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Exercise interventions for smoking cessation (Review)

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TABLE OF CONTENTS

[Intervention Review]

Exercise interventions for smoking cessation

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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

In July 2011, we searched the Cochrane Tobacco Addiction Group Specialized Register for studies including the terms 'exercise' or 'physical activity'. We also searched MEDLINE, EMBASE, PsycINFO, Dissertation Abstracts and CINAHL using the terms 'exercise' or 'physical activity' and 'smoking cessation'.

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, recruiting smokers or recent quitters, and with a follow up of six months or more.

Data collection and analysis

We extracted data on study characteristics and smoking outcomes. Because of differences in studies we summarized the results narratively, making no attempt at meta-analysis.

Main results

We identified 15 trials, seven of which had fewer than 25 people in each treatment arm. They varied in the timing and intensity of the smoking cessation and exercise programmes. Three 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. 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 one of the 15 trials offered evidence for exercise aiding smoking cessation at a 12-month follow up. All the other trials were too small to reliably exclude an effect of intervention, or included an exercise intervention which was insufficiently intense to achieve the desired level of exercise. Trials are needed with larger sample sizes, sufficiently intense interventions, 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

Exercise is routinely recommended as an aid to smoking cessation by specialist clinics and self-help materials. Fifteen trials have compared an exercise programme plus a smoking cessation programme, or an exercise programme alone, to a cessation programme alone or a cessation programme plus a health education programme, among smokers who were motivated to quit. Since these studies used different types of exercise programmes, and varied in the duration of follow up, the results were not combined. In one study with a difference in quit rates of borderline significance, the exercise component more than doubled the likelihood of not smoking after 12 months.

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 2011; Hughes 2007; Stead 2008). 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 (Taylor 2007b, also see the table of acute studies in the appendix). 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).

Besides the potential benefits of exercise for moderating psychological withdrawal symptoms and cravings, exercise has also been

shown to reduce post-smoking cessation weight gain for up to two years following cessation (Parsons 2009; Kawachi 1996). The weight control benefits of exercise may be of particular importance to 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). 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). Smokers report that they value exercise as a strategy for reducing the risk of developing tobacco-related disease (Haddock 2004), and 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 (Haddock 2000; deRuiter 2008), with confidence to maintain smoking abstinence (King 1996) and with success at stopping smoking (Derby 1994; Paavola 2001; Sedgwick 1988; Abrantes 2009), 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).

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.Hurt 1992, Everson 2010), by pharmaceutical companies (e.g. Boots 1998), in self-help guides (Ashelman 2000; Marcus 2004) 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.

This updated review builds on a previous report (Ussher 2000a). We also note the results of a review which included a meta-analysis using three of the studies identified in the current review and two further studies which had an exercise-only intervention (Nishi 1998).

OBJECTIVES

The objective of the present review was to establish whether exercise-based interventions alone, or combined with a smoking ces-

sation 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 of supervised or unsupervised exercise 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 'exercise' or 'physical activity'. We also searched MEDLINE, Pubmed, EMBASE, PsycINFO, Dissertation Abstracts and CINAHL, using the terms 'smoking', 'smoking cessation', 'exercise', 'physical activity' and 'intervention' (searches completed July 2011). 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 randomization method; subject characteristics including age, gender, smoking behaviour, 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; method of validation. The primary outcome was quitting at longest follow up using the strictest definition of abstinence reported in the study.

Due to the small number of studies, small sample sizes and 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 and the 95% confidence interval were displayed graphically.

