Exercise interventions for smoking cessation (Review)

Ussher MH, Taylor A, Faulkner G

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TABLE OF CONTENTS

[Intervention Review]

Exercise interventions for smoking cessation

Michael H Ussher[1], Adrian Taylor[2], Guy Faulkner[3]

[1]Division of Community Health Sciences, St George's, University of London, London, UK. [2]School of Sports & Health Sciences, University of Exeter, Exeter, UK. [3]Faculty of Physical Education and Health, University of Toronto, Toronto, Canada

Contact address: Michael H Ussher, Division of Community Health Sciences, St George's, University of London, Cranmer Terrace, London, SW17 0RE, UK. m.ussher@sgul.ac.uk.

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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 strategy

In July 2008, 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.

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 13 trials, six 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 13 trials offered evidence for exercise aiding smoking cessation at a 12-month follow up. All the other trials were too small to exclude reliably 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, 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. Thirteen 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. 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). Many attempts to stop smoking are made unaided (West 1997), with a success rate (more than 12 months continuous abstinence) of around 2 to 4% (Hughes 1992). 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 2007; 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 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). 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 neurobiological processes in the brain (Dishman 2006) 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).

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 (Kawachi 1996). The weight control benefits of exercise may be of particular importance to fe-

male smokers who report taking up smoking to control weight (USDHHS 2001), and report fear of post-cessation weight gain as a motivation for continued smoking (Sorenson 1992; USDHHS 2001) and for smoking relapse (Gritz 1989). 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 (Fox 1999). In addition, being physically active has many general health benefits (DOH 2004) 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 recent review suggests that participation in regular physical activity satisfies eight of the principles characterising a tobacco harm reduction strategy (deRuiter 2006).

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; 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 have 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; 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 during adulthood (Kujala 2007). 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 2007), 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 2008).

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), 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). 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 cessation programme, are more effective than a smoking cessation intervention alone.

METHODS

Criteria for considering studies for this review

Types of studies

Randomized controlled trials

Types of participants

Smokers wishing to quit or recent quitters.

Types of interventions

Programmes of supervised or unsupervised exercise alone or as an adjunct to a smoking cessation intervention, compared to 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.

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, EMBASE, PsycINFO, Dissertation Abstracts and CINAHL, using the terms 'smoking', 'smoking cessation', 'exercise', 'physical activity' and 'intervention' (searches completed July 2008). We also carried out a handsearch of reference lists and conference abstracts, conducted additional searches on key authors and we 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. The review has been changed from reporting odds ratio to risk ratio because the Tobacco Addiction group has altered its policy.

RESULTS

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies; Characteristics of ongoing studies.

The literature search identified 13 studies which met the inclusion criteria. Full details for each study are given in the Characteristics of included studies table. Four studies had more than one associated publication or abstract (Kinnunen 2008; Marcus 1999; Prapavessis 2007; Ussher 2003) and these are listed under the study identifier in the reference section. Six trials had fewer than 25 people in each treatment arm. 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 one of the studies a multi-session 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). In the one study with a single session cessation programme, participants were post-acute myocardial infarction (AMI) patients and the intervention was for relapse prevention (Taylor 1988). Three studies included nicotine patches as part of the smoking cessation programme (Marcus 2005; Prapavessis 2007; Ussher 2003), one study used nicotine gum (Kinnunen 2008) and one use nicotine replacement therapy of an unspecified type (Cornuz 2007).

All the 12 studies recruiting current smokers set a quit date. The exercise programme began before the quit date in nine studies (Cornuz 2007; Hill 1993; Kinnunen 2008; Marcus 1991; Marcus 1995; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003) on the quit date in two (Hill 1985; Martin 1997) and after the quit date in one (Russell 1988). Two studies entailed exercise programmes lasting for less than six weeks (Hill 1985; Martin 1997). Most of the trials employed supervised, group-based exercise supplemented by a home-based programme. Three studies did not provide a home programme (Marcus 1991; Marcus 1995; Marcus 1999) and one study used only brief exercise counselling towards pursuing home-based exercise (Ussher 2003).

Excluded studies

The literature search revealed a number of trials which did not satisfy the specific 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 broad 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 habits.

(b) Multiple independent variables and a single dependent variable: Four studies were found which 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 Additional Table 1), almost all following temporary abstinence. The findings of these studies are summarised at the end of the discussion.

Table 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-mod- erate 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	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

Table 1. Studies on the acute effect of exercise (*Continued*)

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

Table 1. Studies on the acute effect of exercise (*Continued*)

	c.17 hrs				ings = 0.53, 0.47 & 0.74, at T2, T3 & T4 (all non sig at P<.05).
Daniel 2004	Between subjects (randomly assigned) . Pre- (T1), mid- (T2), 0 (T3), 5 (T4) & 10 mins (T5) post-treatment. Abstinence period; 11-15 hrs	84 inactive M & F. Mean CPD = 17 Mean age = 30 yrs. Mean FTND = 4.0. Mean baseline SoD = 4.1.	(a) 40-60% HRR cycling; (b)10-20% HRR cycling; (c) passive control. (a) & (b) achieved target intensity prior to 2.5 mins (during warm-up) and maintained until 5 mins, then 2.5 min warm down.	5 MPSS items, plus desire & SoD to smoke items.	Results presented as change scores from baseline. (a) reduced cf (c) for: desire (at T2 & T3); SoD to smoke (at T3 & T4); irritability & restless (at T4 & T5); tension, (at T4). (b) reduced cf (c) poor concentration (at T3). Condition differences, (a) < (c) ES = 1.16, 0.97, 0.58, 0.24 (at T2, T3, T4 & T5, respectively) for SoD.
Taylor 2005 Taylor 2006a	Within subjects. Randomly ordered. Assessments at Pre (T1), mid (T2), immediately (T3), 10 mins (T4), 20 mins (T5) post-treatment. Abstinence period: >15 hrs	10 M & 5 F, active. Mean CPD = 17 Mean age = 26 yrs. Mean FTND = 4.0. Mean baseline SoD = 5.8	(a) Self-paced 1 mile treadmill brisk walk (means = 10.8 RPE; 25% HRR, 18 mins), (b) passive waiting. (a) also had 2 min warm-up and cool down.	MPSS, desire & SoD to smoke, 2 factor 32-item QSU. FS & FAS. POMS scales.	(a) < (b) desire & SoD to smoke at T2, T3, T4, & T5 and both QSU scales at T5. Reduced tension & increased FS at T5 & increased FAS at T3. For desire to smoke, ESs=3.9, 3.7, 3.7, 3.1; & SoD ESs=3.8, 4.6, 2.8, 1.6 at T2, T3, T4 & T5, respectively.
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	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 con-

Table 1. Studies on the acute effect of exercise (*Continued*)

	period: 17.3 hrs				founded 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).
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 2006a Katomeri 2006b	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.

Table 1. Studies on the acute effect of exercise (*Continued*)

					(ES = 0.61). (a) < (b) for time to next cig (66 v. 31 min.)(ES = 0.85)
Taylor 2007 Taylor 2006b	Between subjects (randomly assigned). Measures at baseline, mid- & post-ex. then pre & post 3 tasks: Stroop, speech task, & handled lit cig. Ad lib. smoking. Abstinence period: 2 hrs	34 F & 26 M, moderately active. Mean age = 28.5 years. Mean CPD = 15 Non-quitters. Mean FTND = 3.5. Mean baseline SoD = 4.6.	(a) 15 mins self-paced treadmill brisk walk (means = RPE =11, HRR = 24%); (b) passive waiting. (a) also had 2 min warm-up.	Desire & SoD to smoke. MPSS, Time to next cig. after leaving lab. (from phone text). SBP/DBP & HR.	(a)< (b) for Desire & SoD & 7 MPSS items, at all assessments from mid-ex to post lit cig. ES for desire ranged from 1.04-1.78 with mean = 1.62. ES for SoD ranged from 1.2-2.07 with mean = 1.45. (a) attenuated responses to lit cig. cue for SoD to smoke (ES = 0.61), tension, stress, poor concentration & SBP. (a) also attenuated SBP & DBP responses to Stroop & speech tasks, and restlessness to Stroop. (a) > (b) for time to next cig (84 v 27 min) (ES=1.20)
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 2008	Within subjects (randomly assigned order). Measures at pre- (T1), mid- (T2), & 0 (T3), 10 (T4), 20 (T5), & 30	10 M & 8 F Mean age = 26 yrs. Moderately active. Non-quitters. Mean FTND = 4.4. Mean	All 15 mins. (a) Walking (RPE = 13.4, HR=133 bpm, HRR= 45-50%).	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

