988); diagnosis of depression (McClure 2011); diagnosis of schizophrenia/schizoaffective disorder (Bernard 2013b); teenagers (Horn 2013); and pregnant smokers (Ussher 2012). Males and females were recruited in most studies, one trial only included men (Taylor 1988), and four were women only trials (Gorini 2012; Prapavessis 2007; Ussher 2012; Whiteley 2007). Half the studies provided supervised exercise (i.e. under the guidance of an instructor) (Bernard 2013b; Hill 1985; Leelarungrayub 2010;Prapavessis 2007; Taylor 1988; Whiteley 2007; Ussher 2012), four provided only PA counselling (Gorini 2012; Horn 2013; Maddison 2014; Taylor 2014), two provided just a pedometer-based programme (Kovelis 2012; McClure 2011), and one was based solely on a text message-based PA programme (Ybarra 2013). All the studies focused on cardiovascular type exercise (e.g. brisk walking). Four of the studies did not report levels of adherence to the PA intervention (Bernard 2013b; Hill 1985; Leelarungrayub 2010; Ybarra 2013). In the studies reporting PA adherence, three

observed no significant difference in PA levels for the PA versus control group (Gorini 2012; Horn 2013; McClure 2011). Some studies included a multi-component intervention targeting behaviours other than smoking and PA (McClure 2011; Ybarra 2013). Only three studies reinforced PA as a method for reducing cigarette consumption or increasing cessation (e.g. through promoting exercise as a means for coping with cigarette cravings, withdrawal symptoms, and weight gain) (Bernard 2013b; Taylor 2014; Ussher 2012).

Of the 14 studies identified, just one reported a significant smoking reduction for the PA versus control group, at 16 weeks post-baseline (Taylor 2014). Two further studies observed significantly lower absolute levels of smoking for a PA 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 study reported a significant smoking reduction in the PA group but not in the control group (group differences were not analysed) (Leelarungrayub 2010), two studies with a single PA group reported a significant smoking reduction (Bernard 2013b; Whiteley 2007), one trial reported significantly lower smoking levels for a cessation programme versus a PA programme (Prapavessis 2007), and one study did not report the group effect but observed that those with higher rates of PA adherence were more likely to reduce their cigarette consumption (Horn 2013).

Among the remaining five studies, all not reporting any significant smoking reductions, there were notable methodological challenges which hampered their chances of detecting any effects: two had samples of less than 60 participants (Hill 1985; McClure 2011); two had PA interventions may have been insufficiently intense to significantly raise PA levels (Gorini 2012; Ybarra 2013) (brief PA counselling alone, text message support alone, respectively); and one targeted pregnant smokers at around 16 weeks gestation, the majority of which had already markedly reduced their smoking levels relative to before their pregnancy (Ussher 2012). All these five studies that did not report a significant effect did report a trend such that the smoking reduction tended to be higher for the PA group versus the control group.

In conclusion, we observed that only one of 14 studies observed a significant smoking reduction for the PA versus control group (Taylor 2014). Notably, this study also reported that, compared with the control group, a significantly greater proportion of those in the PA group made a quit attempt. The remaining studies either did not report reduction levels for a PA versus control group or had methodological challenges which limited their chances of detecting a significant difference. Taylor 2014 was by far the most rigorous study as it was an RCT, with a sufficiently large sample size to have a realistic chance of detecting a significant effect on short-term reduction outcomes, recruiting men and women who wished to reduce but not quit in the next month. Reduction strategies were incorporated, exercise was promoted as a reduction strategy, the intervention was sufficient to result in a significant increase in PA levels for the PA versus control group, follow-up support was offered and, as well as smoking reduction, quit attempts and smoking cessation were assessed. However, this was a feasibility study which only followed-up participants to 16 weeks post-baseline. Larger trials with methods comparable to those used by Taylor 2014 are needed with a follow-up of at least six months.

Overall commentary

A comparison of the studies was complicated by differences in study design and intervention, and by the relative paucity of rigorous research in this field. There were marked variations between the studies in the length, type, and timing of the exercise intervention, in the design of the control condition and cessation programme, and in the demographic factors recorded. In addition, there was often a lack of data relating to the physical activity levels of the control groups, and of either group during the follow-up period. Together, these factors restricted meaningful comparison of results between studies. The findings presented in this review have implications for future research in this field. One of the first requirements for future work must be to have trials with larger sample sizes.

It is possible that a greater integration between the smoking cessation and exercise programmes may have enhanced abstinence rates (Taylor 2010). In future research exercise could be presented more as a self-control strategy as well as as a means of increasing fitness and general health and of managing body weight (Marlatt 1985). For example, in initiating abstinence, exercise could be presented as a strategy for managing withdrawal symptoms and overcoming physical dependency (Taylor 2007b). The evidence we have reviewed consistently demonstrates the benefits of an acute bout of exercise on 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 (Verkooijen 2008) in such a way that being a smoker is incompatible with these perceptions (Fox 1998). Critically, it is likely that exercise needs to be maintained for it to continue to aid smoking cessation. An ongoing trial is assessing the effectiveness of a home and community-based lifestyle exercise maintenance intervention in assisting women to *maintain* exercise following the termination of an exercise aided smoking cessation program, and hence reduce smoking relapse (Fitzgeorge 2011; Jung 2010).

At what point should the smoker who is trying to quit begin an exercise programme? In the studies reviewed, there was wide variation in the timing of the exercise programme. Some recommendations for changes in exercise and smoking behaviour are for sequential rather than simultaneous changes but this is likely to be

specific to the individual's needs (Emmons 1994; Everson 2008b; King 1996; McEwen 2006). Another study showed a tendency for higher quit rates among those increasing exercise simultaneously rather than sequentially (Hyman 2007). It has been argued that a physical activity programme should begin prior to quitting, thereby allowing individuals to adjust to the demands of being more active before significantly changing their smoking behaviour (Marcus 1995). Elsewhere, it has been shown that abstaining smokers are more confident about adopting exercise than those preparing to quit (King 1996), which would support beginning an exercise programme when already abstinent, although delaying the start of the programme reduces the potential for managing withdrawal symptoms (Taylor 2007b). A quasi-experimental study has reported higher adherence rates for smokers who undergo an exercise regimen commencing eight weeks before the quit day compared with those starting exercise on the quit day (Patten 2001). Further empirical work is required in order to ascertain the relative benefits of initiating exercise at different points in the cessation schedule. All of the 20 studies in the main review only included smokers who wished to attempt to quit smoking and to do so 'abruptly'; a recent feasibility study has shown the potential for exercise being used to increase quit attempts, through first gradually reducing their smoking intake, among those who are not motivated to initiate such an attempt (Taylor 2014) and further studies are needed in this area (see above section 'Effect of exercise interventions on smoking reduction'). Certainly, the majority of the studies we have reviewed did not demonstrate a significant smoking reduction among individuals in a physical activity treatment arm.

Only one study with balanced contact time showed a long-term effect of exercise on smoking cessation (Marcus 1999). This study combined a vigorous intensity, thrice weekly supervised exercise programme with cognitive-behavioural support. It has yet to be determined whether a less intensive exercise intervention can aid smoking cessation. Additionally, among teenagers, Horn 2011 reported significantly higher abstinence rates at six-month follow-up for a combined exercise and smoking cessation programme compared with brief smoking cessation advice. Further studies are needed to investigate the role of exercise for smoking cessation amongst young smokers. Finally, there is no evidence of harm in promoting physical activity to smokers. That is, no studies report reduced smoking cessation rates in an exercise group compared with control conditions and exercise has many benefits as a harm reduction strategy for smokers (deRuiter 2006).

AUTHORS' CONCLUSIONS

Implications for practice

Only two of the 20 trials reviewed offered evidence for exercise aiding smoking cessation in the long term. The trials which did not show a significant effect of exercise on smoking abstinence were either too small to reliably exclude an effect of the intervention, had numerous methodological limitations, or included an intervention which may not have been intense enough to produce the required changes in exercise levels. There is insufficient evidence to recommend exercise as a specific aid to smoking cessation. There is strong evidence to recommend exercise as an aid for reducing tobacco withdrawal and cravings, and further research is needed to understand how best to integrate this advice into current smoking cessation programmes. There is insufficient evidence to recommend exercise interventions for reducing smoking consumption or for increasing the numbers of smokers who make quit attempts.

Implications for research

Further trials are needed with larger sample sizes, sufficiently intense exercise interventions, equal contact control conditions, and measures of exercise adherence across the sample. Further work is needed to unravel the relationship between different intensities and timings of exercise intervention, and different types of exercise, and the effect on smoking abstinence and on underlying processes such as tobacco withdrawal and cravings, particularly during actual quit attempts. Trials are needed to assess the impact of exercise programmes on attempts to quit and on smoking reduction among those who do not wish to quit immediately.

ACKNOWLEDGEMENTS

We would like to acknowledge Robert West and Andrew McEwen who contributed to earlier versions of this review.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

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

Abrantes 2014

Methods	Country: USA Randomization: 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 min 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) (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 < 10ppm. Where CO not available, significant other reports were used for one participant at the 6-month follow-up and one participant at the 12-month follow-up Follow-up: end of treatment, 6 months, 12 months
Notes	Contact time balanced between (a) and (b). Acute outcomes reported in Abrantes 2013 conference abstract used in Appendix 1

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer generated
Allocation concealment (selection bias)	Unclear risk	No information
Incomplete outcome data (attrition bias) All outcomes	Low risk	ITT analysis. Number of missing self-reports counted as smoking is not stated

Bize 2010

Methods	Country: Switzerland Randomized: 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

Bize 2010 (*Continued*)

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 per week CP (including NRT prescription) + Health Education for equal time as exercise intervention (not exercise) Exercise started one week before quit date
Outcomes	Continuous abstinence Validation: CO <10ppm Follow-up: 5 weeks, 5 mths & 47 weeks after quit date
Notes	Contact time balanced between a and b First included as Cornuz 2007

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Remotely and randomly generated by a computer', block size 50
Allocation concealment (selection bias)	Low risk	'Concealment of allocation was secured by means of sealed envelopes.' Not stated whether those delivering the intervention were aware of the possible treatment allocations
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	62 post randomization exclusions: 11 I & 2 C did not attend first group session, 1 C pregnant, 20 I & 28C regular exercisers, or marijuana users. 45% I & 38% C lost to f-up at one year, included as smokers in analysis

Bock 2012

Methods	Country: USA Randomization: Computer generated
Participants	55 women, mean age 46, mean CPD 16, FTQ score 5.0, < 3 days of moderate-intensity PA and < 2 days of vigorous intensity PA per week, not currently practicing yoga
Interventions	(a) Intervention: Group-based yoga program for 60 minutes, including 45 minutes of physical exercise (twice a week for 8 weeks) + group-based CP (once a week for 8 weeks) (b) Control: Wellness programme (twice a week for 8 weeks) + CP as (a) Interventions began before quit date.

Bock 2012 (*Continued*)

Outcomes	Continuous abstinence Validation: Saliva cotinine <57 nmol/L Follow-up: end of treatment, 3 months, 6 months	
Notes	Contact time balanced between (a) and (b)	
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer generated
Allocation concealment (selection bias)	Unclear risk	No information
Incomplete outcome data (attrition bias) All outcomes	Low risk	ITT analysis Number of missing self-reports counted as smoking is not stated.