RESULTS

Description of studies

The literature search identified 15 studies which met the inclusion criteria. Full details for each study are given in the Characteristics of included studies table. Six studies had more than one associated publication or abstract (Bize 2010; Kinnunen 2008; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003) and these are listed under the study identifier in the reference section. Seven trials had fewer than 25 people in each treatment arm (Ciccolo 2011; Hill 1985; Hill 1993; Marcus 1991; Marcus 1995; Russell 1988; Taylor 1988). Seven trials were limited to women (Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Prapavessis 2007; Russell 1988), and one 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 six studies this began prior to quit day (Hill 1993; Kinnunen 2008; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003). 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). Four studies included nicotine patches as part of the smoking cessation programme (Ciccolo 2011; Marcus 2005; Prapavessis 2007; Ussher 2003), one study used nicotine gum (Kinnunen 2008) and two promoted nicotine replacement therapy in general (Bize 2010; McKay 2008).

Twelve 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 nine studies (Bize 2010; Hill 1993; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003) on the quit date in three (Ciccolo 2011; Hill 1985; Martin 1997), after the quit date in two (Russell 1988;Taylor 1988) and one study did not state the timing of the exercise programme (McKay 2008). Two studies entailed 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. Four studies did not provide a home programme (Ciccolo 2011; Marcus 1991; Marcus 1995; Marcus 1999), one study used only brief one-to-one counselling towards pursuing home-based exercise (Ussher 2003), 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).

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 (see Appendix 1), mostly following temporary abstinence. The findings of these studies are summarised at the end of the discussion.

(e) Did not meet other inclusion criteria: These studies either had a follow up of less than six months, did not include smokers who were motivated to quit, did not include a non-exercise control group or did not have smoking abstinence as an outcome.

Risk of bias in included studies

Only seven studies described the randomization method in detail (Bize 2010; Ciccolo 2011; Marcus 1999; Marcus 2005; McKay 2008; Prapavessis 2007; Ussher 2003). The strictest measure of abstinence was continuous in five studies, prolonged abstinence in two, point prevalence in six, and was not specified in two.

Post-randomization dropouts were excluded from the denominator in six studies (Bize 2010; Ciccolo 2011; Hill 1993; Kinnunen 2008; Prapavessis 2007; Taylor 1988).

Eight studies stated that those lost to follow up were counted as having relapsed to smoking (Bize 2010; Ciccolo 2011; Hill 1985; Marcus 1991; Marcus 1999; Marcus 2005; McKay 2008; Ussher 2003).

Effects of interventions

We defined the efficacy of the intervention in terms of the risk ratio (RR) for quitting in the treatment group versus the controls. Three studies showed significantly higher abstinence rates in a physically active group versus a control group at end of treatment (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% confidence interval (CI), 0.97 to 4.96) at the 12-month follow up. 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 (Ciccolo 2011; Hill 1985; Kinnunen 2008; Marcus 1995; Prapavessis 2007). Only six 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; 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).

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

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). This study differed from the others in that 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 four of the studies the exercise condition received more staff contact time than the control (Hill 1985; Marcus 1991; Martin 1997; Taylor 1988), 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 only seven of the trials did this (Bize 2010; Hill 1993; Kinnunen 2008; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003). 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, socio-economic status and occupation could influence outcomes for both smoking cessation (Jarvis 1997; Vangeli 2011) and exercise behaviour (Caspersen 1994; Pate 1995). Of the six trials which recruited men and women, two compared outcomes by gender (Hill 1993; Ussher 2003), and no differences were reported. None of the studies considered outcomes relative to occupation, socio-economic 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 three of the studies were North American. Seven studies recorded ethnic status, and all reported a predominantly white sample (Ciccolo 2011; Kinnunen 2008; Marcus 1999; Marcus 2005; Martin 1997; McKay 2008; Ussher 2003). 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, while 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 people 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 (Vickers 2009). One excluded study showed that teenage smokers are likely to benefit from an exercise intervention (Horn 2011), although this study was limited by including individuals with various levels of motivation for quitting. Further trials with teenagers who are motivated to quit are warranted. 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 an ongoing trial is assessing the effects of an exercise intervention in this population (Ussher 2008; Ussher 2011). Five of the studies did not present the participants' level of exercise at baseline (Ciccolo 2011; Hill 1985;McKay 2008; Russell 1988; Taylor 1988). All the remaining studies 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 (Derby 1994; Paavola 2001; Sedgwick 1988; Abrantes 2009), yet

it is not clear whether exercise interventions are effective as an aid to smoking cessation for a more active population.