Table 1. Studies on the acute effect of exercise (*Continued*)

	(T6) min post-treatment.Abstinence period > 3hrs + smoking cues at baseline.	baseline SoD = 5.5	(b) Running (RPE = 16.2, HR =170 bpm, HRR=80-85%). (c) Passive seating (HR= 80 bpm)		& T4 and only (b) < (c) at T5. By 30 mins, no differences in cravings between (a), (b) & (c).
Janse van Rensburg 2007	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, smoked 13.7 CPD. Non quitters. Mean baseline Desire to smoke = 4.6	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 not reported here.	(a) < (b) at T2 & T3 (ES = 1.08) mins post-treatment only.
Janse van Rensburg 2008a	Within subjects. Randomly ordered. Pre-, Mid- (not QSU-brief) & post-exercise, + 5, 10 & 15 mins post-treatment. Abstinence period 15 hrs.	15 M & 8 F. Mean age 23.1 yrs. Mean CPD 13.7. Non-quitters. Mean FTND= 3.4. Mean baseline Desire to Smoke = 5.0	(a) 15 mins self-paced treadmill brisk walk (+ 2 mins warm-up & 1 min cool down) (means = RPE - 10.8, HR - 113). (b) passive waiting	Desire to smoke. 2 factor 10-item QSU. Other measures of cognitive functioning using Stroop colour-word task not reported here.	(a) < (b) Desire to smoke at T2, T3, T4 (ES = 1.46, 1.20 and 0.93, respectively). (a) < (b) for both QSU measures at T3, T4 & T5 (ES for Factor 1 = 1.96, 2.04 and 1.39, & Factor 2 = 1.47, 1.22 and 0.98, respectively).
Janse van Rensburg 2008b	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).
Everson 2008a	Between subjects (random assigned). Measures at pre- (T1), mid- (T2), & 5 (T3) & 30 (T4) min post-treatment. Mean abstinence	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-

Table 1. Studies on the acute effect of exercise (*Continued*)

	period: 17 hrs				PD, and (b) > (c) for SEES-PWB at T3. (a) < (c) for happiness, and (a) > (c) for composite MPSS & SEES-PD at T2.

AD-ACL: Activation-Deactivation-Adjective Check List; CPD: cigarettes per day; DBP Diastolic blood pressure; ES: effect size; ESR: Evening Symptom Report; F: female; FAS: Felt Arousal Scale; fMRI = functional magnetic resonance imagery (of the brain); FS: Feelings Scale; FTND: Fagerstrom Test for Nicotine Dependence; HONC: Hooked on Nicotine Checklist; HR: heart rate; HRR: heart rate reserve; M: male; MPSS: Mood & Physical Symptoms Scale; PANAS: Positive & Negative Affect Scale; POMS: Profile of Mood States; QSU: Questionnaire on Smoking Urges [Factor 1: anticipation of smoking as pleasant, enjoyable and satisfying, and Factor 2: reduced anticipation of relief from negative affect by smoking] 10-item QSU; RPE: Rating of Perceived Exertion; SAI: State Anxiety Inventory; SBP: systolic blood pressure; SEES: Subjective Exercise Experiences Scale (PWB = positive well-being, PD = psychological distress); SoD: Strength of Desire to smoke; SWS: Shiffman Withdrawal Scale;

* Data not available for ES calculation.

Risk of bias in included studies

Only five studies described the randomization method in detail (Cornuz 2007; Marcus 1999; Marcus 2005; Prapavessis 2007; Ussher 2003). The strictest measure of abstinence was continuous in five studies, prolonged abstinence in one, point prevalence in five, and not specified in two.

Post-randomization dropouts were excluded from the denominator in three studies (Hill 1993; Kinnunen 2008; Taylor 1988).

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 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 (Hill 1985; Kinnunen 2008; Marcus 1995; Prapavessis 2007; Ussher 2003). Only five studies had a sufficiently large sample size to have a good prospect of detecting a significant difference between the treatment and control conditions (Cornuz 2007; Marcus 1999; Marcus 2005; Martin 1997; 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

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 smok-

ers 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 (Cornuz 2007; 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). For example, the potential for exercise to be used to reduce cigarette cravings and withdrawal symptoms (Taylor 2007b) could have been made more explicit.

Demographic factors, such as age, gender, weight, fitness level, socio-economic status and occupation could influence outcomes for both smoking cessation (Jarvis 1997) and exercise behaviour (Caspersen 1994; Pate 1995). Of the four trials which recruited men and women, two compared outcomes by gender (Hill 1993; Ussher 2003), although 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, with only five studies recording ethnic status, and reporting a predominantly white sample (Kinnunen 2008; Marcus 1999; Marcus 2005; Martin 1997; Ussher 2003). Researchers must consider whether these results can be generalized to other national and ethnic populations (Caspersen 1994; King 1997; Mackay 1996). In addition, given the high prevalence of smoking among people with mental illness, research is needed to examine the role that physical activity may play as an aid to quitting and whether there would be interest among such mental health service users (Faulkner 2007).

Three of the studies did not present the participants' level of exercise at baseline (Hill 1985; 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 (Emmons 1994; Prochaska 1992; Ward 2003; deRuiter 2008) and it is not clear whether exercise interventions are effective as an aid to smoking cessation for this population.

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 or at a four-month follow up (Kinnunen 2008; Russell 1988) or at 12-month follow up (Prapavessis 2007). 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.

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 by chance weighed more than the controls at baseline, which makes interpretation of the finding problematic. 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 2005; Ussher 2003) or at 12 months post-cessation (Cornuz 2007; Ussher 2003). However, these latter studies 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.

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. Future work also needs to consider whether exercise is effective as an alternative to NRT for populations in which NRT is contraindicated or not widely used; for example, pregnant smokers have expressed a high level of interest in exercise as an aid to smoking cessation (Ussher 2004; Ussher 2007; Ussher 2008).

Aspects of Exercise Programming

For those beginning exercise either on or after the quit date (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). Furthermore, 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 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 (Marcus 1991; Marcus 1995; Marcus 1999) it is possible that the participants' high level of dependence on supervised exercise may have reduced their level of post-intervention activity.

Those adequately powered trials not showing a consistent effect of exercise on smoking abstinence (Cornuz 2007; Marcus 2005; Ussher 2003) had less intensive interventions than the other studies, in that they promoted moderate intensity rather than vigorous intensity exercise. In one case they relied solely on fairly brief exercise counselling (Ussher 2003), and in the other studies supervised exercise was only provided once per week (Cornuz 2007; Marcus 2005). 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 the intervention effort rather than the exercise intensity per se. 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.

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.

Exercise Adherence Issues

During the treatment period a range of behavioural methods were employed to improve adherence to the exercise programme. All but two of the studies (Kinnunen 2008, Ussher 2003) used group activities with full supervision of facility-based exercise and 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). All the studies reported activity levels for the treatment group during the treatment period with the exception of one study (Hill 1993). Where supervised exercise was offered attendance at these sessions was high. Where the emphasis was on home-based exercise (Cornuz 2007; Marcus 2005; 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 (Cornuz 2007). 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). Future studies need to consider other methods for increasing 'home-based' physical activity. For example, a recent study successfully used pedometers to increase participation in a walking-based intervention during smoking cessation (Prochaska 2008).

Although many of the studies reported fitness measures for the control group during the treatment period (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 (Cornuz 2007; 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 used behavioural techniques to encourage regular exercise. Only two of the studies recorded fitness measures at this time (Prapavessis 2007; Russell 1988) and only two studies reported levels of activity at 12-month follow up (Cornuz 2007; Ussher 2003). Therefore for the vast majority of studies it was not possible to relate long-term abstinence from smoking to exercise behaviour.