Ciccolo 2011

Methods	Country: USA Randomization: computer generated list of numbers	
Participants	26, mean age 37 (36.5), mean CPD 18, exercise < 60 min/week	
Interventions	(a) Resistance training with equipment: alone, facility, 60 min, 2 times/week for 12 weeks, 10 exercises, 65-75% est max, 10 reps, weeks 1-3: 1 set, weeks 4-2: 2 sets, + CP (single 1-20 min counselling + nicotine patches, received prior to randomization). (b) CP as (a) + health education video, 25mins, 2 times/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 <10ppm Follow-up: 3, 6 months	
Notes	Number of contacts balanced between a and b but contact time was not Following four 30 min pre-randomization sessions (orientation, consent and baseline questionnaires), over a 2 week run-in period, 147 were excluded	
Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Randomly generated by a computer

Ciccolo 2011 (*Continued*)

Allocation concealment (selection bias)	Unclear risk	No detail given
Incomplete outcome data (attrition bias) All outcomes	Low risk	1 post randomization exclusion: developed lung cancer. 8% I & 15% C lost to f-up at 3 mth, 38% I & 54% C lost to f-up at 6 mth; all included as smokers in analysis

Hill 1985

Methods	Country: Canada Randomized
Participants	26 women, 10 men, mean age 40, mean CPD 32
Interventions	(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
Outcomes	7 day PP abstinence Validation: CO Follow-up: 1, 3 ,6 months
Notes	Contact time not balanced. Cigarette reduction reported in Appendix 2

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Method not stated
Allocation concealment (selection bias)	Low risk	No details given
Incomplete outcome data (attrition bias) All outcomes	Low risk	One participant not attending follow-ups was counted as a smoker

Hill 1993

Methods	Country: USA Recruitment: community volunteers, smoking at least 30 yrs, not currently walking for exercise Randomization: in blocks of 8 to 12, method not described
Participants	43 women, 39 men, mean age 59, mean CPD 28, irregular walkers. (excludes 4 treatment drop-outs and 8 non-attenders)

Hill 1993 (*Continued*)

Interventions	(a) Intervention 1: Walk: group/individual, facility/ home, 15-35 min, 60-70% HR reserve, 1-3 times/week for 12 weeks (b) Intervention 2: as (a) + CP 1-4 times/week for 12 weeks (c) Intervention 3: CP as (b) + nicotine gum. (d) Control: , CP alone Exercise began before quit date
Outcomes	5-day PP abstinence, Validation: CO <10ppm Follow-up: 1, 4, 9 months
Notes	(b) compared to (d) for effect of exercise programme

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Method not stated
Allocation concealment (selection bias)	Low risk	No details given
Incomplete outcome data (attrition bias) All outcomes	Low risk	Four individuals dropped out and were excluded from the analysis. The main findings were the same with or without the four dropouts

Horn 2011

Methods	Country: USA Randomization: Computer generated
Participants	233 participants, 54% female, mean age 17, mean CPD 11, mean days with 30 minutes of PA in past 7 days at baseline: 3
Interventions	(a) Intervention: Group-based PA counselling and pedometer + group-based CP (both once a week for 10 weeks) plus one 10-15-min brief smoking cessation advice session at baseline (b) Control: CP plus brief advice as (a). (c) Brief advice only as (a) Exercise began before quit date.
Outcomes	At 3 months: 7 day PPA, validated with carbon monoxide < 9ppm At 6 months: Self-classified PP, not validated
Notes	Contact time not balanced between (a) and (b) or (c). In forest plot (a) compared with (b). Reduction outcomes reported in Horn 2013, in Appendix 2

Horn 2011 (*Continued*)

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer generated
Allocation concealment (selection bias)	Unclear risk	No details given
Incomplete outcome data (attrition bias) All outcomes	Low risk	ITT 63% follow-up at 6 months

Kinnunen 2008

Methods	Country: USA Randomization: Method not stated
Participants	182 women, mean age 39, mean CPD 19, exercise < 3 times a week
Interventions	(a) Intervention 1: CV equipment, individual, facility, 40 min, 60-80% HR max (twice a week for 5 weeks, then once per week for 14 weeks) + CP (once a week for 19 weeks) + nicotine gum (b) Intervention 2: CP and nicotine gum as (a) + health education for same number of sessions as for exercise in (a) (c) Control: CP and nicotine gum as (a)
Outcomes	Prolonged abstinence Validation: CO, cotinine Follow-up: 1 week, 1, 4, 12 months
Notes	Contact time balanced between (a) and (b). (b) used as control condition in forest plot. 2/34 quit in control (c)

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Randomized 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 randomized into the exercise intervention than into the equal contact condition.

Kinnunen 2008 (*Continued*)

Allocation concealment (selection bias)	Unclear risk	No details reported. No evidence of important differences in baseline characteristics between groups
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not an intention to treat analysis as 263 women were randomized, 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

Maddison 2014

Methods	Country: New Zealand Randomization: Computer generated
Participants	906 participants, 54% female, mean age 38, mean CPD 20, FTCD score 7, < 150 min of MVPA per week
Interventions	(a) Intervention: PA counselling, one face-to-face and 9 telephoned-based sessions over 6 months) + telephoned-based CP for 3 months (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). Reduction outcomes reported in Appendix 2

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer generated
Allocation concealment (selection bias)	Low risk	Concealment of allocation was ensured by means of a central computerized service up to the point of randomization Study researchers conducting assessments were not blinded to treatment allocation
Incomplete outcome data (attrition bias) All outcomes	Low risk	ITT analysis Follow-up rate lower in intervention group (89%) than in control group (96%)

Marcus 1991

Methods	Country: USA Randomization: method not stated
Participants	20 women, mean age 39, mean CPD 28, exercise < once a week.
Interventions	(a) CV equipment: group, facility 30-45 min, 70-85% HR max, 3 times/week for 15 weeks + CP (twice a week for 4 weeks). (b) CP only (twice a week for 4 weeks) Exercise began before quit date
Outcomes	7-day PP abstinence Validation: saliva cotinine <10ng/ml. Follow-up: 1, 3, 12 months
Notes	Contact time not balanced

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Method not stated
Allocation concealment (selection bias)	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Low risk	One participant did not attend follow-ups and was counted as a smoker

Marcus 1995

Methods	Country: USA Randomization: method not stated
Participants	20 women, mean age 38, mean CPD 23, exercise < once a week.
Interventions	(a) CV equipment: group, facility, 30-40 min, 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 <10ng/ml. Follow-up: 1, 3, 12 months
Notes	Contact time balanced between a and b

Risk of bias

Marcus 1995 (*Continued*)

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not stated
Allocation concealment (selection bias)	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not stated

Marcus 1999

Methods	Country: USA Randomization: Computer-generated
Participants	281 women, mean age 40, mean CPD 22 exercise < twice a week.
Interventions	(a) Intervention: CV equipment: group, facility, 30-40 min, 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 < 10ng/ml, CO < 8ppm. Follow-up: 3, 12 months
Notes	Contact time balanced between (a) and (b). Acute outcomes reported in Appendix 1

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'The randomization code for group assignment was generated by a computer program'
Allocation concealment (selection bias)	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Low risk	44% (a) and 50% of (b) lost at 12 months, included as smokers

Marcus 2005

Methods	Country: USA Randomization: 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 min, 45-59% HR reserve, (facility: once/week for 8 weeks, goal: 165 min/week) + CP (once a week for 8 weeks). (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 < 10ng/ml, CO < 8ppm. Follow-up: 3, 12 months
Notes	Contact time balanced between a and b

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Group assignment was based on a randomization code generated by a computer software program and was stratified based on participant's patch usage decision'
Allocation concealment (selection bias)	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	High risk	75% (a) & 68% (b) did not attend 12-month follow-up session, included as smokers

Martin 1997

Methods	Country: USA Randomization: method not stated
Participants	92 women, 113 men, problem drinkers, mean age 42, mean CPD 27, exercise < once a week
Interventions	(a) Intervention 1: CV activity: various, group/individual, facility/home, 15-45 min, 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

Martin 1997 (*Continued*)

Outcomes	7-day PP abstinence Validation: CO < 10ppm Follow-up: 7 days, 6, 12 months
Notes	Contact time not matched, different cessation programmes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Randomized, method not stated
Allocation concealment (selection bias)	Unclear risk	No details reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Numbers lost to follow-up not reported, but all participants included in denominators

McKay 2008

Methods	Country: USA Randomization: Computer-generated online
Participants	2318, 78% > 30 years of age, 83% > 10 CPD
Interventions	(a) Web-based, multi-step program designed to encourage physical activity with a motivational component (e.g. exploring benefits and barriers) and a behavioral action plan (e.g. weekly schedules), plus access to a peer support forum (b) Web-based, multi-step program introducing users to the key concepts and strategies of a behavioral quit smoking program, including a peer support forum and 'ask the expert' tool Did not state when exercise began relative to the quit date
Outcomes	7 day point-prevalence abstinence Validation: No biochemical validation as outcomes reported online or via telephone Follow-up: 3, 6 months
Notes	Exercise condition (a) intended to be an attention placebo control condition

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	randomly generated by a computer via the Internet

McKay 2008 (*Continued*)

Allocation concealment (selection bias)	Unclear risk	No detail given
Incomplete outcome data (attrition bias) All outcomes	High risk	60.2% I & 61.3% C lost to f-up at 6 months, included as smokers in analysis

Prapavessis 2007

Methods	Country: NZ Randomization: Computer-generated
Participants	142 women, mean age 38, exercise < twice a week. (excludes 21 pretreatment drop-outs)
Interventions	(a) Intervention 1: CV activity: various, group/facility, 45 min, 60-75% HR reserve, (3 times/week for 12 weeks) + CP (three times/week for 12 weeks). (b) Intervention 2: exercise as (a) plus nicotine patches (c) Intervention 3: Cognitive behavioural cessation programme three times/week for 12 weeks. (d) Intervention 4: as (c) plus nicotine patches. Exercise began before quit date
Outcomes	Continuous abstinence, Validation: saliva cotinine < 10ng/ml, CO < 10ppm. Follow-up: 6 weeks, 3, 12 months
Notes	Contact time balanced between a, b, c and d. Cigarette reduction reported in Appendix 2

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer-generated randomization.
Allocation concealment (selection bias)	Low risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	21 pretreatment dropouts excluded. Loss to follow-up higher in (a)+(b), 40%, than in (c)&(d), 23% (p=.05). Not stated whether those lost to follow-up were counted as smokers

Russell 1988

Methods	Country: USA Randomization: method not stated
Participants	42 women, mean age 28, mean CPD 23.
Interventions	(a) Intervention 1: Walk/jog: group/individual, facility/home, 20-30min, 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)

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Not stated
Allocation concealment (selection bias)	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not stated

Taylor 1988

Methods	Country: USA Randomization: method not stated
Participants	58 men, post-acute myocardial infarction
Interventions	(a) Intervention 1: CV activity: various, group, facility, 30-40 min, 70-85% HR max, (i) [3, 23] (ii) [3, 8] + CP x 1 session; (b) Intervention 2: (i, ii) as (a) home: 20 min, x 5/wk (c) Control: Fitness test at end of treatment only (d) Intervention 3: Fitness test at baseline & end of treatment, cessation programme as (a)
Outcomes	Validation: plasma thiocyanate Follow-up: 23 weeks
Notes	Contact time not balanced. Cigarette reduction reported in Appendix 2

Taylor 1988 (*Continued*)

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Not stated
Allocation concealment (selection bias)	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not stated

Ussher 2003

Methods	Country: UK Randomization: Computer-generated
Participants	188 women, 121 men, mean age: 43, mean CPD: 22; < 5 days of 30 mins moderate intensity exercise per week
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 < 10ppm. Follow-up: 6 weeks, 12 months
Notes	Contact time balanced between (a) and (b)

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer generated
Allocation concealment (selection bias)	Unclear risk	Not specified
Incomplete outcome data (attrition bias) All outcomes	Low risk	27 participants could not be contacted at the 12 month follow-up and were counted as smokers

Whiteley 2012

Methods	Country: USA Randomization: Computer generated
Participants	330 women, mean age 44, mean CPD 17, FTND score 5.0, < 20 minutes of vigorous activity two times per week
Interventions	(a) Intervention: 12 weeks YMCA membership, four individual personal training sessions over 12 weeks (aerobic and resistance exercise) plus group-based CP (once a week for 12 weeks) (b) Control: Four 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)

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer generated
Allocation concealment (selection bias)	Unclear risk	Not specified
Incomplete outcome data (attrition bias) All outcomes	Low risk	ITT analysis 78.5% followed up at 12 months.

