The role of mindfulness in physical activity: A systematic review

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Abstract

Despite continued public health campaigns to promote physical activity, a majority of the population is inactive. In recent years, mindfulness-based approaches have been used in health and lifestyle interventions for physical activity promotion. We conducted a systematic literature review using the PRISMA guidelines to investigate the evidence for the potential of mindfulness-based approaches for physical activity. We searched electronic databases for papers that met eligibility criteria and identified 40 studies for inclusion. Evidence from cross-sectional studies (n = 20) indicated a positive relationship between dispositional mindfulness and physical activity, particularly with psychological factors related to physical activity. Five studies found that the mindfulness-physical activity relationship was mediated by stress, psychological flexibility, negative affect and shame, satisfaction, and state mindfulness. Evidence from mindfulness-based interventions (n = 20) suggested positive between-subjects effects on physical activity, but interventions varied in duration, session length, group size, delivery, content, and follow-up. Mindfulness-based interventions were more likely to be successful if they were physical activity-specific and targeted psychological factors related to physical activity. The body of research shows a need for more methodologically rigorous studies to establish the effect of mindfulness on physical activity and to identify potential mechanisms involved in the mindfulness-physical activity relationship reliably.

Introduction

Research has consistently demonstrated the beneficial effect of physical activity (PA) for health promotion and obesity prevention [1, 2]. PA refers to any bodily movement produced by skeletal muscles that results in energy expenditure [3]. PA therefore broadly encompasses exercise, sports, and activities done as part of daily living, occupation, leisure, and active transportation [4]. Department of Health advice for the United Kingdom recommends adults to do at least 150 minutes of moderate intensity PA weekly [5, 6]. However, despite continued public health campaigns to promote the benefits of PA and motivate people to become more active [7] and less sedentary [8], physical inactivity affects one fourth of the global adult population [9] and continues to pose a risk of overweight and obesity [10], type-2 diabetes [5], and related cancers [11]. Lifestyle interventions aimed at increasing PA show only modest changes in target behaviours [12-15] and limited long-term effects [16-18]. Such interventions suffer from high drop-out and low adherence in the short [19] and long term [20].

Several psychological factors may contribute to greater PA adherence and maintenance, such as autonomous motivation, self-efficacy, and the use of self-regulation skills [21]. However, more research is needed to identify the mechanisms of successful PA behaviour change. This is particularly important for individuals with overweight and obesity who may experience additional barriers to PA [21-24], such as discomfort while exercising [25-29], feeling too overweight [30-32], feeling embarrassed or insecure [30], lacking motivation [25, 27, 31, 33], and reporting less positive attitudes towards PA [27, 31, 33, 34]. Novel interventions are therefore required that remove such barriers to optimise PA uptake, adherence, and maintenance. In recent years,

mindfulness practices have received increasing attention in lifestyle interventions, because of their potential to address psychological barriers to change [35]. The purpose of the current review is to summarise and evaluate evidence for the potential of mindfulness-based approaches for PA promotion and obesity prevention.

Mindfulness is widely described as paying attention on purpose to unfolding moment-by-moment experience with an open, non-judging, and accepting attitude [36, 37]. In addition to purposeful attention and accepting attitude, intention is often cited as a core concept of mindfulness meditation training (MMT) [38-40]. Psychological research distinguishes between dispositional mindfulness and mindfulness cultivated through MMT. Dispositional mindfulness is often defined as a "basic human quality" [41] that everyone possesses to a varying extent; it is widely assessed by self-report questionnaires in cross-sectional studies. Meditation practice, on the other hand, involves intention to attend to the present moment [42] and is aimed at cultivating mindful awareness [41, 43].

Mindfulness-based interventions (MBIs) typically comprise educational advice and MMT [44], the latter adapted for a Western secular context from Eastern traditions of meditation practices, most notably Buddhism. MMT is thus an inherent part of several MBIs, for example, Mindfulness-Based Stress Reduction (MBSR) [45], Mindfulness-Based Cognitive Therapy (MBCT) [46], and Mindfulness-Based Strengths Practice (MBSP) [47]. Other therapeutic approaches, such as Acceptance and Commitment Therapy (ACT) [48] and Dialectical Behaviour Therapy (DBT) [49], are often referred to as MBIs as they include training in mindfulness skills (e.g., through exercises and education), even though they do not necessarily include MMT [38]. ACT,

for instance, is structured to increase the psychological flexibility of participants through various core processes [48]. These approaches, collectively dubbed "the third wave of behavioural therapies" [35, 50], differ greatly in session length, content, delivery method, and purpose [39]. Variation in MBIs has led to vague and incongruent definitions of mindfulness elements [38, 51], which makes comparison between studies difficult.

Mindfulness training enhances self-regulation abilities, including attentional mechanisms, behaviour flexibility, and emotion regulation [40, 52, 53]. Regarding PA, mindful awareness could enhance acceptance of negative or uncomfortable thoughts and sensations that are likely to occur during PA, particularly in novice exercisers or individuals with overweight and obesity (e.g., pain, fatigue, exertion) and thus encourage people to sustain PA in the short [20] and long term [54]. Mindfulness-based approaches used as an adjunct to weight-loss interventions have the potential to prepare people who have difficulty starting and maintaining an exercise program [55] by improving their acceptance of PA-related discomfort [56]. However, little is currently known about the effect of mindfulness on PA behaviour change.