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). 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. Cornuz 2007 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 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, a recent 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

Of the included studies, only Marcus 1999 assessed the acute effects of each bout of exercise, reporting a significant reduction in tobacco withdrawal symptoms and cigarette cravings for the vast majority of the bouts throughout the intervention (Bock 1999). Twenty experimental studies have shown significant benefits of a single bout of exercise on cigarette cravings and withdrawal symptoms, almost exclusively among temporarily abstinent smokers (Taylor 2007b). We therefore recommend that future exercise and smoking cessation studies should include measures of both the acute and chronic effects on tobacco withdrawal and cravings. The 20 experimental studies are presented in Additional Table 1 and are summarised here. 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 (see Table 1). The effects are evident for moderate and vigorous intensity exercise, and for durations from 5 minutes of seated isometric exercise to 20 to 30 minutes of moderate intensity aerobic activity. Encouragingly, relatively convenient forms of physical activity (e.g., 10 to 15 minutes of brisk walking) can be just as effective as longer bouts. 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 2008). This suggests that cortisol changes do not mediate any effects of exercise on cravings. Taylor 2006a reported that reductions in urges to smoke in response to exercise were mediated by reductions in tension. One study 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 2007; Janse van Rensburg 2008b) following moderate intensity exercise. Finally, one study 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 simultaneously presented (alongside) matched neutral images. Further work is needed to understand how different types of activity (e.g., brief bouts of seated exercise, walking) influence symptoms known to cause relapse among actual quitters. Also, given this experimental evidence further research is needed to understand how best to promote the use of physical activity as a momentary aid to smoking cessation, in contrast to longer scheduled bouts of vigorous structured or facility-based exercise. Four studies (Reeser 1983; Thayer 1993; Katomeri 2006b; Taylor 2007) reported that a bout of moderate intensity exercise delayed ad libitum smoking, and further work is needed to assess whether a physical activity intervention would help as a smoking reduction strategy.

Overall commentary

A comparison of the studies was complicated by differences in study design and intervention, and by the relative paucity of 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. 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 in such a way that being a smoker is incompatible with these perceptions (Fox 1998).

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 trying to quit smoking and increase 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.

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.

AUTHORS' CONCLUSIONS

Implications for practice

Only one of the 13 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 the effect on smoking abstinence and on underlying processes such as tobacco withdrawal and cravings.

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REFERENCES

References to studies included in this review

Cornuz 2007 *{published data only}*

Cornuz J, Willi C, Chiolero A, Payot S, Stolanov R, Bize R. Physical activity as an aid to smoking cessation: A randomized controlled trial of sedentary adults smokers. *Journal of General Internal Medicine* 2007;**22**(S1):107.

Hill 1985 *{published data only}*

Hill JS. Effect of a program of aerobic exercise on the smoking behaviour of a group of adult volunteers. *Canadian Journal of Public Health* 1985;**76**:183–6.

Hill 1993 *{published data only}*

Hill RD, Rigdon M, Johnson S. Behavioural smoking cessation treatment for older chronic smokers. *Behavioural Therapy* 1993;**24**: 321–9.

Kinnunen 2008 *{published data only}*

* Kinnunen T, Leeman RF, Korhonen T, Quiles ZN, Terwal DM, Garvey AJ, et al.Exercise as an adjunct to nicotine gum in treating tobacco dependence among women. *Nicotine & Tobacco Research* 2008;**10**:689–703.

Quiles ZN, Leeman RF, Molinelli L, Nordstrom BL, Garvey AJ, Hartley LH, et al.Exercise as a behavioral adjunct to nicotine gum for smoking cessation - preliminary findings (PO2 42). Society for Research on Nicotine and Tobacco 8th Annual Meeting February 20-23, 2002, Savannah, Georgia. 2002:59.

Marcus 1991 *{published data only}*

Marcus BH, Albrecht AE, Niaura RS, Abrams DB, Thompson PD. Usefulness of physical exercise for maintaining smoking cessation in women. *American Journal of Cardiology* 1991;**68**:406–7.

Marcus 1995 *{published data only}*

Marcus BH, Albrecht AE, Niaura RS, Taylor ER, Simkin LR, Feder SI, et al.Exercise enhances the maintenance of smoking cessation in women. *Addictive Behaviors* 1995;**20**:87–92.

Marcus 1999 *{published data only}*

Albrecht AE, Marcus BH, Roberts M, Forman DE, Parisi AF. Effect of smoking cessation on exercise performance in female smokers participating in exercise training. *American Journal of Cardiology* 1998;**82**:950–5.

Bock BC, Marcus BH, King TK, Borrelli B, Roberts MR. Exercise effects on withdrawal and mood among women attempting smoking cessation. *Addictive Behaviors* 1999;**24**:399–410.

* Marcus BH, Albrecht AE, King TK, Parisi AF, Pinto BM, Roberts M, et al.The efficacy of exercise as an aid for smoking cessation in women: a randomised controlled trial. *Archives of Internal Medicine* 1999;**159**:1229–34.

Marcus 2005 *{published data only}*

Marcus B, Lewis B, Hogan J, King T, Albrecht RN, Bock B, et al.The efficacy of moderate intensity physical activity for smoking cessation among women. Annual Meeting of the Society of Behavioral Medicine, Salt Lake City, USA. 2003.

* Marcus BH, Lewis BA, Hogan J, King TK, Albrecht AE, Bock B, et al.The efficacy of moderate-intensity exercise as an aid for smoking cessation in women: a randomized controlled trial. *Nicotine & Tobacco Research* 2005;**7**:871–80.

Marcus BH, Lewis BA, King TK, Albrecht AE, Hogan J, Bock B, et al.Rationale, design, and baseline data for Commit to Quit II: an evaluation of the efficacy of moderate-intensity physical activity as an aid to smoking cessation in women. *Preventive Medicine* 2003; **36**:479–92.

Martin 1997 *{published data only}*

* Martin JE, Kalfas KJ, Patten CA. Prospective evaluation of three smoking interventions in 205 recovering alcoholics: one-year results of project SCRAP-Tobacco. *Journal of Consulting and Clinical Psychology* 1997;**65**:190–4.

Patten CA, Martin JE, Calfas KJ, Brown SA, Schroeder DR. Effect of three smoking cessation treatments on nicotine withdrawal in 141 abstinent alcoholic smokers. *Addictive Behaviors* 2000;**25**: 301–6.

Patten CA, Martin JE, Calfas KJ, Lento J, Wolter TD. Behavioral treatment for smokers with a history of alcoholism: predictors of successful outcome. *Journal of Consulting and Clinical Psychology* 2001;**69**:796–801.

Prapavessis 2007 *{published data only}*

Prapavessis H. The effects of exercise and nicotine replacement therapy on smoking rates in women. Eighth International Congress of Behavioural Medicine, Mainz, Germany. 2004.

* Prapavessis H, Cameron L, Baldi JC, Robinson S, Borrie K, Harper T, et al.The effects of exercise and nicotine replacement therapy on smoking rates in women. *Addictive Behaviors* 2007;**32**: 1416–32.

Russell 1988 *{published data only}*

Russell PO, Epstein LH, Johnson JJ, Block DR, Blair E. The effects of exercise as maintenance for smoking cessation. *Addictive Behaviors* 1988;**13**:215–8.

Taylor 1988 *{published data only}*

Taylor CB, Houston-Miller N, Haskell WL, Debusk RF. Smoking cessation after acute myocardial infarction: The effects of exercise training. *Addictive Behaviors* 1988;**13**:331–4.

Ussher 2003 *{published data only}*

Ussher, M, West, W, McEwen, A, Taylor, AH, & Steptoe, A. Randomized controlled trial of physical activity counseling as an aid to smoking cessation: 12 month follow-up. *Addictive Behaviors* 2007;**32**:3060–4.

* Ussher M, West R, McEwen A, Taylor A, Steptoe A. Efficacy of exercise counselling as an aid for smoking cessation: a randomized controlled trial. *Addiction* 2003;**98**:523–32.