CO: carbon monoxide
CP: cessation programme
CPD: cigarettes per day
CV: cardiovascular
FTQ: Fagerstrom Tolerance Questionnaire
HR: heart rate
PP(A): point prevalence (abstinence)
ppm: parts per million

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

Study	Reason for exclusion
Al-Chalabi 2008	Follow-up less than six months and combined isometric exercise and body-scanning interventions; therefore it was not possible to assess the specific effects of exercise
Arbour-Nicitopoulos 2011	Acute study. See Appendix 1
Bernard 2013b	Did not assess smoking abstinence. Cigarette reduction reported in Appendix 2
Caliani 2004	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Chaney 2008	Follow up was less than six months
Cinciripini 1996	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Clark 2005	A non-exercise control group was not included
Cooke 2014	Acute study. See Appendix 1
Copeland 2006	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Daley 2004	Acute study. See Appendix 1
Daniel 2004	Acute study. See Appendix 1
Daniel 2006	Acute study. See Appendix 1
Daniel 2007	Acute study. See Appendix 1
De Jesus 2014	Acute study. See Appendix 1
Elibero 2011	Acute study. See Appendix 1
Everson 2006	Acute study. See Appendix 1
Everson 2008a	Acute study. See Appendix 1
Faulkner 2010	Acute study. See Appendix 1
Fong 2014	Acute study. See Appendix 1
Fortmann 1995	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise

(*Continued*)

Gorini 2012	Not all participants wished to quit. Cigarette reduction reported in Appendix 2
Grove 1993	The outcome was withdrawal symptoms rather than smoking abstinence
Grove 2006	Had sleep disturbance as the main outcome, rather than smoking abstinence
Haasova 2011	Acute study. See Appendix 1
Harper 2012	Acute study. See Appendix 1
Harper 2013	Acute study. See Appendix 1
Hassandra 2012	Lack of a control group
Ho 2014	Acute study. See Appendix 1
Hurt 1992	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Hurt 1994	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Hwang 2012	A non-exercise control group was not included. Also follow-up was less than 6 months
Janse van Rensburg 2008	Acute study. See Appendix 1
Janse van Rensburg 2009a	Acute study. See Appendix 1
Janse van Rensburg 2009b	Acute study. See Appendix 1
Janse van Rensburg 2010	Acute study. See Appendix 1
Janse Van Rensburg 2012	Acute study. See Appendix 1
Janse Van Rensburg 2013	Acute study. See Appendix 1
Jones 2001	Included an exercise programme in a self-help manual as part of a multiple component programme. Therefore it was not possible to examine the specific effects of exercise
Jonsdottir 2001	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
Katomeri 2007	Acute study. See Appendix 1
Kinnunen 2013	Did not include a non-exercise condition
Kovelis 2012	Did not assess smoking abstinence. Cigarette reduction reported in Appendix 2

(*Continued*)

Kurti 2014	Acute study. See Appendix 1
Leelarungrayub 2010	Did not include smoking abstinence as an outcome. Cigarette reduction reported in Appendix 2
Linke 2012	Assessment of smoking abstinence less than 6 months
Mantoani 2014	Lack of a control group
McClure 2009	Included exercise counselling as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
McClure 2011	Included exercise counselling as part of a multiple risk factor intervention. Therefore it was not possible to examine the specific effects of exercise on smoking cessation. Cigarette reduction reported in Appendix 2
McIver 2004	There was no control group
Mikhail 1983	Acute study. See Appendix 1
Nguyen 2012	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Oenema 2008	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Oh 2014	Acute study. See Appendix 1
Ortega Sanchez-Pinilla 2006	Retrospective study
Pomerleau 1987	Acute study. See Appendix 1
Prapavessis 2014	Acute study. See Appendix 1
Prochaska 2008	Included exercise counselling as part of a multiple component relapse prevention programme. Therefore it was not possible to examine the specific effects of exercise. Also, follow-up was less than six months
Ramsay 2004	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Reeser 1983	Acute study. See Appendix 1
Reid 2014	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Saltychev 2012	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise

(*Continued*)

Scerbo 2010	Acute study. See Appendix 1
Schneider 2014	Acute study. See Appendix 1
Spring 2004	Combined an exercise programme with a dietary intervention. Therefore it was not possible to examine the specific effects of exercise
Taylor 2005	Acute study. See Appendix 1
Taylor 2006a	Acute study. See Appendix 1
Taylor 2006b	Acute study. See Appendix 1
Taylor 2014	Assessment of smoking abstinence less than 6 months. Reduction outcomes reported in Appendix 2.
Thayer 1993	Acute study. See Appendix 1
Toobert 2011	Included an exercise programme as part of a multiple component smoking cessation programme. Therefore it was not possible to examine the specific effects of exercise
Treviño 2012	Lack of a non-exercise control group and not all participants wished to quit
Trigwell 2014	Non-randomised study
Ussher 2001	Acute study. See Appendix 1
Ussher 2006	Acute study. See Appendix 1
Ussher 2008	Did not include a control group
Ussher 2009	Acute study. See Appendix 1
Vander Weg 2008	Included an exercise programme as part of a multiple component programme for smoking cessation and management of weight and blood pressure. Therefore it was not possible to examine the specific effects of exercise
Vickers 2005	The follow up was less than six months
Vickers 2009	Follow-up was less than six months.
Whiteley 2007	Did not include a control group. Cigarette reduction reported in Appendix 2
Williams 2010	Follow-up was less than six months.
Williams 2011	Acute study. See Appendix 1
Ybarra 2013	Assessment of smoking abstinence less than 6 months. Cigarette reduction reported in Appendix 2

(*Continued*)

Zwick 2006	Unable to obtain details of study from authors

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

Abrantes 2014b

Trial name or title	Exercise for Depressed Smokers
Methods	RCT
Participants	250
Interventions	(a) 12-week moderate-intensity behavioral exercise intervention. Weekly sessions with an exercise physiologist who will also assign weekly exercise goals. Two 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, completion date: September 2018
Contact information	Dr Ana Abrantes, ana_abrantes@brown.edu
Notes	

Bock 2012b

Trial name or title	Efficacy of Yoga as a Complementary Therapy for Smoking Cessation (ClinicalTrials.gov Identifier: NCT01809678)
Methods	RCT
Participants	300
Interventions	(a) Smoking Cessation plus Yoga Twice weekly, 1-hour yoga classes delivered for 8 weeks combined with once-weekly, 1-hour cognitive-behavioral smoking cessation classes (b) Smoking Cessation plus Wellness Twice-weekly, 1-hour Wellness classes given on a variety of health topics twice weekly to match schedule of the yoga classes, plus 1-hour per week of cognitive-behavioral smoking cessation
Outcomes	Smoking abstinence at 1-year post treatment
Starting date	July 2012 , completion date: July 2017
Contact information	Dr Beth Bock, Bbock@lifespan.org

Bock 2012b (*Continued*)

Notes	

Ciccolo 2012

Trial name or title	Clinical trial investigating resistance training as an aid to smoking cessation in persons with multiple sclerosis
Methods	RCT
Participants	118
Interventions	Resistance Training (RT) or Contact Control (CC) group. Participants in the RT group will attend a 60-minute resistance training session twice weekly for eight weeks, while participants in the CC will attend a 30-minute health education control session twice weekly for eight weeks
Outcomes	The primary outcome will be smoking cessation, indicated by a 7-day abstinence, and verified by biochemical assay (i.e., carbon monoxide breath test) at end of treatment
Starting date	2012
Contact information	Dr Joe Ciccolo, ciccolo@tc.columbia.edu
Notes	

Ciccolo 2013

Trial name or title	Resistance Training as an Aid to Smoking Cessation Treatment (ClinicalTrials.gov Identifier: NCT01951456)
Methods	RCT
Participants	206
Interventions	Resistance training vs Contact control
Outcomes	Smoking cessation, Time Frame: Change from baseline to 3 months, Salivary cotinine-verified 7-day Point Prevalence Abstinence
Starting date	Study Start Date: 2013 Estimated Study Completion Date: 2018
Contact information	Dr Joe Ciccolo, ciccolo@tc.columbia.edu
Notes	

Jung 2010

Trial name or title	Exercise for relapse prevention during smoking cessation
Methods	RCT
Participants	440 women
Interventions	Following a 14 weeks supervised exercise programme, randomised to one of four 'home=based' conditions: (a) exercise maintenance, (b) exercise maintenance plus relapse prevention booklet, (c) relapse prevention booklets plus contact, (d) contact only
Outcomes	Primary outcome is continuous abstinence at 3 and 12 months after the initial 14 week treatment programme
Starting date	2010
Contact information	Dr Lindsay George, lfitzgeo@uwo.ca
Notes	

Oncken 2009

Trial name or title	Exercise for Smoking Cessation in Postmenopausal Women (ClinicalTrials.gov Identifier: NCT00921388)
Methods	RCT
Participants	N = 364
Interventions	All subjects receive smoking cessation counselling and varenicline, plus either (i) one 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) subjects in the control group receive a relaxation program that controls for contact time
Outcomes	Smoking abstinence at weeks 12 and 64
Starting date	start date: March 2009; Estimated Study Completion Date: May 2014
Contact information	Cheryl A Oncken
Notes	

Patten 2012

Trial name or title	Supervised, vigorous intensity exercise intervention for depressed female smokers
Methods	RCT
Participants	80
Interventions	12-week protocol, three sessions each week of exercise intervention vs wellness programme

Patten 2012 (*Continued*)

Outcomes	Smoking abstinence at end of treatment
Starting date	2012 to 2014
Contact information	Professor Christi Patten, patten.christi@mayo.edu
Notes	

Smits 2012

Trial name or title	Smoking Termination Enhancement Project (STEP) (ClinicalTrials.gov, NCT01065506)
Methods	RCT
Participants	150
Interventions	All will receive standard treatment (ST) for smoking cessation that includes cognitive behavioral therapy (CBT) and nicotine replacement therapy (NRT). In addition, participants will be randomly assigned to either an exercise intervention (ST+EX) or a health and wellness education intervention (ST+CTRL)
Outcomes	Smoking status at 24-weeks post Quit Day
Starting date	Sep 2009, completion: Aug 2013
Contact information	Dr Jasper Smits, jsmits@smu.edu
Notes	

Ussher 2012

Trial name or title	LEAP trial of exercise for smoking cessation in pregnancy
Methods	RCT
Participants	785
Interventions	Participants were randomized to 6 weekly sessions of behavioral support for smoking cessation (control) or to this support plus 14 sessions combining supervised treadmill exercise and physical activity consultations
Outcomes	The primary outcome was continuous smoking abstinence from the target quit date until end-of-pregnancy, validated by exhaled carbon monoxide or salivary cotinine
Starting date	2009, completion: 2014
Contact information	Professor Michael Ussher, mussher@sgul.ac.uk

Ussher 2012 (*Continued*)

Notes	Unpublished data for reduction outcomes used in Appendix 2

Studies in Progress

DATA AND ANALYSES

Comparison 1. Exercise component versus smoking cessation programme only

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Smoking cessation at longest follow-up	19		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Analysis 1.1. Comparison 1 Exercise component versus smoking cessation programme only, Outcome 1 Smoking cessation at longest follow-up.