The current review is the first to summarise existing knowledge on the relationship between dispositional mindfulness and PA (by examining cross-sectional and longitudinal studies) and to summarise outcomes from MBIs targeting PA. Three objectives were developed to investigate: 1) the relationship between mindfulness and PA; 2) psychological factors that potentially explain the relationship between mindfulness and PA; and 3) the effect of MBIs on PA outcomes.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [57].

Data sources and search strategies

A systematic search was conducted for papers published up to 1 June 2018 using the databases Google Scholar, MEDLINE (PubMed), PsycINFO, PsycARTICLES, and Ovid. Boolean combinations of the following search terms and their abbreviations were used: mindfulness; dispositional mindfulness; cultivated mindfulness; mindfulness meditation training; Acceptance and Commitment Therapy; Dialectical Behaviour Therapy; Mindfulness-Based Stress Reduction; Mindfulness-Based Cognitive Therapy; Mindfulness-Based Strengths Practice; Zen meditation; Vipassana meditation; physical activity; exercise; fitness; and physical health. The reference sections of included articles were scanned to identify any additional studies that met the inclusion criteria.

Given the relative infancy of the mindfulness and PA literature, a broad view of "mindfulness" was adopted that encompassed dispositional mindfulness, mindfulness skills, and mindfulness meditation. As such, it was important to include all MBIs, even those without MMT, in an effort to investigate the different ways mindfulness is conceptualised within PA intervention research. MBIs were defined as interventions that either involved MMT and/or trained individuals in mindfulness skills through formal or informal exercises. Mindfulness skills were defined as those identified in the mindfulness literature, including observing, describing, acting with

awareness, accepting without judgement [58], non-reactivity (i.e., refraining from impulsive reactions toward internal experience) [59], intention (i.e., purpose), attention (i.e., paying attention in the present moment) [40], openness, and curiosity [41]. This review examined self-reported and objectively measured PA (e.g., frequency, duration, type) and psychological factors related to PA (e.g., motivation, satisfaction, enjoyment).

Inclusion and exclusion criteria

Papers were included if they: 1) were cross-sectional or longitudinal studies providing a quantitative measure of dispositional mindfulness or intervention studies that contained MBIs (with or without a PA component); 2) measured any frequency, type, duration, or intensity of PA using quantitative outcomes; and 3) were published in English. Where the MBI contained PA, only studies that controlled for the PA component by including a PA-based control group were considered for inclusion. This is because MBIs that contain PA within the intervention do not isolate the effects of the MBI on PA outcomes. Studies were not excluded based on participant characteristics (e.g., age, gender, ethnicity, health condition, weight status) or year of publication. The decision to include or exclude studies was based initially on the title, then on the abstract, and finally on the full text.

Data extraction

JS extracted data from the identified studies and PW checked for accuracy and consistency. The following data were extracted: 1) authors and year of

publication; 2) study design; 3) sample size and gender (percentage females); 4) age; 5) body mass index (BMI); 6) measures used; 7) mindfulness and PA outcomes; and 8) study quality. Additional data extracted for intervention studies included information about intervention and control conditions. For studies that described statistically significant outcomes, a *p*-value < .05 was considered significant.

Quality assessment

Quality was assessed using the Effective Public Health Practice Project (EPHPP) tool. The EPHPP provides good interrater agreement for overall quality grade [60] across a variety of quantitative study designs [61]. Studies were assessed on: 1) selection bias; 2) study design; 3) confounders; 4) blinding; 5) data collection methods; and 6) withdrawals and dropouts. Components were scored 1 ("strong"), 2 ("moderate"), or 3 ("weak"). EPHPP guidelines were used to generate a global score: no "weak" component ratings = "strong"; one "weak" component rating = "moderate"; ≥two "weak" component ratings = "weak". JS assessed all studies and PW assessed a subsample (n = 15). Cohen's kappa [62] was calculated to determine interrater reliability, showing good agreement (87%) between scores (κ = .752, p = .001). Discrepancies were due to differences in interpretation of criteria and were discussed with the fourth author (PL) until a 100% agreement in coding was reached.

Results

Paper selection

As of 1 June 2018, the search protocol yielded 2500 papers (see Figure 1). After removing duplicates, 1149 papers were reviewed based on the title. Of those, 245 abstracts were retained for review and 60 articles were reviewed based on the full text. One cross-sectional study was excluded because it did not analyse the relationship between mindfulness and PA. One cross-sectional and one longitudinal study were excluded because they did not provide a measure of dispositional mindfulness. Ten intervention studies were excluded because they did not provide a measure of PA and seven others were excluded because PA was a component of the MBI with no PA-based control group. All full-text articles were independently screened by two reviewers.