Ussher M, West R, McEwen A, Taylor A, Steptoe A. Efficacy of exercise counselling as an aid to smoking cesstion: A randomised controlled trial. European Conference of the Society for Research on Nicotine and Tobacco. 2001.

References to studies excluded from this review

Caliani 2004 *{published data only}*

Caliani SE, Navas JCB, Gomez-Doblas JJ, Rivera RC, Jimenez BG, Lao MM, et al.Postmyocardial infarction cardiac rehabilitation in low risk patients. Results with a coordinated program of

cardiological and primary care.. *Revista Espanola de Cardiologia* 2004;**57**:53–9.

Chaney 2008 ***{published data only}***
Chaney SE, Sheriff S. Weight gain among women during smoking cessation: testing the effects of a multifaceted program. *American Association of Occupational Health Nurses Journal* 2008;**56**:99–105.

Cinciripini 1996 ***{published data only}***
Cinciripini PM, Cinciripini LG, Wallfisch A, Haque W, Van Vunakis H. Behavior therapy and the transdermal nicotine patch: effects on cessation outcome, affect, and coping. *Journal of Consulting and Clinical Psychology* 1996;**64**:314–23.

Clark 2005 ***{published data only}***
Clark MM, Hays JT, Vickers KS, Patten CA, Croghan IT, Berg E, et al.Body image treatment for weight concerned smokers: A pilot study. *Addictive Behaviors* 2005;**30**:1236–40.

Copeland 2006 ***{published data only}***
Copeland AL, Martin PD, Geiselman PJ, Rash CJ, Kendzor DE. Smoking cessation for weight-concerned women: group vs. individually tailored, dietary, and weight-control follow-up sessions. *Addictive Behaviors* 2006;**31**:115–27.

Daley 2004 ***{published data only}***
Daley AJ, Oldham ARH, Townson M. The effects of acute exercise on affective responses and desire to smoke in sedentary temporarily abstaining smokers: a preliminary study. *Journal of Sports Sciences* 2004;**22**:303–4.

Daniel 2004 ***{published data only}***
Daniel JZ, Cropley M, Ussher M, West R. Acute effects of a short bout of moderate versus light intensity exercise versus inactivity on tobacco withdrawal symptoms in sedentary smokers. *Psychopharmacology* 2004;**174**:320–6.

Daniel 2006 ***{published data only}***
Daniel JZ, Cropley M, Fife-Schaw C. The effect of exercise in reducing desire to smoke and cigarette withdrawal symptoms is not caused by distraction. *Addiction* 2006;**101**:1187–92.

Daniel 2007 ***{published data only}***
Daniel JZ, Cropley M, Fife-Schaw C. Acute exercise effects on smoking withdrawal symptoms and desire to smoke are not related to expectation. *Psychopharmacology* 2007;**195**:125–9.

Everson 2006 ***{published data only}***
Everson ES, Daley AJ, Ussher M. Does exercise have an acute effect on desire to smoke, mood and withdrawal symptoms in abstaining adolescent smokers. *Addictive Behaviors* 2006;**31**:1547–58.

Everson 2008a ***{published data only}***
Everson ES, Daley AJ, Ussher M. Moderate and vigorous intensity exercise acutely reduce cravings and withdrawal symptoms in abstaining young adult smokers. *Mental Health and Physical Activity* 2008;**1**:26–31.

Fortmann 1995 ***{published data only}***
Fortmann SP, Killen JD. Nicotine gum and self-help behavioral treatment for smoking relapse prevention: results from a trial using population-based recruitment. *Journal of Consulting and Clinical Psychology* 1995;**63**:460–8.

Grove 1993 ***{published data only}***
Grove JR, Wilkinson A, Dawson BT. Effects of exercise on selected correlates of smoking withdrawal. *International Journal of Sport Psychology* 1993;**24**:217–36.

Grove 2006 ***{published data only}***
Grove JR, Wilkinson A, Dawson BT, Eastwood PR, Heard NP. Effects of exercise on subjective aspects of sleep during tobacco withdrawal. *Australian Psychologist* 2005;**41**: 69–76.

Hurt 1992 ***{published data only}***
Hurt RD, Dale LC, Offord KP, Bruce BK, McClain FL, Eberman KM. Inpatient treatment of severe nicotine dependence. *Mayo Clinic Proceedings* 1992;**67**:823–8.

Hurt 1994 ***{published data only}***
Hurt RD, Eberman KM, Croghan IT, Offord KP, Davis LJ Jr, Morse RM, et al.Nicotine dependence treatment during inpatient treatment for other addictions: a prospective intervention trial. *Alcoholism, Clinical and Experimental Research* 1994;**18**:867–72.

Janse van Rensburg 2007 ***{published data only}***
Janse van Rensburg K, Taylor AH, Hodgson T. The effects of exercise on regional brain activation in response to smoking cues during temporary abstinence from smoking. 12th European Congress of Sport Psychology, Halkidiki, Greece, 4-9 September. 2007.

Janse van Rensburg 2008a ***{published data only}***
Janse van Rensburg K, Taylor AH. The effects of acute exercise on cognitive functioning and cigarette cravings during temporary abstinence from smoking. *Human Psychopharmacology: Clinical and Experimental* 2008;**23**:193–9.

Janse van Rensburg 2008b ***{published data only}***
Janse van Rensburg K, Taylor AH, Hodgson T. The effects of acute exercise on attentional biases to smoking related stimuli during temporary abstinence from smoking. *Journal of Sports Science* (in press);**BASES Conference Abstracts**.

Jones 2001 ***{published data only}***
Jones C, Griffiths RD, Skirrow P, Humphris G. Smoking cessation through comprehensive critical care. *Intensive Care Medicine* 2001; **27**(9):1547–9.

Jonsdottir 2001 ***{published data only}***
Jonsdottir D, Jonsdottir H. Does physical exercise in addition to a multicomponent smoking cessation program increase abstinence rate and suppress weight gain? An intervention study. *Scandinavian Journal of the Caring Sciences* 2001;**15**:275–82.

Katomeri 2006a ***{unpublished data only}***
Katomeri M, Taylor AH. Effects of a single session of walking on urge to smoke, using the 10-item Urges to Smoke Questionnaire (QSU). British Association of Sport and Exercise Sciences Student Conference, Edinburgh. 2006.

Katomeri 2006b ***{unpublished data only}***
Katomeri M, Taylor A. Effects of walking on desire to smoke and withdrawal symptoms during a smoking cue, and *ad libitum* smoking. 11th Annual Congress of the European College of Sport Science, Lausanne, Switzerland, 5-8 July. 2006.

McIver 2004 *{published data only}*
McIver S, O'Halloran P, McGartland M. The impact of Hatha yoga on smoking behavior. *Alternative Therapy Health & Medicine* 2004; **10**:22–3.

Mikhail 1983 *{published data only}*
Mikhail C. The acute effects of aerobic exercise on cigarette smoking. Masters Thesis, University of Lethbridge, Canada. 1983.

Oenema 2008 *{published data only}*
Oenema A, Brug J, Dijkstra A, de Weerdt I, de Vries H. Efficacy and use of an internet-delivered computer-tailored lifestyle intervention, targeting saturated fat intake, physical activity and smoking cessation: a randomized controlled trial.. *Annals of Behavioral Medicine* 2008;**35**:125–35.

Ortega Sanchez-P 2006 *{published data only}*
Ortega Sanchez-Pinilla R, Aquilar-Blanco EM. Running and its influence on smoking habits. *Atencion Primaria* 2006;**37**:478–81.

Pomerleau 1987 *{published data only}*
Pomerleau OF, Scherzer HH, Grunberg NE, Pomerleau CS, Judge J, Fetig JB, et al.The effects of acute exercise on subsequent cigarette smoking. *Journal of Behavioral Medicine* 1987;**10**:117–27.

Prochaska 2008 *{published data only}*
Prochaska JJ, Hall SM, Humfleet G, Munoz RF, Reus V, Goerecki J, et al.Physical activity as a strategy for maintaining tobacco abstinence: a randomized controlled trial. *Preventive Medicine* 2008;**in press**.