Review: Exercise interventions for smoking cessation

Comparison: 1 Exercise component versus smoking cessation programme only

Outcome: 1 Smoking cessation at longest follow-up

Study or subgroup	Treatment n/N	Control n/N	Risk Ratio M-H,Fixed,95% CI	Risk Ratio M-H,Fixed,95% CI
Kinnunen 2008	9/92	7/56		0.78 [0.31, 1.98]
Hill 1993	5/18	7/22		0.87 [0.33, 2.29]
Ussher 2003	19/154	19/145		0.94 [0.52, 1.71]
Bize 2010	62/229	72/252		0.95 [0.71, 1.26]
Maddison 2014	78/455	80/451		0.97 [0.73, 1.28]
Marcus 2005	1/109	1/108		0.99 [0.06, 15.64]
Martin 1997	19/72	18/70		1.03 [0.59, 1.79]
McKay 2008	120/1159	112/1159		1.07 [0.84, 1.37]
Taylor 1988	29/42	16/26		1.12 [0.78, 1.62]
Prapavessis 2007	12/68	8/53		1.17 [0.52, 2.65]
Hill 1985	7/18	5/18		1.40 [0.54, 3.60]
Bock 2012	6/32	3/23		1.44 [0.40, 5.16]
Horn 2011	25/80	19/90		1.48 [0.88, 2.48]
Whiteley 2012	11/166	6/164		1.81 [0.69, 4.78]
Ciccolo 2011	2/13	1/12		1.85 [0.19, 17.84]

(*Continued* . . .)

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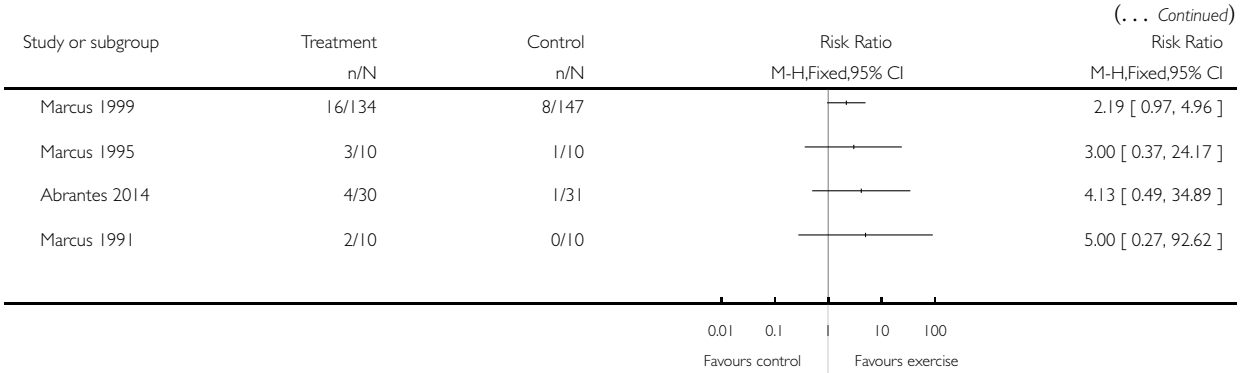

APPENDICES

Appendix 1. Studies on the acute effect of exercise

Study	Design	Subject characteristics	Exercise characteristics	Measures	Outcome
Mikhail 1983	Within subjects. 1 hr in lab post- treatment + 23 hr post-lab. Abstinence period: 30 mins	18 M, inactive, low-moderate fitness. Mean age = 26yrs. Mean time as smoker = 10 yrs. Smoked ≥1 pack/day for 3 yrs. Non-quitters	All 10 mins. (a) & (b) = + 4-5 min cool down) (a) cycle @ 104 bpm (66-69% max hr) (b) cycle @ 120 bpm (82-85% max hr) (c) passive (reading)	60 mins of surreptitious observation in lab with freedom to smoke/read. -Time to 1st puff. -Duration of 1st lit cig. & no. of puffs. -No. cigs in follow-up 60 mins + 23 hr. (adjusted for wake hrs)	(a) & (b) less time with 1st lit cig. cf. (c). (a) & (b) not different. No other sig. diffs.
Reeser 1983	Between-subjects (matched by age & sex) then randomized. Data presented from 2 lab sessions with same treatment condition. No abstinence period prescribed but	25 F & 12 M, inactive. Mean age = 24 yrs. Mean CPD = 23. Mean time as smoker = 8.4 yrs. Smoked ≥1 pack/day for 2 yrs. Non-quitters	20 mins (a) = 3 min stretch + 13 min ex. + 2 min cool-down + 2 min stretch. (a) cycle @ 140 bpm (60% max HR) (b) stretch & isometrics (c) passive	30 mins of surreptitious observation in lab with freedom to smoke/read. SAI. Time to 1st cig & no. of puffs & time lit. No. who smoked. Time to 1st cig after leaving lab.	Data averaged from 2 sessions: (b)<(c) on no. of puffs (ES=0.69). (b)>(c) on time to 1st cig (net diff = 24 mins) (ES=1.0) (a=14 min; b= 31 min; c=7 min).

(*Continued*)

	mean time = 30 mins.			(self-reported)	28% in (a & b) and 15% (in c) didn't smoke during 30 min observation
Pomerleau 1987	Within subjects. Follow-up to 20 mins post-exercise. Abstinence period: 30 mins.	10 M, inactive healthy. Mean age = 24 yrs. Mean CPD = 28	Both 30 mins cycling (a) 80% VO_2max (b) 30% VO_2max.	POMS, SWS	(a) v. (b) NS for all measures
Thayer 1993	Within subjects. Follow-up immediately post-exercise Abstinence period: 45 mins.	5 M & 11 F, Age = 18-44 years. Smoked 1-2 packs per day	5 mins of either (a) brisk walk (b) inactivity	Short AD-ACL (energy & tension), urge to smoke, time to next cig	(a) reduced Urge to smoke, increased energy & time to next cig. (17 vs. 9 mins delay)
Marcus 1999 (reported in Bock 1999)	Within (pre-post exercise/ control) subjects. During smoking cessation	Group 1= 24 F Group 2 = 44 F Both groups inactive. Mean age = 38 yrs. Mean CPD = 20	(a) 30-40 mins 60-85% HRR, aerobic activity (group 1 & 2) (b) Equal contact passive. All grps (a1, a2, & b) were involved in an 11 wk trial	PANAS, ESR, & cravings.	(a) Group 1 & 2 reduced negative affect, nicotine withdrawal and cigarette cravings, in all weeks (5-10) after quit date. No effect on positive affect
Ussher 2001	Between subjects (randomly assigned) . Assessments Pre (T1) , mid (T2), immediately post (T3), 5 (T4) & 10 mins post (T5) treatment. Abstinence period: 15 hrs	78 inactive M & F, Mean CPD = 18 . Mean age = 36 yrs. Mean FTND = 5.9. Mean baseline SoD = 6.4 (ranging from 6.1-6.6)	(a) 40-60% HRR, cycling+video; (b) video control; (c) passive control, All for 10 min + 1-2 min warm-up	MPSS, plus Tiffany 'desire to smoke' item	(a) < (b & c) for desire & SoD to smoke, irritability, restlessness, tension, depression, poor concentration, stress at T2, T3, T4 & T5 (not SoD). ES (a) v (c) for SoD to smoke = 0.54, 0.47, 0.27, & 0.14, at T2, T3, T4 & T5, respectively. Effects of exercise greater for less active
Daley 2004	Between subjects. Pre- (T1), post- (T2), 30 (T3) & 60 mins (T4) post- treatment. Abstinence period:	16 sedentary M & F. Mean CPD = 13 Mean age = 21 yrs.	a) 60-65% age predicted maximum HR cycling; (b) passive video on smoking cessation. Both for 30 min	PANAS & SWS	(b) maintained negative affect while (a) increased it. No other sig. time X group interaction. ES (a) v (b) for crav-

(*Continued*)

	c.17 hrs				ings = 0.53, 0.47 & 0.74, at T2, T3 & T4 (all non sig at P<. 05)
Daniel 2004	Between subjects (randomly assigned) . Pre- (T1), mid- (T2), 0 (T3), 5 (T4) & 10 mins (T5) post-treatment. Abstinence period; 11-15 hrs	84 inactive M & F. Mean CPD = 17 Mean age = 30 yrs. Mean FTND = 4.0. Mean baseline SoD = 4.1	(a) 40-60% HRR cycling; (b)10-20% HRR cycling; (c) passive control. (a) & (b) achieved target intensity prior to 2.5 mins (during warm-up) and maintained until 5 mins, then 2. 5 min warm down	5 MPSS items, plus desire & SoD to smoke items.	Results presented as change scores from baseline. (a) reduced cf (c) for: desire (at T2 & T3); SoD to smoke (at T3 & T4) ; irritability & restless (at T4 & T5) ; tension, (at T4). (b) reduced cf (c) poor concentration (at T3). Condition differences, (a) < (c) ES = 1.16, 0.97, 0. 58, 0.24 (at T2, T3, T4 & T5, respectively) for SoD
Taylor 2005 Taylor 2006a	Within subjects. Randomly ordered. Assessments at Pre (T1), mid (T2), immediately (T3), 10 mins (T4), 20 mins (T5) post-treatment. Abstinence period: >15 hrs	10 M & 5 F, active. Mean CPD = 17 Mean age = 26 yrs. Mean FTND = 4.0. Mean baseline SoD = 5.8	(a) Self-paced 1 mile treadmill brisk walk (means = 10.8 RPE; 25% HRR, 18 mins), (b) passive waiting. (a) also had 2 min warm-up and cool down	MPSS, desire & SoD to smoke, 2 factor 32-item QSU. FS & FAS. POMS scales	(a) < (b) desire & SoD to smoke at T2, T3, T4, & T5 and both QSU scales at T5. Reduced tension & increased FS at T5 & increased FAS at T3. For desire to smoke, ESs=3.9, 3.7, 3.7, 3. 1; & SoD ESs=3.8, 4.6, 2.8, 1.6 at T2, T3, T4 & T5, respectively
Daniel 2006	Between subjects (random assigned). Measures at pre- (mean of -10, -5 & 0 mins), during- (mean of mid and end of treatment), & post-treatment (mean of + 5 & + 10 min).	23 M & 17 F, sedentary. Mean age = 23. 4 yrs. Mean CPD = 14. Non-quitters. Mean FTND = 3.0 Mean baseline SoD = 4.0	(a) 10 mins cycle (40-60% HRR). (b) Passive (Cognitive distraction task)	SoD to smoke, MPSS, PANAS	(a) < (b) during and after treatment for desire & SoD, difficulty concentrating and stress. ES (a) v (b) for cravings = 2.0 & 1. 0 during and post treatment, for both desire and SoD to

(*Continued*)