Weight gain

One trial reported a significantly smaller weight gain for those in the exercise condition compared with the controls at the end of treatment (Marcus 1999). However, in this study those in the exercise condition weighed more than the controls at baseline, and this difference was not controlled for in the analysis, 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, Prapavessis showed that 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 (Marcus 1991; Marcus 1995; Marcus 2005; Ussher 2003), 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 and Marcus 1995 were too small to have a realistic chance of detecting significant differences. The other studies (Bize 2010; Marcus 2005; Ussher 2003) 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 Parsons 2009 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). 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 2008). Future studies need to establish whether exercise offers additional benefits to those provided by NRT alone. It is feasible that exercise could address psychosocial and physical needs that are not currently met by NRT-based programmes.

Exercise Programming

For those beginning exercise either on or after the quit date (Ciccolo 2011; Hill 1985; 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 (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.

Those adequately powered trials not showing a consistent effect of exercise on smoking abstinence (Bize 2010; 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), 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 providing (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 two of the studies provided any post-intervention exercise programming (Hill 1993; 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.

One study promoted resistance exercise (Ciccolo 2011) and the remaining studies focussed 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). Also, yoga has been found to reduce cravings for tobacco (Elibero in press) and an ongoing study is assessing a yoga intervention as a smoking cessation aid (Bock 2010).

Exercise Adherence Issues

During the treatment period a range of cognitive-behavioural methods were employed to improve adherence to the exercise programme. All but four of the studies used group-based exercise (Ciccolo 2011, Kinnunen 2008, McKay 2008; Ussher 2003). Only three studies did not provide full supervision of facility-based exercise (Kinnunen 2008, McKay 2008; Ussher 2003). All the studies included goal setting; five used self-monitoring (Hill 1985; Kinnunen 2008; Martin 1997; Russell 1988; Taylor 1988); one used reinforcement (Martin 1997); one used telephone follow up in the case of non-attendance (Hill 1993); and one used remote monitoring of heart rate (Taylor 1988). One study employed exercise counselling, including a broad range of cognitive-behavioural techniques (Ussher 2003). Three studies did not report overall activity levels for the treatment group during the treatment period (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; 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). Another study reported lower attendance for the exercise intervention compared with the health education programme (Kinnunen 2008). 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).

Fitness measures

Although many of the studies reported fitness measures for the control group during the treatment period (Ciccolo 2011; Hill 1985; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Prapavessis 2007; Russell 1988; Taylor 1988) only four of the investigations reported physical activity (PA) levels for the controls at this time (Bize 2010; Hill 1985; Kinnunen 2008; Ussher 2003). Therefore in the vast 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 or behavioural techniques to encourage regular exercise. Only three of the studies recorded fitness measures at this time (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 (Taylor 2008; Pate 1995) it is possible that exercise could aid smoking cessation independently of any 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). Three studies showed an increase in fitness for the intervention conditions compared with the controls at end of treatment (Marcus 1999; Prapavessis 2007; Taylor 1988); others showed no differences at end of treatment, at a four-month follow up (Kinnunen 2008; Russell 1988) or at 12-month follow up (Prapavessis 2007).