Ramsay 2004 *{published data only}*
Ramsay J, Hoffmann A. Smoking cessation and relapse prevention among undergraduate students: a pilot demonstration project. *Journal of the American College of Health.* 2004;**53**:11–18.

Reeser 1983 *{published data only}*
Reeser KA. The effects of repeated aerobic and non-aerobic exercise on cigarette smoking. Masters Thesis, University of Alberta, Canada. 1983.

Scerbo 2008 *{unpublished data only}*
Scerbo, F. The impact of acute vigorous physical activity on cravings, affect, and cortisol concentration among abstinent smokers experiencing withdrawal. Master's thesis, University of Toronto, Canada 2007.

Spring 2004 *{published data only}*
Spring B, Doran N, Pagoto S, Schneider K, Pingitore R, Hedeker D. Randomized controlled trial for behavioral smoking and weight control treatment: effect of concurrent versus sequential intervention. *Journal of Consulting and Clinical Psychology* 2004;**72**: 785–96.

Taylor 2005 *{published data only}*
Taylor AH, Katomeri M, Ussher M. Acute effects of self-paced walking on urges to smoke during temporary smoking abstinence. *Psychopharmacology* 2005;**181**:1–7.

Taylor 2006a *{published data only}*
Taylor AH, Katomeri M, Ussher M. Effects of walking on cigarette cravings and affect in the context of Nesbitt's paradox and the circumplex model. *Journal of Sport & Exercise Psychology* 2006;**28**: 18–31.

Taylor 2006b *{published data only}*
Taylor AH, Katomeri M. Effects of a brisk walk on blood pressure responses to the Stroop, a speech task and a smoking cue among temporarily abstinent smokers. *Psychopharmacology* 2006;**184**: 247–53.

Taylor 2007 *{published data only}*
Taylor AH, Katomeri M. Walking reduces cue-elicited cigarette cravings and withdrawal symptoms, and delays *ad libitum* smoking. *Nicotine & Tobacco Research* 2007;**9**:1–8.

Thayer 1993 *{published data only}*
Thayer R, Peters D, Takahaski P, Birkhead-Flight A. Mood and behaviour (smoking and sugar snacking) following moderate exercise: A partial test of self-regulation theory. *Personality and Individual Differences* 1993;**14**:97–104.

Ussher 2001 *{published data only}*
Ussher M, Nunziata P, Cropley M, West R. Effect of a short bout of exercise on tobacco withdrawal symptoms and desire to smoke. *Psychopharmacology* 2001;**158**:66–72.

Ussher 2006 *{published data only}*
Ussher M, Doshi R, Sampuran AK, West R. Acute effect of isometric exercise on desire to smoke and tobacco withdrawal symptoms. *Human Psychopharmacology: Clinical & Experimental* 2006;**21**:39–46.

Ussher 2008 *{published data only}*
Ussher M, Aveyard P, Coleman T, Strauss L, West R, Marcus B, et al.Physical activity as an aid to smoking cessation during pregnancy: two feasibility studies. *BioMed Central Public Health* 2008;**in press**.

Vickers 2005 *{published data only}*
Vickers KS, Patten CA, Clark MM, Ebbert JO, Croghan IT, Hathaway JC. Exercise intervention for women with depressive symptoms interested in smoking cessation. Society for Research on Nicotine and Tobacco 11th Annual Meeting, Prague, Czech Republic. 2005.

Whiteley 2007 *{published data only}*
Whiteley JA, Napolitano MA, Lewis BA, Williams DM, Albrecht A, Neighbors CJ, et al.Commit to Quit in the YMCAs: translating an evidence-based quit smoking program for women into a community setting. *Nicotine & Tobacco Research* 2007;**9**:1227–35.

Zwick 2006 *{published data only}*
Zwick RH, Mutzbacher P, Dovjak N, Heinzle C, Burghuber OC, Zwick H. Exercise in addition to nicotine replacement therapy improves success rates in smoking cessation.. *Chest* 2006;**130**:145s.

References to ongoing studies

Bock 2007 *{published data only}*
Yoga for women attempting smoking cessation. Ongoing study 2007.

Ussher 2008b *{published data only}*
A pragmatic randomized controlled trial of physical activity as an aid to smoking cessation during pregnancy. Ongoing study 2008.

Additional references

Aaron 1995
Aaron DJ, Dearwater SR, Anderson R, Olsen T, Kriska AM, Laporte RE. Physical activity and the initiation of high-risk health

behaviors in adolescents. *Medicine and Science in Sports and Exercise* 1995;**27**:1639–45.

Abrantes 2007
Abrantes AM, Strong DR, Lloyd-Richardson EE, Niaura R, Kahler CW, Brown RA. Regular exercise as a protective factor in relapse following smoking cessation treatment. Society for Research on Nicotine and Tobacco 13th Annual Meeting February 21-24, Austin, Texas.. 2007.

Albrecht 1998
Albrecht AE, Marcus BH, Roberts M, Forman DE, Parisi AF. Effect of smoking cessation on exercise performance in female smokers participating in exercise training. *American Journal of Cardiology* 1998;**82**:950–5.

Allen 2004
Allen SS, Brintnell DM, Hatsukami D, Reich B. Energy intake and physical activity during short-term smoking cessation in postmenopausal women. *Addictive Behaviors* 2004;**29**:947–51.

Ashelman 2000
Ashelman MW. *Stop Smoking Naturally*. New Canaan, Connecticut: Keats Publishing Inc., 2000.

Audrain-McGovern 2003
Audrain-McGovern J, Rodriguez D, Moss HB. Smoking progression and physical activity. *Cancer Epidemiology, Biomarkers and Prevention* 2003;**12**:1121–9.

Blair 1985
Blair SN, Jacobs DR Jr, Powell KE. Relationships between exercise or physical activity and other health behaviors. *Public Health Reports* 1985;**100**:172–80.

Bock 1999
Bock BC, Marcus BH, King TK, Borrelli B, Roberts MR. Exercise effects on withdrawal and mood among women attempting smoking cessation. *Addictive Behaviors* 1999;**24**:399–410.

Boots 1998
The Boots Company PLC. *Give up Smoking! Your guide to a brighter future without smoking*. Nottingham UK: The Boots Company PLC, 1998.

Borrelli 2002
Borrelli B, Hogan JW, Bock B, Pinto B, Roberts M, Marcus B. Predictors of quitting and dropout among women in a clinic-based smoking cessation program. *Psychology of Addictive Behaviors* 2002; **16**:22–7.

Boutelle 2000
Boutelle K N, Murray DM, Jeffery RW, Hennrikus DJ, Lando HA. Associations between exercise and health behaviors in a community sample of working adults. *Preventive Medicine* 2000;**30**:217–24.

Boyle 2000
Boyle RG, O'Connor P, Pronck N, Tan A. Health behaviors of smokers, ex-smokers, and never smokers in an HMO. *Preventive Medicine* 2000;**31**:177–82.

Cahill 2007
Cahill K, Stead LF, Lancaster T. Nicotine receptor partial agonists for smoking cessation. *Cochrane Database of Systematic Reviews* 2008, Issue 3. [DOI: 10.1002/14651858.CD006103.pub3]

Caspersen 1994
Caspersen CJ, Merritt RK, Stephens T. International exercise patterns: a methodological perspective. In: Dishman R editor(s). *Advances in Exercise Adherence*. Champaign Ill: Human Kinetics, 1994:73–110.

Colbert 2001
Colbert LH, Hartman TJ, Malila N, Limburg PJ, Pietinen P, Virtamo J, et al.Physical activity in relation to cancer of the colon and rectum in a cohort of male smokers. *Cancer Epidemiology, Biomarkers and Prevention* 2001;**10**:265–8.

Correia 1998
Correia CJ, Simons J, Carey KB, Borsari BE. Predicting drug use: application of behavioral theories of choice. *Addictive Behaviors* 1998;**23**:705–9.