	Mean abstinence period: 13.6 hrs				smoke. (a) < (b) during treatment for 5 other MPSS items but due to increase during cognitive distraction task rather than reduction during exercise
Everson 2006	Between subjects (stratified, by gender, randomly assigned) design. Measures at pre- (T1), mid- (T2), 5 (T3) & 30 min (T4) post-treatment. Mean abstinence period: 17.2 hrs	19 M & 18 F, less active. Mean age = 17.7 yrs. Mean CPD = 13.6 Non-quitters. Mean dependence = 7.2 (on 0-10 scale of HONC). SoD = 3.4 (estimated from original 0-5 scale)	Both 10 mins cycle (a) (RPE = 12.3, HR= 112 bpm, 55% age-predict HR max). (b) (RPE = 8.3, HR =89 bpm, 44% age-predicted HR max).	SoD to smoke, MPSS, SEES-PWB, SEES-PD, SEES-fatigue.	No differences between groups at any time point (except higher SEES-PD only during (a)(not after). ES (a) v (b) for SoD = 0.50, 0.15 & 0.47 at T2, T3 & T4 (all non sig at p<.05), with lower cravings for (a)
Ussher 2006	Between subjects (randomly assigned). Assessments at Pre (T1), immediately (T2), 5 mins (T3), 10 mins (T4) 15 mins (T5), & 20 mins (T6) post-treatment. Mean abstinence period: 17.3 hrs	27 F & 33 M. Mean CPD = 19 Mean age = 32 yrs. Mean FTND = 3.9. Mean baseline SoD = 5.2	5 mins of: (a) seated isometric exercise; (b) body scan; (c) sitting passively	SoD to smoke, & MPSS items.	(a) < (c) for SoD to smoke (at T2 & T3), ESs=0.27, 0.29, respectively), poor concentration (at T3, T4, & T5). No effects at T6. (b) < (a & c) on baseline scores which confounded results
Daniel 2007	Between subjects (randomly assigned). Measures at pre- (mean of -10, -5 & 0 mins), during- (mean of mid and end of treatment), & post-treatment (mean of + 5 & + 10 min). Mean abstinence period: 13 hrs	22 M & 23 F, sedentary. Mean age = 24 yrs. Mean CPD = 14. Non-quitters. Mean FTND = 4.1. Mean baseline SoD = 4.4	3 groups = positive, negative or neutral expectations of effects of exercise. All groups cycled10 mins cycle (40-60% HRR) (plus 1-2 min warm-up)	SoD & MPSS	All groups reduced SoD & MPSS items from pre- to during & post exercise (ES = 0.4-0.9)(except restlessness & poor concentration during exercise). No difference between groups

(*Continued*)

Katomeri 2007	Within subjects. Randomly ordered. Pre-, Mid- & post-exercise + pre- & post-smoking cue. Ad libitum smoking. Abstinence period 2 hrs.	17 M & 13 F, moderately active. Mean age = 21.9 yrs Mean CPD =13.7. Non-quitters. Mean FTND= 3.5. Mean baseline SoD = 5.2	(a) 15 mins self-paced treadmill brisk walk (means = RPE - 12.2, HRR - 37.3%). (b) passive waiting	Desire & SoD to smoke. MPSS, FS & FAS. 2 factor 10-item QSU.Time to next cig. after leaving lab. (from phone text)	(a) < (b) Both desire & SoD to smoke measures, both QSU scores & 7 MPSS items during & post-treatment (ES for desire and SoD ranged from 1.5 to 3.1; mean = 2.3). (a) > (b) for change in desire to smoke in response to lit cig. cue. (ES = 0.61). (a) < (b) for time to next cig (66 v. 31 min.)(ES = 0.85)
Taylor 2007a Taylor 2006b	Between subjects (randomly assigned). Measures at baseline, mid- & post-ex. then pre & post 3 tasks: Stroop, speech task, & handled lit cig. Ad lib. smoking Abstinence period: 2 hrs	34 F & 26 M, moderately active. Mean age = 28.5 years. Mean CPD = 15 Non-quitters. Mean FTND = 3.5. Mean baseline SoD = 4.6.	(a) 15 mins self-paced treadmill brisk walk (means = RPE =11, HRR = 24%); (b) passive waiting. (a) also had 2 min warm-up.	Desire & SoD to smoke. MPSS, Time to next cig. after leaving lab. (from phone text). SBP/DBP & HR	(a)< (b) for Desire & SoD & 7 MPSS items, at all assessments from mid-ex to post lit cig. ES for desire ranged from 1.04-1.78 with mean = 1.62. ES for SoD ranged from 1.2-2.07 with mean = 1.45. (a) attenuated responses to lit cig. cue for SoD to smoke (ES = 0.61), tension, stress, poor concentration & SBP. (a) also attenuated SBP & DBP responses to Stroop & speech tasks, and restlessness to Stroop. (a) > (b) for time to next cig (84 v 27 min) (ES=1.20)
Everson 2008a	Between subjects (random assigned). Measures at pre- (T1), mid- (T2), & 5 (T3)	25 M & 20 F. Mean age = 21.8 yrs. Mean CPD = 13.6. Non-quitters. Mean FTND = 3.4. Mean	All 10 mins. (a) Cycle (RPE = 12.5, HR=131 bpm, HRR= 50%). (b) Cycle (RPE = 14.	SoD, MPSS & SEES	(a) & (b) < (c) at T2 & T3 for SoD, and only (a) < (c) for total MPSS & SEES (positive well-

(*Continued*)

	& 30 (T4) min post-treatment. Mean abstinence period: 17 hrs	baseline SoD = 4.6. HONC = 7.6	8, HR =155 bpm, HRR=68%). (c) Passive seating.		being) at T3. (b) < (c) for composite MPSS & SEES-PD, and (b) > (c) for SEES-PWB at T3. (a) < (c) for happiness, and (a) > (c) for composite MPSS & SEES-PD at T2
Janse van Rensburg 2008	Within subjects. Randomly ordered. Pre-, Mid- (not QSU-brief) & post-exercise, + 5, 10 & 15 mins post-treatment. Abstinence period 15 hrs.	15 M & 8 F. Mean age 23.1 yrs. Mean CPD 13.7. Non-quitters. Mean FTND= 3.4. Mean baseline Desire to Smoke = 5.0	(a) 15 mins self-paced treadmill brisk walk (+ 2 mins warm-up & 1 min cool down) (means = RPE - 10.8, HR - 113). (b) passive waiting	Desire to smoke. 2 factor 10-item QSU. Other measures of cognitive functioning using Stroop colour-word task not reported here	(a) < (b) Desire to smoke at T2, T3, T4 (ES = 1.46, 1.20 and 0.93, respectively). (a) < (b) for both QSU measures at T3, T4 & T5 (ES for Factor 1 = 1.96, 2.04 and 1.39, & Factor 2 = 1.47, 1.22 and 0.98, respectively)
Janse van Rensburg 2009a	Within subjects (randomly ordered). Desire to smoke measured at baseline, mid, immediately post treatment and post eye tracking protocol. Abstinence period 15 hrs.	13 M & 3 F. Mean age 29.01 yrs. Mean CPD = 15.5 Non-quit-ters. Mean FTND = 3.9. Mean baseline Desire to Smoke =5.3 and 4.8 for control and exercise session respectively	(a) 15 min. cycling at RPE 11-13 (mean RPE = 12.7; HR = 135 bpm) b) passive waiting	Desire to smoke. Other measures of attentional bias to smoking v neutral images not reported here (using eye tracker technology)	(a) < (b) Desire to smoke at T2, T3 & T4 (Eta^2 ES = 0.64, 0.65, 0.29, respectively).
Janse van Rensburg 2009b	Within subjects (randomly assigned). Measures at pre- (T1), mid- (T2), & 0 (T3), 20 (T4)(post-scan) post-treatment. Abstinence period > 8hrs	6 M & 4 F, Mean FTND = 3.4, Mean CPD = 13.7. Non quitters.	Both 10 mins: (a) cycling, mean HR= 136 (b) passive sitting Both followed by fMRI during presentation of smoking & neutral images	Desire to smoke. Other measures of regional brain activation (using fMRI) in response to smoking images.	(a) < (b) for desire to smoke at T2 & T3 (ES = 1.08) mins post-treatment only fMRI: differences (a) v. (b) in brain activation in areas of interest
Ussher 2009	Between subjects (randomly assigned). Measures at pre- (T1) and 0 (T2), 5	31 M & 17 F Mean age = 27.8 yrs. Mean FTND = 5.0. Mean CPD = 15.5	All 10 min & delivered by MP3 player. (a) seated isometric exercise. (b) body scan	SoD & MPSS	(a & b) < (c) for SoD at T3, T4 & T5 and (b) < (c) at T2 in lab settings (a & b) < (c) for SoD

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	(T3), 10 min (T4), & 30 min post treatment, first in lab then in natural environment on same day using a remote hand held device. Abstinence period >16 hrs		(c) passive		at T2 & T3 in natural environment. (a & b) < (c) for poor concentration and restlessness and (a) < (c) for tension in lab settings (a & b) < (c) for irritability, poor concentration & stress, and (a) < (c) for tension, and (b) < (c) for irritability in natural environment No difference between (a) and (b) at any point.
Faulkner 2010	Within Subject (randomly assigned). Measures pre- (T1), mid- (T2), post- (T3), and 10 (T4) & 20 min post- treatment (T5). Abstinence period > 3hrs	11M & 8F. Mean age = 24.6 yrs. Mean FTND=4.5. CPD=15.2.	All 10 min. (a) brisk walk (mean HR=115.7 bpm, mean RPE=11.9) (b) passive (mean HR = 71.4 bpm, mean RPE = 6.4)	Desire to smoke, smoking topography.	(a) > (b) for time to 1st puff (71.9 v 57. 0 s) (a) < (b) for Desire to smoke at T2, but not after controlling for abstinence (a) < (b) for puff volume & puff duration.
Janse van Rensburg 2010	Within Subjects (randomly assigned). Measures at pre- (T1), mid- (T2) & post-treatment (T3). Abstinence period >14 hrs	20 (M & F) Mean age = 20.3 yrs. Mean CPD = 12.3. Mean FTND = 2.3	Both 10 mins: (a) cycling (mean HR=124.5 bpm & mean RPE=12.6) (b) passive. Both followed by fMRI during presentation of smoking & neutral images	Desire to smoke. Other measures of regional brain activation (using fMRI) in response to smoking images	(a) < (b) for desire to smoke at T2 &T3. fMRI: differences (a) v. (b) in brain activation in a areas of interest
Scerbo 2010	Within subjects (randomly assigned order). Measures at pre- (T1), mid- (T2), & 0 (T3), 10 (T4), 20 (T5), & 30 (T6) min post-treatment.	10 M & 8 F Mean age = 26 yrs. Moderately active. Non-quitters. Mean FTND = 4.4. Mean baseline SoD = 5.5	All 15 mins. (a) Walking (RPE = 13.4, HR=133 bpm, HRR= 45-50%). (b) Running (RPE = 16. 2, HR =170 bpm,	Desire & SoD, cortisol	(a) & (b) < (c) for SoD at T2 & T3, and only (b) < (c) at T4. (a) & (b) < (c) for desire at T2, T3 & T4 and only (b) < (c) at T5. By 30 mins, no differences