Psychological measures

The majority of the studies used psychological measures at baseline, but only seven trials reported changes in these measures (Kinnunen 2008; Marcus 1999; Marcus 2005; Martin 1997; Prapavessis 2007; Russell 1988; Ussher 2003). 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 (Taylor 2000; Taylor 2008; Stathopoulou 2006). The reported effect on psychological outcomes may have been caused by extraneous variables which could not be controlled for with such 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, although 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 (Williams 2008). Ussher 2003 observed a reduction in some withdrawal symptoms for exercise versus controls up to three weeks post-cessation. None of the above studies looked in detail at 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

The Appendix presents a summary of 27 studies we identified which have assessed the acute effects of exercise on smoking outcomes. Two studies only used outcomes related to smoking intake (Mikhail 1983; Reeser 1983). The remaining 25 studies included outcomes related to tobacco withdrawal/mood and/or tobacco cravings. Three studies assessed outcomes during an attempt to quit smoking (Arbour-Nicitopoulos 2011, Bock 1999; Williams 2011). Of these studies one reported a significant reduction in tobacco withdrawal symptoms and cigarette cravings for the vast majority of the exercise bouts throughout the intervention (Bock 1999). Of the other two studies involving a quit attempt, one found no effect of exercise on cravings or withdrawal symptoms (Arbour-Nicitopoulos 2011) and the other showed that exercise increased energy and reduced tiredness but had no effect on cravings (Williams 2011), compared with a passive control group. We found 22 studies that examined the acute effects of exercise on withdrawal symptoms and/or cravings among temporarily abstinent smokers and all but five of these studies (Daley 2004; Daniel 2007; Everson 2006; Faulkner 2010; Pomerleau 1987) observed a significant reduction in cravings and/or withdrawal symptoms compared with a passive control. A previous systematic review (Taylor 2007b) of 14 studies provides 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 17 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 5 minutes of seated isometric exercise to 20 - 30 minutes of cardiovascular activity. Encouragingly, relatively convenient forms of physical activity (e.g. 10 - 15 minutes of brisk walking) can be effective. Haasova 2011 quantified the effects of a single bout of exercise on strength of desire to smoking using original data from 15 studies. The pooled estimate for treatment effect (non-standardised mean difference) was -1.908 (95% CI -2.721; -1.095), 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) and expectancy (Daniel 2007) do not appear to explain the effects. Cortisol remained constant in a vigorous exercise condition, compared with declines in moderate and passive conditions, despite similar and significant reductions in cravings in both physically active conditions (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. Two 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 (Janse van Rensburg 2009b, Janse van Rensburg 2010) following moderate intensity exercise. Finally, one study (Janse van Rensburg 2009a) 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. Ussher 2001, Ussher 2006, Daniel 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 six studies (Reeser 1983; Mikhail 1983; Thayer 1993;Katomeri 2007; Faulkner 2010; Taylor 2007a) reported that a bout of exercise delayed ad libitum smoking, or favourably influenced smoking topography. Overall, given this experimental evidence further research is needed to understand how best to promote the use of acute bouts of physical activity, in con-

trast to longer scheduled bouts of exercise, as a momentary aid to smoking cessation,

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 a general absence 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 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). 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 (Jung 2010; Fitzgeorge 2011).

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; King 1996; McEwen 2006; Everson 2008b). 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 people 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 the notion of beginning an exercise programme when already abstinent, although delaying the start of the programme would reduce 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. In addition, studies included in the current review focus on individuals who are motivated to quit smoking. A recent study recruited teenage smokers at different stages of motivation for quitting (Horn 2011), although the data was not analysed according to level of motivation to quit. Studies are needed to determine whether exercise can be used to increase quit attempts among those who are not motivated to initiate such an attempt and this issue is being explored in an ongoing study (Taylor 2011).

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. 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 one of the 15 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 exclude reliably an effect of the intervention, had numerous methodological limitations or included an intervention which was not 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.

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.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

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

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
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

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
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

Hill 1985 (*Continued*)

Outcomes	7 day PP abstinence Validation: CO Follow up: 1, 3 ,6 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)	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)
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

Hill 1993 (*Continued*)

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

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.
Allocation concealment (selection bias)	Low risk	No details reported. No evidence of import 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

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)	Low 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 less than 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

Marcus 1995 (*Continued*)

Notes	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)	Low risk	Those delivering the intervention were not blinded to treatment allocation
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)	
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)	Low 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)	Low risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Low 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)	Low 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	Low 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.