Cosgrove 2002
Cosgrove KP, Hunter RG, Carroll ME. Wheel-running attenuates intravenous cocaine self-administration in rats: sex differences. *Pharmacology, Biochemistry and Behavior* 2002;**73**:663–71.

Coulson 1997
Coulson NS, Eiser C, Eiser JR. Diet, smoking and exercise: interrelationships between adolescent health behaviours. *Child: Care, Health and Development* 1997;**23**:207–16.

Davis 1997
Davis TC, Arnold C, Nandy I, Bocchini JA, Gottlieb A, George RB, et al.Tobacco use among male high school athletes. *Journal of Adolescent Health* 1997;**21**:97–101.

Derby 1994
Derby CA, Lasater TM, Vass K, Gonzalez S, Carleton RA. Characteristics of smokers who attempt to quit and of those who recently succeeded. *American Journal of Preventive Medicine* 1994; **10**:327–34.

deRuiter 2006
deRuiter W, Faulkner G. Tobacco harm reduction strategies: the case for physical activity. *Nicotine & Tobacco Research* 2006;**8**: 157–68.

deRuiter 2008
Deruiter WK, Faulkner G, Cairney J, Veldhuizen S. Characteristics of physically active smokers and implications for harm reduction. *American Journal of Public Health* 2008;**9**:925–31.

Dishman 2006
Dishman RK, Berthoud HR, Booth FW, Cotman CW, Edgerton VR, Fleshner MR, et al.Neurobiology of exercise. *Obesity (Silver Spring)* 2006;**14**(3):345–56.

DOH 2004
Department of Health. *At least five a week: Evidence on the impact of physical activity and its relationship to health, a report from the Chief Medical Officer*. London: Department of Health, 2004.

Doherty 1995
Doherty K, Kinnunen T, Militello FS, Garvey AJ. Urges to smoke during the first month of abstinence: relationship to relapse and predictors. *Psychopharmacology* 1995;**119**:171–8.

Doherty 1998
Doherty SC, Steptoe A, Rink E, Kendrink T, Hilton S. Readiness to change health behaviours among patients at high risk of

cardiovascular disease. *Journal of Cardiovascular Risk* 1998;**5**: 147–53.

Doll 2004
Doll R, Peto R, Boreham J, Sutherland I. Mortality in relation to smoking: 50 years' observations on male British doctors. *BMJ* 2004;**328**:1519.

Emmons 1994
Emmons KM, Marcus BH, Linnan L, Rossi JS, Abrams DB. Mechanisms in multiple risk factor interventions: Smoking, exercise, and dietary fat intake among manufacturing workers. *Preventive Medicine* 1994;**23**:481–9.

Escobedo 1993
Escobedo LG, Marcus SE, Holtzman D, Giovino GA. Sports participation, age at smoking initiation, and the risk of smoking among US high school students. *JAMA.* 1993;**269**:391–5..

Everson 2008b
Everson ES, Taylor AH, Ussher M. Promoting physical activity to aid smoking cessation: A qualitative perspective on multiple health behaviour change. British Psychological Society (Division of Health Psychology)/European Society of Health Psychology Conference, Bath. 2008.

Faulkner 2007
Faulkner G, Taylor AH, Munro S, Selby P, Gee C. Exploring the acceptability of physical activity programming within a smoking cessation service for individuals with severe mental illness. *Patient Education and Counselling* 2007;**66**:123–6.

Fox 1998
Fox KR. *The physical self: From motivation to well being*. Champaign Ill: Human Kinetics, 1998.

Fox 1999
Fox KR. The influence of physical activity on mental well-being. *Public Health Nutrition* 1999;**2**:411–8.

Gritz 1989
Gritz ER, Klesges RC, Meyers AW. The smoking and body weight relationship: Implications for intervention and postcessation weight control. *Annals of Behavioral Medicine* 1989;**11**:144–53.

Haddock 2000
Haddock CK, O'Byrne KK, Klesges RC, Talcott W, Lando H, Peterson AL. Relapse to smoking after basic military training in the U.S. Air Force. *Military Medicine* 2000;**165**:884–8.

Haddock 2004
Haddock CK, Lando H, Klesges RC, Peterson AL, Scarinci IC. Modified tobacco use and lifestyle change in risk-reducing beliefs about smoking. *American Journal of Preventive Medicine* 2004;**27**: 35–41.

Hall 1989
Hall SM, McGee R, Tunstall C, Duffy J, Benowitz N. Changes in food intake and activity after quitting smoking. *Journal of Consulting and Clinical Psychology* 1989;**57**:81–6.

Hedblad 1997
Hedblad B, Ogren M, Isacsson SO, Janzo L. Reduced cardiovascular mortality risk in male smokers who are physically active. *Archives of Internal Medicine* 1997;**157**:893–9.

Helmert 1994
Helmert U, Herman B, Shea S. Moderate and vigorous leisure-time physical activity and cardiovascular disease risk factors in West Germany, 1984-1991. *International Journal of Epidemiology* 1994; **23**:285–92.

Hill 1981
Hill JS. Health behaviour: The role of exercise in smoking cessation. *Canadian Association for Health, Physical Education and Recreation (CAHPER) Journal* 1981;**28**:15–8.

Hu 2002
Hu G, Pekkarinen H, Hanninen O, Yu Z, Guo Z, Tian H. Commuting, leisure-time physical activity, and cardiovascular risk factors in China. *Medicine and Science of Sports and Exercise* 2002; **34**:234–8.

Hughes 1992
Hughes JR, Gulliver SB, Fenwick JW, Valliere WA, Cruser K, Pepper S, et al.Smoking cessation among self-quitters. *Health Psychology* 1992;**11**:331–4.

Hughes 2007
Hughes JR, Stead LF, Lancaster T. Antidepressants for smoking cessation. *Cochrane Database of Systematic Reviews* 2007, Issue 1. [DOI: 10.1002/14651858.CD000031.pub3]

Hyman 2007
Hyman DJ, Pavlik VN, Taylor WC, Goodrick GK, Moye L. Simultaneous vs sequential counseling for multiple behavior change. *Archives of Internal Medicine* 2007;**167**:1152–8.

Jarvis 1997
Jarvis M. Patterns and predictors of smoking cessation in the general population. In: Bollinger CT, Fagerstrom KO editor(s). *The Tobacco Epidemic, Progress in Respiratory Research*. Vol. **28**, Basel: Karger, 1997:151–4.

Jorenby 1996
Jorenby DE, Hatsukami DK, Smith SS, Fiore MC, Allen S, Jensen J, et al.Characterization of tobacco withdrawal symptoms: transdermal nicotine reduces hunger and weight gain. *Psychopharmacology* 1996;**128**:130–8.

Kaczynski 2008
Kaczynski AT, Manske SR, Mannell RC, Grewal K. Smoking and physical activity: a systematic review. *American Journal of Health Behavior* 2008;**32**:93–110.

Kawachi 1996
Kawachi I, Troisi RJ, Rotnitzky AG, Coakley EH, Colditz MS, Colditz MD. Can exercise minimise weight gain in women after smoking cessation?. *American Journal of Public Health* 1996;**86**: 999–1004.

King 1989
King AC, Frey-Hewitt B, Dreon D, Wood P. Diet versus exercise in weight maintenance: The effects of minimal intervention strategies on long term outcomes in men. *Archives of Internal Medicine* 1989; **149**:2741–6.

King 1992
King AC, Blair SN, Bild DE, Dishman RK, Dubbert PM, Marcus BH, et al.Determinants of physical activity and interventions in adults. *Medicine and Science in Sports and Exercise* 1992;**24**: S221–36.

King 1996
King TK, Marcus BH, Pinto BM, Emmon, KM, Abrams DB. Cognitive behavioural mediators of changing multiple behaviours: Smoking and a sedentary lifestyle. *Preventive Medicine* 1996;**25**: 684–91.

King 1997
King TK, Borrelli B, Black C, Pinto BM, Marcus BH. Minority women and tobacco: Implications for smoking cessation interventions. *Annals of Behavioral Medicine* 1997;**19**:301–13.

Kujala 2007
Kujala UM, Kaprio J, Rose RJ. Physical activity in adolescence and smoking in young adulthood: a prospective twin cohort study.. *Addiction* 2007;**102**:1151–7.