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	Abstinence period > 3hrs + smoking cues at baseline		HRR=80-85%). (c) Passive seating (HR= 80 bpm)		in cravings between (a), (b) & (c)
Arbour-Nicitopoulos 2011	Within Subject (randomly assigned). Measures at pre- (T1), mid- (T2), post- (T3), and 10 (T4) & 20 min post-treatment (T5) Participants undergoing smoking cessation treatment including receipt of NRT. Abstinence period > 3 hrs	6M & 8F, with severe mental illness. Mean age = 50.14 yrs. Mean FTND = 4.7.	Both 10 min. (a) brisk walk (mean HR = 109 bpm; RPE = 10) (b) passive (mean HR=89 bpm; RPE= 7)	Desire to smoke, MPSS.	No differences between groups on any outcome at any time point except (a) > (b) for positive affect at T2
Elibero 2011	Between subjects (randomly assigned). Measures pre- (T1), post- (T2) & 20 min post-treatment (T3). Abstinence > 1hr	76 participants Mean age = 37 yrs. Mean FTND=4.6. CPD = 19.7.	All 30 min (a) brisk walking (Mean HR = 125 bpm, RPE = 12.4). (b) Hatha yoga. (Mean HR = 81 bpm, RPE = 8.5) (c) Rest (exercise video)(Mean HR = 77 bpm; RPE = 7.98)	QSU brief, PANAS, & cue reactivity to smoking images.	(a) & (b) v (c) decreased QSU total and Factor 1 (but not Factor 2) only at T2, (a) & (b) v (c) decreased negative mood & increased positive mood only at T2, Only (a) reduced cue-reactivity
Haasova 2011	Randomised crossover, 3 conditions. Aimed to assess the effects of walking or seated isometric exercise (v rest) on cravings and attentional bias (AB) to cigarette images	20 participants 7F Mean age = 31yrs Mean FTCD = 3.5 Mean CPD = 14.6 At least 3hrs abstinence, CO<10ppm required.	10 mins moderate intensity treadmill walking or seated isometric exercise (listening to an audio recording) Passive control: seated for 10 min listening to neutral audio narrative	Desire to Smoke (Tiffany and Drobes 1991), Strength of Desire to Smoke (West and Hajek 2004), and MPSS (West and Hajek 2004) assessed at baseline (pre-AB tasks) and post intervention, and twice post AB tasks AB assessed using dot probe task & eye tracking task before	

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				and after intervention	
Williams 2011	Between subject (randomly assigned) . Measures pre- (T1) , post- treatment (T2) & upon arriving at next destination (T3). Participants undergoing smoking cessation treatment including receipt of NRT	60F Mean age = 42 yrs. Mean FTND = 4.8.	(a) Multiple acute 50 min brisk walks over 8 weeks (3 x per week) (b) Multiple 30 min film viewing over 8 weeks (3x per week) .	Cigarette cravings (5-items using visual analogue scale (0-100)). Affect (ADACL)	No differences in cravings between groups at any time point. At T2: (a) > (b) for energy, (a) < (b) for tiredness.
Harper 2012	Single group, pre-post design Assessed the acute effects of exercise on craving and withdrawal symptoms during an NRT-based smoking cessation programme.	178 female participants Mean age = 41.3 Mean FTCD = 5.4 Mean CPD = 17.1 No required period of abstinence (during attempt to quit) , CO<6 ppm required.	20 mins moderate intensity treadmill walking No control group. Cessation programme included NRT.	Shiffman-Jarvik scale immediately before and after first scheduled exercise session during weeks 5, 11, and 13 of the cessation programme First exercise session (wk 5) about 1 week after target quit (week 4) and commencement of NRT Analysis only included those who reached the exercise intensity goals, followed NRT protocol, and confirmed as having CO<6 ppm prior to exercise: at wk 5 n=96, wk 11 n=137, wk 13 n= 127	
Janse Van Rensburg 2012	Randomised crossover, 2 conditions Aimed to assess the effect of exercise on regional brain acti-	20 participants (gender not stated) Age = 18-50 yrs (mean not given) Mean FTCD = 2.3 Mean CPD = 12.3	(a) 10 min moderate-intensity stationary cycling (b) Passive control: seated for 10 min without access to	Functional magnetic resonance imaging (fMRI) brain scanning. Strength of desire	Significantly lower desire and strength of desire scores at mid and post exercise compared with

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	vation in response to smoking related images during temporary nicotine abstinence	Self-reported 15 hours temporary abstinence required, confirmed by CO<10ppm Self-reports of actual hours of abstinence not reported.	reading materials	to smoke (West) , desire to smoke (Tiffany). Assessed baseline, mid- and post-intervention	control. fMRI showed increased activation to smoking images in areas associated with visual processing following rest, but not after exercise
Harper 2013	Single group, pre-post design. Examined if expectancy beliefs towards exercise reducing smoking craving and withdrawal symptoms are related to these symptoms following an acute bout of exercise as part of a smoking cessation programme	149 female participants Mean age = 42.0 Mean FTCD = 5.2 Mean CPD = 16.6 No required period of abstinence (during quit attempt), CO<6 ppm required.	20 mins moderate intensity treadmill walking No control group Cessation programme included NRT.	Exercise expectancy beliefs collected at baseline and at wk 5 (one week after quitting smoking and beginning 21 mg patch) . At wk 5, participants reported craving and withdrawal symptoms immediately before and after exercise Analysis only included 91 participants who reached the exercise intensity goals, followed NRT protocol, and confirmed as having CO<6 ppm prior to exercise.	Significant reduction in craving and withdrawal (i.e. craving, psychological, sedation) from pre- to post-exercise. Both level of exercise expectancy and residual change in exercise expectancy were significantly (but only mildly) correlated with residual change in psychological symptoms, and were unrelated to residual changes in craving and sedation
Janse Van Rensburg 2013	Between subjects, quasi-randomised (higher number in vig. Exercise condition) to 3 conditions Assessed the effects of light vs vigorous intensity exercise on cigarette cravings, subjective and physiological reactivity to smoking cues, and affect after overnight nicotine deprivation.	162 participants 55F Mean age = 30.8 Mean FTCD = 4.8 Mean CPD = 18.0 Approximately half of participants reported regular exercise on at least a weekly basis Self-reported overnight abstinence, confirmed by CO<10ppm. Actual self-reported hours of abstinence not stated	3 conditions: 20 min light intensity treadmill exercise, or 20 min vigorous intensity treadmill exercise, or passive control condition for same time as exercise conditions (watched educational video)	After each condition, participants engaged in a standardized cue reactivity assessment (startle eyeblink reflex) Self-reported urges to smoke (QSU-brief) , affect (PANAS), and salivary cortisol were assessed at baseline (i.e., before each condition), immediately after each condition, and after	Light and vigorous exercise significantly decreased urges to smoke and increased positive affect, relative to the control condition Those in the vigorous exercise condition demonstrated suppressed appetitive reactivity to smoking cues Changes in cortisol concentration were not

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				the cue reactivity assessment	related to changes in craving or cue reactivity
Abrantes 2014 (Acute data reported in Abrantes 2013 conference abstract)	Between subjects, randomised to 2 conditions. Examined the extent to which smoking status moderates the acute benefits of exercise on mood and craving during a smoking cessation programme	61 participants, 40F Mean age = 47.9 Mean CPD = 19.7 During quit attempt: Included abstainers and continuing smokers	Randomized to 12-week aerobic exercise (AE) intervention or health education (HE), plus 8 weeks telephone-based smoking cessation programme	In each week of programme, participants rated mood, anxiety, and urges to smoker before and after each AE and HE session	Participants in the AE showed significant acute improvements in mood and reductions in urges to smoke Observed a significant condition by smoking status interaction, such that abstinence on the day of either AE or HE session was associated with greater acute improvements in mood for AE and lower mood improvement in HE, while no differences in acute mood changes were observed between conditions if participants smoked on that session day
Cooke 2014	Between subjects, randomised to 3 conditions. Examined if exercise imagery could contribute to reductions in smoking cravings and withdrawal symptoms after a short period of abstinence	29 Participants, 17F Mean age = 28.3 Mean CPD = 12.6 Mean FTCD = 3.6 Self-reported 15h of abstinence, confirmed by CO<6ppm. Actual self-reported hours of abstinence not stated.	Exercise: 10 min moderate intensity treadmill walking. Imagery: 10 min audio describing physical behaviour and physiological responses experienced in the actual exercise bout. Control: 10 min audio describing activities of daily living.	Strength of Desire to Smoke and the Mood and Physical Symptoms Scale (West) pre- and post-treatment	3 (Condition) by 2 (Time) repeated measures ANOVA showed a significant reduction in tension for the exercise group versus the other conditions. There were no other significant interactions
De Jesus 2014	Between subjects, randomised to 2 conditions. Examined acute effects of exercise on	82 participants, 43F Mean age = 31.6 Mean CPD = 15.4 Mean FTCD = 4.7 18 hours of tempo-	Passive sitting (PS) or moderate exercise condition (EC)(40-68% of heart rate reserve) for 10 min-	Assessments at pre-abstinence and immediately before and after the treatment:	Significant reduction in cravings and negative affect for EC vs PS. Ad libitum smoking

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	ad libitum smoking, smoking topography (ST), and affect, with changes to cravings serving as a fidelity check	rary smoking abstinence.	utes	smoking topography, cravings, affect. Plus time to first cigarette post-treatment	significantly delayed for EC (8.9min) vs PS (2.5min). No between group differences for smoking topography
Fong 2014	Between subjects, randomised to 2 conditions. Examined the effect of an acute bout of moderate intensity exercise on cravings and ad libitum smoking following concurrent Stressors during temporary abstinence.	25 participants, 14F Mean age = 37.4 Mean CPD = 14.1 Mean FTCD = 3.8 Moderate/vigorous intensity activity in the past week (hours): 2.5 Means hours of self-self-reported temporary abstinence: 18.0, confirmed by CO<10ppm	15-minute bout of moderate intensity treadmill walking or passive sitting for 15 min Exercise or passive control was preceded by stressors of stroop cognitive task and cue-elicited smoking stimuli.	Strength of desire to smoke (West) administered at baseline, post-abstinence, post-stressors, after 5 and 10 min of treatment, end of treatment 15 min and immediately post-treatment Shiffman-Jarvik withdrawal scale, assessed at baseline, post-abstinence, post-stressors, at pre-treatment and 2-minutes post-treatment Time to first cigarette after leaving lab.	Significant decreases in craving and withdrawal symptoms for exercise vs control condition Exercise had no effect on ad libitum smoking.
Ho 2014	Randomised crossover, 2 conditions Examined effects of resistance exercise on hypothalamic-pituitary-adrenal axis (HPA) response to mental challenge, withdrawal symptoms, urge to smoke, and cognitive stress during 24-hour smoking abstinence	8 sedentary male smokers Mean age = 20.1 Self-reported 24h abstinence confirmed by serum cotinine concentrations	Six whole body resistance exercises or a control condition in the morning, followed by mental challenge tasks in afternoon. Two 24-hour smoking abstinence periods one week apart, one for exercise and one for control	Initial measures during 24-hour ad libitum smoking. Plasma adrenocorticotropin hormone (ACTH), and salivary and serum cortisol were measured during each visit at rest, and then before exercise or mental challenges, immediately after and 30 min after Urge to smoke and withdrawal symptoms (West), and stress scales were ad-	The HPA axis response to mental challenge was similar after exercise and control conditions. Exercise did not reduce withdrawal symptoms, urge to smoke, or stress