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)	Low 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

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)	Low 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)	Unclear risk	Computer generated
Allocation concealment (selection bias)	Low risk	Those delivering the intervention were not blinded to treatment allocation
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

CO: carbon monoxide

CP: cessation programme
CPD: cigarettes per day
CV: cardiovascular
HR: heart rate
PP: point prevalence
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
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
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
Daniel 2004	Acute study
Daniel 2006	Acute study
Daniel 2007	Acute study
Elibero in press	Acute study
Everson 2006	Acute study
Everson 2008a	Acute study
Faulkner 2010	Acute study
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*)

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
Horn 2011	Not all the participants were motivated to quit smoking
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 2010	A non-exercise control group was not included. Also follow-up was less than 6 months
Janse van Rensburg 2008	Acute study
Janse van Rensburg 2009a	Acute study
Janse van Rensburg 2009b	Acute study
Janse van Rensburg 2010	Acute study
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
Leelarungrayub 2010	Did not include smoking abstinence as an outcome.
McClure 2009	Included an 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 an 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
McIver 2004	There was no control group
Mikhail 1983	Acute study
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
Ortega Sanchez-P 2006	Retrospective study

(*Continued*)

Pomerleau 1987	Acute study
Prochaska 2008	Included an 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
Scerbo 2010	Acute study
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
Taylor 2006a	Acute study
Taylor 2006b	Acute study
Thayer 1993	Acute study
Ussher 2001	Acute study
Ussher 2006	Acute study
Ussher 2008	Did not include a control group
Ussher 2009	Acute study
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
Williams 2010	Follow-up was less than six months.
Williams 2011	Acute study
Zwick 2006	Unable to obtain details of study from authors

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

Bock 2010

Trial name or title	Yoga for women attempting smoking cessation
Methods	RCT
Participants	60 women
Interventions	8-week programme with 1-hour per week of cognitive-behavioural smoking cessation group treatment. Participants randomly assigned to receive either a supplemental wellness programme (contact-control) or 1 hour twice weekly of yoga.
Outcomes	The primary outcome is 7-day point prevalence abstinence at 6 month follow up
Starting date	2007
Contact information	Professor Beth Bock Bbock@lifespan.org
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	
Contact information	Dr Lindsay George, lfitzgeo@uwo.ca
Notes	

Maddison 2010

Trial name or title	Pragmatic randomized controlled trial of exercise for smoking cessation
Methods	RCT
Participants	1400

Maddison 2010 (*Continued*)

Interventions	Usual care (cessation programme plus NRT) plus exercise programme versus usual care alone
Outcomes	Continuous abstinence and 7 day pp abstinence at 6 months after the quit date
Starting date	
Contact information	Professor Ralph Maddison r.maddison@ctru.auckland.ac.nz
Notes	Contact time not equal between conditions

Ussher 2011

Trial name or title	Pragmatic trial of physical activity for smoking cessation during pregnancy
Methods	RCT
Participants	866 pregnant smokers
Interventions	Physical activity intervention plus cessation programme versus cessation programme alone
Outcomes	Prolonged abstinence at end of pregnancy and 6 months post-partum
Starting date	2009
Contact information	Dr Michael Ussher mussher@sgul.ac.uk
Notes	Contact time not equal between conditions

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	14		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
Hill 1985	7/18	5/18		1.40 [0.54, 3.60]
Taylor 1988	29/42	16/26		1.12 [0.78, 1.62]
Marcus 1991	2/10	0/10		5.00 [0.27, 92.62]
Hill 1993	5/18	7/22		0.87 [0.33, 2.29]
Marcus 1995	3/10	1/10		3.00 [0.37, 24.17]
Martin 1997	19/72	18/70		1.03 [0.59, 1.79]
Marcus 1999	16/134	8/147		2.19 [0.97, 4.96]
Ussher 2003	19/154	19/145		0.94 [0.52, 1.71]
Marcus 2005	1/109	1/108		0.99 [0.06, 15.64]
Prapavessis 2007	12/68	8/53		1.17 [0.52, 2.65]
Bize 2010	62/229	72/252		0.95 [0.71, 1.26]
McKay 2008	120/1159	112/1159		1.07 [0.84, 1.37]
Kinnunen 2008	9/92	7/56		0.78 [0.31, 1.98]
Ciccolo 2011	2/13	1/12		1.85 [0.19, 17.84]