Mackay 1996
Mackay J, Crofton J. Tobacco and the developing world. *British Medical Bulletin* 1996;**52**:206–21.

Marcus 2004
Marcus BH, Hampl JS, Fisher EB. *How to Quit Smoking without Gaining Weight*. Pocket Books: New York., 2004.

Marlatt 1985
Marlatt GA, Gordon JR. *Relapse prevention: maintenance strategies in the treatment of addictive behaviors*. New York: Guildford, 1985.

McDermot 2008
McDermot L, Dobson A, Owen N. Determinants of continuity and change over 10 years in young women's smoking. *Addiction* 2008;**in press**.

McEwen 2006
McEwen A, Hajek P, McRobbie H, West R. *Manual of smoking cessation: A guide for counsellors and practitioners*. Oxford: Blackwell Publishing, 2006.

Metheny 1998
Metheny KB, Weatherman KE. Predictors of smoking cessation and maintenance. *Journal of Clinical Psychology* 1998;**54**:223–35.

Nguyen 1998
Nguyen MN, Beland F, Otis J. Is the intention to quit smoking influenced by other heart-healthy lifestyle habits in 30- to 60-year-old men?. *Addictive Behaviors* 1998;**23**:23–30.

Niaura 1998
Niaura R, Marcus B, Albrecht A, Thompson P, Abrams D. Exercise, smoking cessation, and short-term changes in serum lipids in women: a preliminary investigation. *Medicine and Science in Sports and Exercise* 1998;**30**:1114–8.

Nishi 1998
Nishi N, Jenicek M, Tatara K. A meta-analytic review of the effect of exercise on smoking cessation. *Journal of Epidemiology* 1998;**8**: 79–84.

Paavola 2001
Paavola M, Vartianen E, Puska P. Smoking cessation between teenage years and adulthood. *Health Education Research* 2001;**16**: 49–57.

Pate 1995
Pate PR, Pratt M, Steven SN, Haskell WL, Macera CA, Bouchard C, et al.Exercise and public health: A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 1995;**273**:402–7.

Pate 1996
Pate RR, Heath GW, Dowda M, Trost SG. Associations between physical activity and other health behaviors in a representative sample of US adolescents. *American Journal of Public Health* 1996; **86**:1577–81.

Patten 2001
Patten CA, Vickers KS, Martin JE, Williams CD. Exercise interventions for smokers with a history of alcoholism: Exercise adherence rates and effect of depression on adherence. *Addictive Behaviors* 2001;**27**:1–11.

Peretti-Watel 2003
Peretti-Watel P, Guagliardo V, Verger P, Pruvost J, Mignon P, Obadia Y. Sporting activity and drug use: Alcohol, cigarette and cannabis use among elite student athletes. *Addiction* 2003;**98**: 1249–56.

Peretti-Watel 2002
Peretti-Watel P, Beck F, Legleye S. Beyond the U-curve: the relationship between sport and alcohol, cigarette and cannabis use in adolescents. *Addiction* 2002;**97**:707–16.

Peto 1996
Peto R, Lopez AD, Boreham J, Thun M, Heath C Jr, Doll R. Mortality from smoking worldwide. *BMJ* 1996;**52**:12–21.

Prochaska 1992
Prochaska JO, DiClemente CC, Norcross JC. In search of how people change. Applications to addictive behaviors. *The American Psychologist* 1992;**47**:1102–14.

Quit 1994
QUIT. *Helping Smokers to Quit: A handbook for the practice nurse, health visitor and midwife*. London: Department of Health, 1994.

Raw 1998
Raw M, McNeill A, West R. *Smoking cessation guidelines for health professionals: A guide to effective smoking cessation interventions for the health care system*. London: HEA, 1998.

Rodriguez 2004
Rodriguez D, Audrain-McGovern J. Team sport participation and smoking: analysis with general growth mixture modeling. *Journal of Pediatric Psychology* 2004;**29**:299–308.

Rodriguez 2008
Rodriguez D, Dunton GF, Tcherne J, Sass J. Physical Activity and Adolescent Smoking: A Moderated Mediation Model. *Mental Health and Physical Activity* 2008;**in press**.

Russell 1983
Russell PO, Epstein LH, Erickson KT. Effects of acute exercise and cigarette smoking on autonomic and neuromuscular responses to a cognitive stressor. *Psychological Reports* 1983;**53**:199–206.

Sasco 2002
Sasco AJ, Laforest L, Benhaim-Luzon V, Poncet M, Little RE. Smoking and its correlates among preadolescent children in France. *Preventive Medicine* 2002;**34**:226–34.

Schneider 2007
Schneider KL, Spring B, Pagoto SL. Affective benefits of exercise while quitting smoking: influence of smoking-specific weight concern. *Psychology of Addictive Behaviors* 2007;**21**:255–60.

Schroder 2003
Schroder H, Elosua R, Marrugat J [REGICOR Investigators]. The relationship of physical activity with dietary cancer-protective nutrients and cancer-related biological and lifestyle factors. *European Journal of Cancer Prevention* 2003;**12**:339–46.

Schuman 2001
Schumann A, Hapke U, Rumpf HJ, Meyer C, John U. The association between degree of nicotine dependence and other health behaviours. Findings from a German general population study. *European Journal of Public Health* 2001;**11**:450–2.

Sedgwick 1988
Sedgwick AW, Davidson AH, Taplin RE, Thomas DW. Effects of physical activity on risk factors for coronary heart disease in previously sedentary women: A five-year longitudinal study. *Australian and New Zealand Journal of Medicine* 1988;**18**:600–5.

Senti 2001
Senti M, Elosua R, Tomas M, Sala J, Masia R, Ordovas JM, et al.Physical activity modulates the combined effect of a common variant of the lipoprotein lipase gene and smoking on serum triglyceride levels and high-density lipoprotein cholesterol in men. *Human Genetics* 2001;**109**:385–92.

Shinton 1997
Shinton R. Lifelong exposures and the potential for stroke prevention: The contribution of cigarette smoking, exercise and body fat. *Journal of Epidemiology and Community Health* 1997;**51**: 138–43.

Sorenson 1992
Sorenson G, Goldberg R, Ockene J, Klar J, Tannenbaum T, Lemeshow S. Heavy smoking among a sample of employed women. *American Journal of Preventive Medicine* 1992;**8**:207–14.

Stead 2008
Stead LF, Perera R, Bullen C, Mant D, Lancaster T. Nicotine replacement therapy for smoking cessation. *Cochrane Database of Systematic Reviews* 2008, Issue 1. [DOI: 10.1002/14651858.CD000146.pub3]

Steptoe 1989
Steptoe A, Edwards S, Moses J, Mattews A. The effects of exercise training on mood and perceived coping ability in anxious adults from the general population. *Journal of Psychosomatic Research* 1989;**33**:537–47.

Takemura 2000
Takemura Y, Sakurai Y, Inaba Y, Kugai N. A cross-sectional study on the relationship between leisure or recreational physical activity and coronary risk factors. *Tohoku Journal of Experimental Medicine* 2000;**192**:227–37.

Taylor 2000
Taylor AH. Physical activity, stress and anxiety: a review. In: Biddle SJH, Fox K, Boutcher S editor(s). *Physical activity and psychological well-being*. London: Routledge, 2000.

Taylor 2007b
Taylor AH, Ussher MH, Faulkner G. The acute effects of exercise on cigarette cravings, withdrawal symptoms, affect and smoking behaviour: A systematic review. *Addiction* 2007;**102**:534–43.

Taylor 2008
Taylor AH, Faulkner, G. Inaugural Editorial. *Mental Health and Physical Activity* 2008;**in press**.

USDHHS 1990
US Department of Health & Human Services. *The health consequences of smoking cessation: A report of the Surgeon General*. Rockville, MD: Public Health Service, Office on Smoking & Health, 1990.

USDHHS 2001
US Department of Health & Human Services. *Women and Smoking: A Report of the Surgeon General*. Rockville, MD: Public Health Service, Office of the Surgeon General, 2001.