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				ministered during the ad lib smoking, exercise and control conditions at pre, after and 30 min after	
Kurti 2014	Within-subject cross-over, 2 conditions. Assessed whether the effects of exercise on craving mediated relationship between exercise and delay to ad libitum smoking (Experiment 2 only reported here)	20 participants 5 female Mean age = 39.5 yrs Mean CPD = 15.6 Mean FTCD = 4.7 One hour of abstinence, confirmed in lab.	A. Control: sat quietly for 20 mins with access to magazines, TV etc.. B. 20 min of moderate intensity exercise. Mode of exercise not stated	QSU-Brief	Delays to smoking were significantly longer after exercise (mean = 21 min) versus inactivity (mean = 4 min), and the effect was mediated through the reward component of craving
Oh 2014	Randomised crossover, 3 conditions. Aimed to assess the effects of moderate or vigorous intensity exercise (v rest) on cravings and attentional bias (AB) to cigarette images	15 male & 8 female participants. Mean age = 24yrs Mean FTCD = 2.8 At least 15hrs abstinence, CO<10ppm required.	15 min cycle ergometer at either moderate or vigorous intensity, or quiet rest	Strength of desire (SoD) to smoke (West & Hajek, 2004). Initial (IAB) and maintained (MAB) attentional bias (using eye tracking technology with paired smoking related and neutral images and video clips)	SoD was significantly lower after moderate and vigorous exercise, compared with rest, immediately and 10 mins after treatment. Only 10 mins after treatment was SoD lower after vigorous than moderate exercise Initial AB was lower than control after both moderate and vigorous exercise, but for MAB only after vigorous exercise
Prapavessis 2014	Between subjects, randomised to 2 conditions Examined effect of exercise on cravings and withdrawal among temporarily abstinent pregnant smokers.	30F Mean age = 25.7 Gestation = 18.2 wks FTCD = 3.3 CPD = 9.3 Self-reported mean hours of abstinence: 15.5 (confirmed by CO<10ppm)	(a) Single bout of 20 min of mild-to-moderate treadmill walking (b) control: watched a DVD for comparable time to (a)	Strength of desire to smoke and tobacco withdrawal symptoms (West) assessed immediately before, during (at 10 min), immediately post, and at 10, 20, and 30 min post-condi-	A 2 (condition) × 6 (time) repeated measures ANOVA revealed that the exercise condition significantly reduced desire to smoke compared with control. There were no sig-

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				tion	nificant effects on withdrawal symptoms
Schneider 2014	Between subjects, randomised to 2 conditions. Examined effect of an acute bout of exercise on smoking topography following temporary smoking abstinence	48 participants, 34F Mean age = 42.5 Mean CPD = 16.2 Mean FTCD = 4.9 Mean hours of abstinence =14.4, confirmed by CO<10ppm.	Exercise: 10 min moderate intensity treadmill walking. Control: 10 min passive sitting.	Desire to smoke (Tiffany) assessed at baseline and immediately pre and post treatment condition Smoking topography, including puff count, puff volume, puff duration, inter-puff interval, and total cigarette duration was assessed at baseline and post treatment	Exercise significantly reduced cravings, compared with the control group. Smoking topography remained unchanged across time between groups.
List of abbreviations:	AD-ACL: Activation-Deactivation Adjective Check List CO: Expired carbon monoxide CPD: Cigarettes per day ESR: Evening Symptom Report FAS: Felt Arousal Scale FS: Feelings Scale F: female FTND: Fagerstrom Test of Nicotine Dependence FTCD: Fagerstrom Test of Cigarette Dependence HRR: Heart rate reserve MPSS: Mood and Physical Symptom Scale NRT: Nicotine replacement therapy PANAS: Positive and Negative Affect				

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	Schedule POMS: Profile of Mood States QSU: Questionnaire on Smoking Urges RPE: Rating of Perceived Exertion SAI: State Anxiety Inventory SoD: Strength of desire to smoke SEES-PD: Subjective Exercise Experience Scale- psychological distress SEES-PWB: Subjective Exercise Experience Scale- positive wellbeing SWS: Shiffman Withdrawal Scale				

Appendix 2. Studies examining the effect of an exercise intervention on cigarette consumption

Study ID:	Methods	Participants	Interventions offered	Outcomes related to smoking reduction	Findings
Hill 1985	Country: Canada Aim: To assess the effects of an aerobic exercise programme on smoking cessation (main outcome) and intake (secondary outcome) Design: Two-arm RCT Randomisation method: Not specified Reduction method: NA	Sample size: 36 Gender: 72.2% female Mean CPD: 32 (at least 10 CPD) Mean (SD) Age: 40 All wished to quit smoking.	(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	Mean change in CPD (for previous week) at baseline vs follow ups at end of treatment (EOT) and 1, 3 and 6 months post-treatment. Smoking abstinence at above follow-ups	There was no overall significant difference between groups in change in CPD: (a) (b) EOT: -36.9, -27.1 1 mth: -33.0, -23.6 3mths: -26.3, -20.4 6mths: -25.2, -18.2 No significant group difference in smoking abstinence rates. Small sample size. Change in PA levels not reported.

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Taylor 1988	Country: USA Aim: To determine the influence of exercise on smoking cessation (primary outcome) and intake (secondary outcome) after acute myocardial infarction Design: Six-arm RCT Randomisation method: Not specified Reduction method: NA	Sample size: 58 Gender: 100% male, Patients recruited 10 to 14 days after acute myocardial infarction Level of intention to quit or reduce smoking not stated.	(a) Fitness test + single session CP + group CV exercise at facility, three times a week for (i) 8 weeks or (ii) 23 weeks (b) Fitness test + single session CP + home-based exercise five times a week for (i) 8 weeks or (ii) 23 weeks (c) Single session CP + fitness test at baseline & end of treatment, (d) Control: fitness test at end of treatment only	Cigarette consumption and smoking abstinence for exercise groups (a & b) versus non-exercise groups (c & d) at 23 weeks post-treatment	Cigarette consumption in exercise groups was half of that in non-exercise (CPD: 11 +7 vs 22 + 16) (p<0.03). No significant difference in abstinence rates between exercise and non-exercise groups Absolute CPD, rather than change in CPD relative to baseline, was used in analysis Over 70% of exercise sessions were attended. Motivation towards quitting not reported. Contact time not balanced between groups. Specific to post-acute myocardial infarction.
Prapavessis 2007	Country: New Zealand Aim: To examine the effects of supervised and intensive exercise as well as the combined effects of exercise and nicotine replacement therapy on smoking cessation (primary outcome) and reduction rates (secondary outcome) Design: Four-arm RCT Randomisation method: Computer generated Reduction method:	Sample size: 142 randomised (121 commenced programme) Gender: 100% female CPD: > 10 CPD for last 3 years Mean Age: 38 PA: less than 30 min of MVPA twice per week for the past 6 months All were attempting to quit smoking.	(a) CV activity: various, group/facility, 45 min, 60-75% HR reserve, (3 times/week for 12 weeks) (b) exercise as (a) plus nicotine patches (c) CP (three times/week for 12 weeks). (d) CP as for (c) plus nicotine patches. Exercise began before quit date.	Change in mean cigarettes consumed over previous 48hrs for pre-quit compared with end of treatment (6 week post-quit) and 3 and 12 month follow-ups Smoking abstinence at 6 weeks, 3, 12 months.	Control group (c) reported significantly fewer cigarettes compared with exercise group (a) during weeks 7 through 10 and week 12 Also significantly higher abstinence rates for (c) vs (a) The exercise group significantly increased their physical fitness at end of treatment. This gain was lost at 12 months.

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	NA				There was no significant fitness improvement for those in the non-exercise programme Around 70% of the 121 starting the programme were followed up at each time point
Whiteley 2007	Country: USA Aim: To test the feasibility of a YMCA-based exercise programme for increasing abstinence (primary outcome) and reducing smoking consumption (secondary outcome) Design: Single group within-subjects Reduction method: NA	43 women Mean CPD: 18.2 Mean Age: 44.3 Participants attempted to quit smoking. Exercising for no more than 20 min at a vigorous intensity for two or more times per week	Cognitive-behavioral smoking cessation program one session per week over 12 weeks. YMCA Personal Fitness Program led by YMCA personal trainers. Individual sessions with trainer at weeks 1, 4, 8, and 12. Recommended aerobic activity at the YMCA 3 days/ week for 30-40 min per session during the 12 weeks of study	Change in cigarette consumption between baseline and end of treatment. Smoking abstinence at 1 week post-quit and EOT	Significant decrease in the mean number of cigarettes smoked from 9.9 at baseline to 4.8 at end of treatment ($p<0.001$) 11.6% quit at one week and 7% quit at EOT. Did not include a control group. Analysis included 25 women (58%) who completed the program. Self-reported exercise significantly increased from 530.3 kcal/week at baseline to 1,256.4 kcal/ week at the end of treatment
Leelarungrayub 2010	Country: Thailand Aim: To evaluate the efficacy of both exercise and Vernonia cinerea Less (VC) supplementation alone and in combination with regards to smoking rate (primary outcome) Design: Four-arm RCT Randomi-	Sample size: 112 Gender: 43.9% female CPD: 43% smoking > 11 CPD Mean Age: 50 Level of intention to quit or reduce smoking not stated.	(a) VC supplementation (b) exercise with VC supplementation (c) exercise only (d) usual care control-no change to normal routine. Supervised exercise programme of 30 min of treadmill running, thrice weekly for two months	Change in cigarette consumption between baseline and end of two months of treatment, according to whether light cigarettes or self-rolled	Percent reduction in light cigarettes and self-rolled, respectively, by group: (a) 59.52% & 54.47% (b) 62.79% & 40.00% (c) 53.75% & 42.30% (d) 14.04% increase & 9.2% reduction. Significant cigarette

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	sation method: Not specified Reduction method: NA				reduction for both light and self-rolled, in all groups except (d). Group comparison not reported, but levels of reduction suggest that comparison between (c) and (d) is very likely to be significant 8 participants were not followed up. Change in PA levels not reported.
Horn 2011, reported in Horn 2013	Country: USA Aim: To explore the effects of a teen smoking cessation intervention plus PA intervention on smoking cessation and examine associations between increases in PA and smoking levels (secondary outcome) Design: Three-arm RCT, at school level Randomisation method: Computer generated Reduction method: NA	Sample size: 236 (19 schools) Gender: 46% female Mean age: 17 Mean CPD: 12.4 Mean days of 30 min. PA/past 7days (baseline): 2.8 Participants were seeking to quit smoking.	Interventions: (a) group-based teen smoking cessation (CP) programme versus (b) CP + PA programme CP: x10 weekly sessions of counselling. PA programme: x10 5min PA consultations (including PA log and pedometer) (c) Control group: Single session of 10-15 min of brief advice	Association between changes in PA and smoking rates. Effect of PA intervention on smoking abstinence.	Teens who reported increasing the number of days on which they received at least 20 minutes of PA were significantly more likely to reduce their CPD Significantly higher abstinence rates for exercise vs other two conditions at 3 and 6 months There was no significant difference in the increase in PA between the groups Examined association between PA adherence and smoking reduction but did not examine effect of PA intervention on reduction Targeted those 14 - 19 years of age. Loss to follow-up was not reported.
McClure 2011	Country: USA Aim: To assess feasibility and acceptability of a	Sample size: 52 Gender: 67% female Mean Age: 44.5	(a) Intervention: Usual care + pedometer programme, x10	Change in cigarette consumption between baseline and follow-ups at 4 and	No significant change in CPD for intervention vs control. Mean change