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 mean time = 30 mins.	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. (self-reported)	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). 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). *

(*Continued*)

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: c.17 hrs	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 cravings = 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	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)

(*Continued*)

			until 5 mins, then 2. 5 min warm down		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
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
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)

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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). Mean abstinence period: 13.6 hrs	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 smoke. (a) < (b) during treatment for 5 other MPSS items but due to increase during cognitive distraction task rather than reduction during exercise
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

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					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)
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
Scerbo 2010	Within subjects (randomly assigned order). Measures at pre- (T1), mid- (T2), & 0 (T3), 10 (T4), 20 (T5), & 30 (T6) min post-treatment. Abstinence period > 3hrs + smoking cues at baseline	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, HRR=80-85%). (c) Passive seating (HR= 80 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 in cravings between (a), (b) & (c)
Janse van Rensburg 2008	Within subjects. Randomly ordered. Pre-, Mid- (not QSU-brief) & post-exercise, + 5, 10 & 15 mins post-treatment. Abstinence period	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,

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	15 hrs.				2.04 and 1.39, & Factor 2 = 1.47, 1. 22 and 0.98, respectively)
Everson 2008a	Between subjects (random assigned). Measures at pre- (T1), mid- (T2), & 5 (T3) & 30 (T4) min post-treatment. Mean abstinence period: 17 hrs	25 M & 20 F. Mean age = 21.8 yrs. Mean CPD = 13.6. Non-quitters. Mean FTND = 3.4. Mean baseline SoD = 4.6. HONC = 7.6	All 10 mins. (a) Cycle (RPE = 12. 5, HR=131 bpm, HRR= 50%). (b) Cycle (RPE = 14. 8, HR =155 bpm, HRR=68%). (c) Passive seating.	SoD, MPSS & SEES	(a) & (b) < (c) at T2 & T3 for SoD, and only (a) < (c) for total MPSS & SEES (positive well-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 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-quitters. 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
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 smok-	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

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			ing & neutral images		
Ussher 2009	Between subjects (randomly assigned). Measures at pre- (T1) and 0 (T2), 5 (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	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 (c) passive	SoD & MPSS	(a & b) < (c) for SoD at T3, T4 & T5 and (b) < (c) at T2 in lab settings (a & b) < (c) for SoD 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.
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
Faulkner 2010	Within Subject (randomly assigned) . Measures pre- (T1) , mid- (T2), post- (T3), and 10 (T4) & 20 min post- treatment (T5). Absti-	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

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	nence period > 3hrs				(a) < (b) for puff volume & puff duration.
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.
Elibero in press	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
List of abbreviations:	AD-ACL: Activation-Deactivation Adjective Check List CPD: Cigarettes per day ESR: Evening Symptom Report FAS: Felt Arousal Scale FS: Feelings Scale FTND: Fagerstrom Test of Nicotine Dependence HRR: Heart rate reserve MPSS: Mood and Physical Symptom				

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	Scale PANAS: Positive and Negative Affect 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				

WHAT'S NEW

Last assessed as up-to-date: 25 September 2011.

Date	Event	Description
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

HISTORY

Review first published: Issue 3, 2000

Date	Event	Description
21 July 2008	New search has been performed	Two new studies included, several excluded studies added, background updated, table of acute studies added
21 July 2008	New citation required but conclusions have not changed	Change of authorship
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.

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.
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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