USDHHS 2008
US Department of Health & Human Services. *Treating Tobacco Use and Dependence:2008 Update. A report of the Surgeon General*. Rockville, MD: Public Health Service, 2008.

Ussher 2004
Ussher M, West R, Hibbs N. A survey of pregnant smokers' interest in different types of smoking cessation support. *Patient Education and Counselling* 2004;**54**:67–72.

Ussher 2007
Ussher M, Ah-Yoon M, West R, Straus L. Factors associated with exercise participation and attitudes to exercise among pregnant smokers. *Journal of Smoking Cessation* 2007;**2**:12–16.

Vander Weg 2001
Vander Weg MW, Klesges RC, Eck Clemens LH, Meyers AW, Pascale RW. The relationship between ethnicity, gender, and short-term changes in energy balance following smoking cessation. *International Journal of Behavioral Medicine* 2001;**8**:163–77.

Vickers 2003
Vickers KS, Patten CA, Lane K, Clark MM, Croghan IT, Schroeder DR, et al.Depressed versus nondepressed young adult tobacco users: differences in coping style, weight concerns and exercise level. *Health Psychology* 2003;**22**:498–503.

Ward 2003
Ward KD, Vander Weg MW, Klesges RC, Kovach KW, Elrod MC, DeBon M, et al.Characteristics of highly physically active smokers in a population of young adult military recruits. *Addictive Behaviors* 2003;**28**:1405–18.

West 1989
West R, Hajek P, Belcher M. Severity of withdrawal symptoms as a predictor of outcome of an attempt to quit smoking. *Psychological Medicine* 1989;**19**:981–5.

West 1997
West R. Getting serious about smoking cessation: a review of products services and techniques. No Smoking Day Report, London 1997.

Williams 2008
Williams DM, Lewis BA, Dunsiger S, King TK, Jennings E, Marcus BH. Increasing fitness is associated with fewer depressive symptoms during successful smoking abstinence among women. *International Journal of Fitness* 2008;**4**:39–44.

Woodhouse 1990
Woodhouse K, Rigg E. *Quit & Get Fit: A guide to running a six week course*. London: HEA, 1990.

References to other published versions of this review

Ussher 2000a

Ussher MH, Taylor AH, West R, McEwen A. Does exercise aid smoking cessation? A systematic review. *Addiction* 2000;**95**: 199–208.

Ussher 2000b

Ussher M, West R, Taylor AH, McEwen A. Exercise interventions for smoking cessation. *Cochrane Database of Systematic Reviews* 2000, Issue 3.[Art. No.: CD002295. DOI: 10.1002/14651858.CD002295.pub3]

Ussher 2002

Ussher MH, Taylor AH, West R, McEwen A. Exercise interventions for smoking cessation. *Cochrane Database of Systematic Reviews* 2002, Issue 3.[Art. No.: CD002295. DOI: 10.1002/14651858.CD002295.pub3]

Ussher 2005

Ussher M. Exercise interventions for smoking cessation. *Cochrane Database of Systematic Reviews* 2005, Issue 1. [DOI: 10.1002/14651858.CD002295.pub2]

* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

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

Cornuz 2007

Methods	Country: Switzerland Randomization: computer generated
Participants	481, mean age 42, mean cpd 27, sedentary: < 150 mins moderate intensity physical activity per week and <60 mins vigourous 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 5 weeks 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 Data from published abstract, confirmed by authors

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Hill 1985

Methods	Country: Canada Randomization: method not stated
Participants	26 women, 10 men, mean age 40, mean cpd 32
Interventions	(a) Intervention: CV activity: various, group, facility, 30 mins, twice weekly for 5 weeks + home activity + CP twice weekly for 5 weeks (b) Control, CP alone Exercise began on quit date
Outcomes	7 day PP abstinence Validation: CO Follow up: 1, 3 ,6 months
Notes	Contact time not balanced

Hill 1985 (*Continued*)

Risk of bias		
Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

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		
Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

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)

Kinnunen 2008 (*Continued*)

Outcomes	Prolonged abstinence Validation: CO, cotinine Follow-up: 1 week, 1, 4, 12 months
Notes	Not an intention to treat analysis as 263 women were randomized, but only those considered to have made a quit attempt (N=182) were included in the analysis. Contact time balanced between (a) and (b)

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B Unclear

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

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

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).

Marcus 1995 (*Continued*)

	(b) CP as (a) + health education 3 times/week for 15 weeks Exercise began before quit date
Outcomes	7 day PPA Validation: saliva cotinine <10ng/ml. Follow-up: 1, 3, 12 months
Notes	Contact time balanced between a and b

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

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

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Marcus 2005

Methods	Country: USA Randomization: Computer-generated
Participants	217 women, mean age 43, mean cpd 21 exercise <= 90 mins /wk.

Marcus 2005 (*Continued*)

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

Item	Authors' judgement	Description
Allocation concealment?	Yes	A- Adequate

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. (c) Control: Different CP (once/week for 8 weeks) and Nicotine Anonymous meetings (3 times/week for 4 weeks) Exercise began on quit date
Outcomes	7-day PP abstinence Validation: CO < 10ppm Follow up: 7 days, 6, 12 months
Notes	Contact time not matched, different cessation programmes

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Prapavessis 2007

Methods	Country: NZ Randomization: Computer-generated
Participants	142 women, mean age 38, exercise < twice a week. (excludes 21 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

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - adequate

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

Item	Authors' judgement	Description

Russell 1988 (*Continued*)

Allocation concealment?	Unclear	B - Unclear

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

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

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

Ussher 2003 (*Continued*)

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

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]*

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
Everson 2006	Acute study
Everson 2008a	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
Grove 1993	The outcome was withdrawal symptoms rather than smoking abstinence

(*Continued*)

Grove 2006	Had sleep disturbance as the main outcome, rather than smoking abstinence
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
Janse van Rensburg 2007	Acute study
Janse van Rensburg 2008a	Acute study
Janse van Rensburg 2008b	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.
Katomeri 2006a	Acute study
Katomeri 2006b	Acute study
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
Pomerleau 1987	Acute study
Prochaska 2008	The 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 2008	Acute study
Spring 2004	Combined an exercise programme with a dietary intervention. Therefore it was not possible to examine the specific effects of exercise.

(*Continued*)

Taylor 2005	Acute study
Taylor 2006a	Acute study
Taylor 2006b	Acute study
Taylor 2007	Acute study
Thayer 1993	Acute study
Ussher 2001	Acute study
Ussher 2006	Acute study
Ussher 2008	Did not include a control group
Vickers 2005	The follow up was less than six months
Whiteley 2007	Did not include a control group
Zwick 2006	Unable to obtain details of study from authors

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

Bock 2007

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	

Ussher 2008b

Trial name or title	A pragmatic randomized controlled trial of physical activity as an aid to smoking cessation during pregnancy
Methods	RCT
Participants	866 pregnant women
Interventions	14 sessions of supervised exercise (treadmill walking) + 6 sessions of behavioural support versus 6 sessions of behavioural support alone
Outcomes	Main outcome: smoking abstinence at end of pregnancy
Starting date	2008
Contact information	Dr Michael Ussher, mussher@sgul.ac.uk
Notes	

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	12		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]
Cornuz 2007	26/241	28/240		0.92 [0.56, 1.53]
Prapavessis 2007	12/68	8/53		1.17 [0.52, 2.65]
Kinnunen 2008	9/92	2/34		1.66 [0.38, 7.31]

WHAT'S NEW

Last assessed as up-to-date: 5 July 2008.

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.

HISTORY

Review first published: Issue 3, 2000

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 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.

DECLARATIONS OF INTEREST

The first and second authors (MHU and AT) were involved in the conduct of one of the included studies (Ussher 2003).

SOURCES OF SUPPORT

Internal sources

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- University of Exeter, UK.

External sources

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- Canadian Tobacco Control Research Initiative, Canada.

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INDEX TERMS

Medical Subject Headings (MeSH)

*Exercise; Randomized Controlled Trials as Topic; Smoking [psychology]; Smoking Cessation [*methods]

MeSH check words

Humans