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	cognitive-behavioral program, among those with a diagnosis of depression, designed to improve mental and physical well-being (primary outcomes) . Effects on cigarette consumption as secondary outcome Design: Two-arm RCT Randomisation method: Not given Reduction method: NA	Mean CPD: 10.6 16% in 'Preparation' stage for quitting smoking. PA: Mean days a week walk for exercise: 1.5 Mean minutes of MVPA/week: 169.9 Excluded those meeting PA guidelines. - All had depression diagnosis in previous 2 year. 31% were in the preparation stage of change for quitting.	weekly 30 min cognitive-behavioral, telephone-based, counselling sessions. Plus 2 follow-up calls. Focus on mood management, smoking cessation and PA (b) Control: Usual care of standard self-help and information materials on depression, PA, and smoking. Phone-based smoking cessation program.	6 months. Numbers making a quit attempt and quitting at 4 and 6 months	in CPD: (a) (b) 4 mths -3.2 -1.8 6 mths -2.1 -2.4 No significant effects of intervention on quit attempts or abstinence No significant changes in PA between groups. Feasibility study with small sample. Multicomponent intervention. Limited to those with depression.
Gorini 2012	Country: Italy Aim: To assess the effect of PA counselling plus a smoking cessation programme on quit rates and smoking rates (both primary outcomes) Design: Three-arm RCT Randomisation method: Not specified Reduction method: NA	Sample size: 1100 Gender: female (age 25-64) Mean cpd 12 (7.1) Mean PA levels: not specified Targeted those attending cervical cancer screening. Various levels of stages of change for exercise (numbers not given)	Intervention groups: (a) single session of brief smoking cessation counselling (CP) (tailored to stage of change) (b) single session CP + stage specific PA counselling (c) self-help booklet on smoking cessation and increasing PA	Cigarette consumption at 6 months follow-up relative to baseline. Smoking abstinence at 6 months. Change in motivational stage of change for smoking cessation.	There was no significant difference between the three groups in changes in smoking rates (details not reported) No significant difference in quit rates between exercise group and other groups No difference in change in stage of change for smoking cessation between groups Those in PA + CP did not show any significant increases in PA compared with those in CP alone 93 were lost to the follow-up.
Kovelis 2012	Country: Brazil Aim: To assess effects of pedometer-based intervention	Sample size: 40 Gender: 55% female Median Age: 51	(a) Intervention: Daily pedometer use for one month, aiming	Change in cigarette consumption between baseline and end of treatment	No significant effect of intervention on CPD. The median CPD remained at

(*Continued*)

	vs a PA booklet on PA levels (primary outcome) and cigarette consumption (secondary outcome) Design: Two-arm RCT Randomisation method: Using concealed envelopes. Reduction method: NA	Median CPD: 20 Mean FTCD: 5 Median steps/Day: 9063 Level of intention to quit or reduce smoking not reported.	to achieve 10,000 steps/day. Use of PA log (b) Control: Booklet promoting regular walking, to be used for 1 month.	Separate analysis for whether active or inactive at baseline	20 in both groups after the intervention In inactive subjects, significant correlation between steps/day and CPD Abstinence not reported. 36 (47%) dropouts were excluded from analysis from an initial sample of 76 In intervention group, only physically inactive group showed increase in steps/day
Ussher 2012	Country: UK Aim: To assess the effects of a PA intervention on smoking reduction (as a secondary outcome, and abstinence (primary outcome) during pregnancy Design: Two-arm RCT Randomisation method: Secure online server Reduction method: NA	Sample size: 785 Pregnant women with mean gestation of 15.6 weeks. Median CPD: 10 Mean (SD) Age: 27.5 All were attempting to quit smoking.	(a) Intervention: CP once a week for six weeks. 14 sessions supervised treadmill walking over weeks. 9 PA consultations (b) Control: CP only	Change in CPD between baseline and 4 weeks after quit day, end of pregnancy and six months after birth Smoking abstinence at 4 weeks post-quit, end of pregnancy and 6 months post-birth Only assessed among those who did not succeed at quitting smoking and who reported that they were still smoking on a daily basis	There was no significant difference in the change in CPD between the groups at any time point. Mean (SD) reduction in CPD: PA Control 4 weeks (n=137) 4.3 (4.4) 4.0 (4.7) End of pregnancy (n=249) 4.0 (4.7) 2.9 (5.9) 6 mth post-natal (n=197) 1.4 (4.5) 1.0 (5.3) No significant group difference in smoking abstinence rates. Only included those who were followed up. 88 (11.2) lost to follow-up at end of pregnancy
Bernard 2013b	Country: France Aim: To examine the feasibility of a counselling and ex-	Sample size: 12 psychiatric inpatients (3 with schizoaffective disorder; 9 with	8 weekly sessions: five 75min "smoking reduction" group coun-	Smoking reduction calculated between baseline versus post-intervention and	At end of treatment, significant decreases in cigarette consump-

(*Continued*)

	ercise intervention for reducing smoking (primary outcome) among those with schizophrenia/ schizo-affective disorder Design: Single group within-subjects Reduction method: No specific goals; no quit date set	schizophrenia) Gender: 2 females Mean age: 46 Mean cpd: 17 (smoke at least 15 cigarettes per day for at least 1 year) Mean PA levels (baseline): not specified Level of intention to quit or reduce smoking not reported.	selling sessions, based on the Transtheoretical Model. Three 70 min supervised group walking sessions over 8 weeks	6 weeks post-intervention (number of cigs smoked within last 7 days) Smoking cessation motivation.	tion with 42% reporting a reduction of 50% from baseline Smoking cessation motivation significantly increased at end of treatment At six week follow-up, consumption was lower than baseline but was no longer statistically significant Attendance at walking sessions was not reported.
Ybarra 2013	Country: USA Aim: Pilot study to assess the effects of text message-based interventions on smoking cessation (primary outcome) and reduction (secondary outcome) Design: Two-arm pilot RCT Randomisation method: Computer generated Reduction method: NA	Sample size: 164 Gender: 43.9% female Mean CPD: 12.2 Mean (SD) Age: 21.6 (2.1) Smoking 24 cigarettes or more per week (at least four per day on at least 6 days/week) Seriously thinking about quitting smoking next 30 days	(a) Intervention: 6 weeks text message-based smoking cessation programme. (b) Control: 6 weeks text message-based programme aimed at improving PA and sleep	Change in cigarette consumption between baseline and 3 month follow-up. Smoking abstinence at 4 weeks and 3 months post-quit	Among 93 participants who reported smoking at > one cigarette in past 28 days at 3-month follow-up, intervention group reported reducing Mean CPD by 6.7 and control (PA) group by 5.9 CPD. This difference was not significant Non-PA group reported significantly higher abstinence rates, compared with PA control, at 4 weeks but there was no significant difference at 3 mths PA was promoted in control condition only and was combined with a sleep intervention PA levels not assessed.

(*Continued*)

					Around three quarters completed the follow-up at 3 mths. Focus on young adults (18 - 25 years).
Maddison 2014	Country: New Zealand Aim: To assess the effects of a telephoned-based PA counselling intervention on smoking reduction (secondary aim), and abstinence (primary aim) Design: Two-arm RCT Randomisation method: Secure online server Reduction method: NA	Sample size: 906 Gender: 54.2% female Mean CPD: 19.6 Mean FTCD: 5.6 Mean (SD) Age: 37.5 < 150 min of MVPA per week. All were attempting to quit smoking.	(a) Intervention: PA counselling, one face-to-face and 9 telephoned-based sessions over 6 months + telephoned-based CP for 3 months (b) Control: CP only as (a).	At 24 weeks after quit day: Number of cigarettes smoked per day in the past 7 days. Number of cigarettes smoked per day since nominated quit date Rates of smoking abstinence at 24 weeks post quit.	There was a small but statistically significant difference in the number of cigarettes smoked in the previous 7 days (mean difference, −0.92 cigarettes per day; 95 % CI 0.06-0.39; p=0.006) as well as in the number of cigarettes smoked since participants' nominated quit date (mean difference, −1.01 cigarettes per day; 95 % CI −1.74 to −0.09, p=0.02) in favour of the intervention group Mean (SE) number of cigarettes smoked per day in the past 7 days: PA: 4.75 (0.34) Control: 5.67 (0.34) Mean (SE) number of cigarettes smoked per day since nominated quit date: PA: 5.07 (0.37) Control: 6.08 (0.36) There was no significant effect on smoking abstinence.

(*Continued*)

					PA levels were significantly higher for PA vs control group at 24 weeks Based on absolute number of cigarettes, rather than change in CPD relative to baseline
Taylor 2014	Country: UK Aim: To evaluate the feasibility of a PA and smoking reduction (secondary outcome) counselling intervention for disadvantaged smokers (smoking abstinence as primary outcome) Design: Pilot, two-arm RCT Randomisation method: Secure online server Reduction method: Smokers offered four strategies (hierarchical reduction, smoke free periods, scheduled reduction, planned reduction) integrated with PA support. Encouraged to set goal of 50% reduction in CPD during the first 4 weeks	Sample size: 99 Gender: 56 female Mean age: 47 Mean cpd (baseline) : 22 Mean 7 day self-reported MVPA levels (baseline): 73 min/day Accelerometer MVPA levels (baseline): 32 min/day Social Class: 91% manual workers/ Unemployed Participants did not wish to quit in the next month but wanted to reduce their smoking	Intervention group: After an initial face-to-face session, 8 weekly one-to-one support sessions from a health trainer (HT) in person or by telephone. After quitting they were offered weekly HT counselling, for up to 6 weeks, to support ongoing PA, and/or local Stop Smoking Service support. Counselling based around motivational interviewing techniques and self-determination theory Control: Brief advice on quitting (i.e. usual care)	Self-reported 50% reduction in smoking, cigarettes smoked per day, number of quit attempts, rates of smoking abstinence	A significantly greater proportion of participants in the intervention arm (n= 11, 23%) vs control (n=3, 6%) reported making a quit attempt, and reduced smoking by 50% or less at 16 weeks post-baseline (n=19, 39% vs n= 10, 20%) In the intervention v control condition, 14% v 4% had confirmed (with expired CO) abstinence 4 weeks post quit date, and 10% v 4% were abstinent at 16 weeks post baseline, albeit with small numbers. These group differences were not significant Increased odds of achieving at least 150 minutes of MVPA per week in the intervention arm, with imputation analysis

CP: cessation programme
CPD: cigarettes per day

CV: cardiovascular
MVPA: Moderate-to-vigorous intensity physical activity
PA: Physical activity

WHAT'S NEW

Date	Event	Description
21 August 2014	New search has been performed	Five new studies added, several excluded studies added, all of main text updated, 14 studies added to appendix of acute studies, new table/appendix of studies and text examining effect of exercise on cigarette consumption
21 August 2014	New citation required but conclusions have not changed	No change to conclusions.

HISTORY

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

CONTRIBUTIONS OF AUTHORS

The original review was conceived, extracted and written by Michael Ussher, Adrian Taylor, Robert West and Andrew McEwen.

The idea for the review was conceived by Ussher, Taylor and West. Ussher 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 authors for additional information.

All authors made a contribution to the design, search strategy and interpretation of data. The writing of the original review was led by Ussher with assistance from West, Taylor and McEwen.

The 2005 update was conducted solely by Michael Ussher.

The 2008 review was updated to include a table of studies examining the acute effects of physical activity on cravings and withdrawal symptoms. This evidence was synthesised by Adrian Taylor and Guy Faulkner, in both 2008 and 2011.

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

In the 2014 review Ussher added studies to the main review and to the table of acute studies and revised the text. In 2014 a table was added (see Appendix 2) of studies assessing the effect of exercise interventions on cigarette consumption. Taylor or Faulkner checked all the revisions and additions against the original papers. Both Taylor and Faulkner checked all the revisions to the main text.

DECLARATIONS OF INTEREST

The first author (MU) was involved in the conduct of two of the included studies (Ciccolo 2011; Ussher 2003).

The second author (AT) was involved with one of the included trials (Ussher 2003).

SOURCES OF SUPPORT

Internal sources

- St George's, University of London, UK.
- University of Exeter, UK.
- University of Toronto, Canada.

External sources

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

INDEX TERMS

Medical Subject Headings (MeSH)

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

MeSH check words

Humans