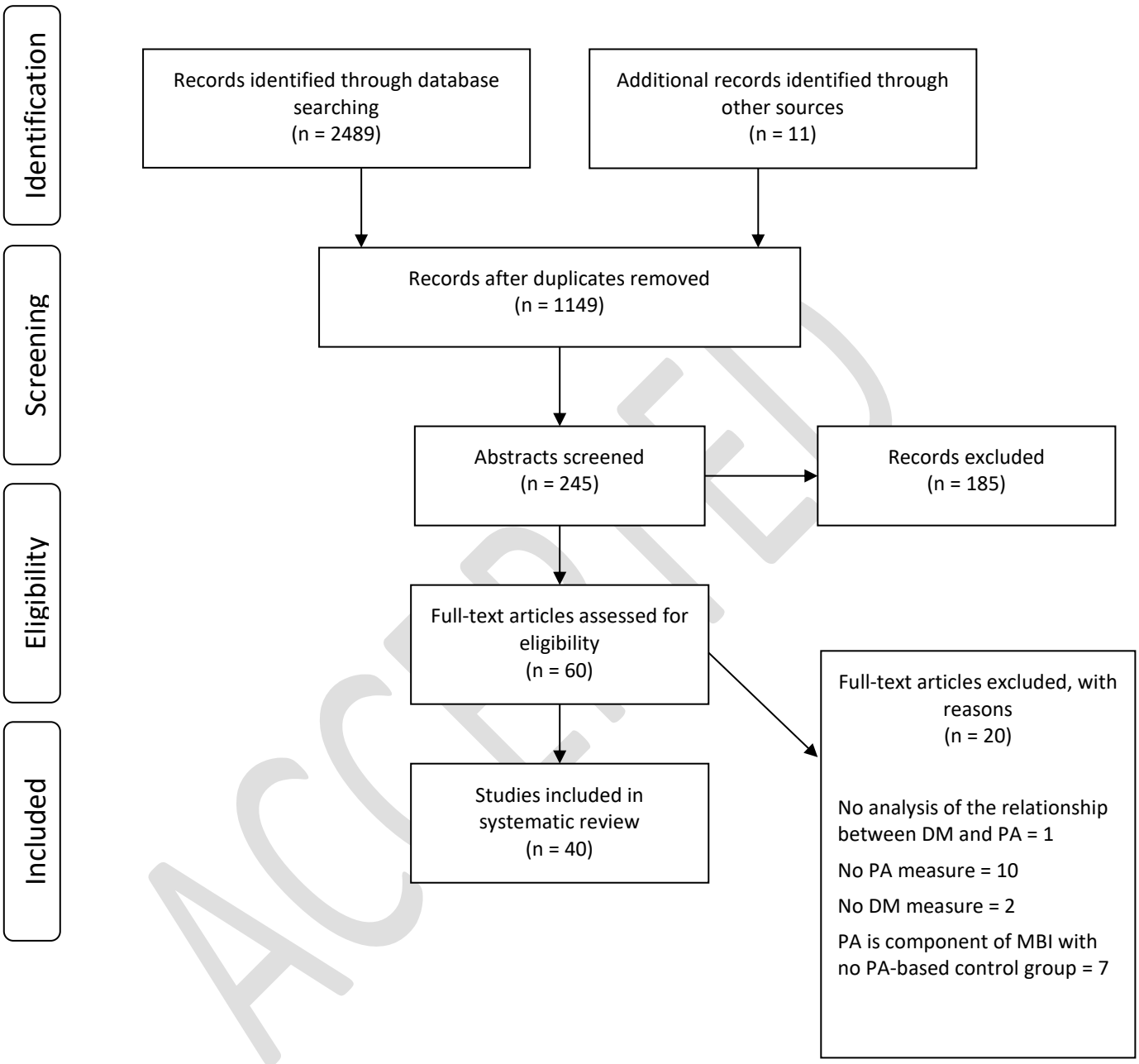

Figure 1. PRISMA flowchart of study selection.
Note. DM = dispositional mindfulness; MBI = mindfulness-based intervention; PA = physical activity.

Study characteristics

A final sample of 40 papers (from 39 studies) was included in this review (see Table 1), consisting of 19 cross-sectional studies, one longitudinal study, five cohort studies (no control group), one non-randomised controlled trial, and 14 randomised controlled trials (RCTs). The majority of the included studies were rated as “weak” (n = 18) or “moderate” (n = 21); one study was rated “strong”.

Table 1. Characteristics of the reviewed studies.

Author (year)	Design	Participants			Intervention	Control	Measures†	Main findings	Study quality
		N (% female)	Mean years (SD)	Mean BMI (SD)					
Caluyong et al. (2015) [63]	CS	74 (39.2)	63.4 (10.2)	-	N/A	N/A	**DM:** FFMQ **PA:** SDSCA **Other:** none	DM not correlated with PA	Weak
Chatzisarantis & Hagger (2007) [64]	CS	**Study 1:** 226 (51.3) **Study 2:** 292 (52.4)	**Study 1:** 19.23 (1.1) **Study 2:** 19.48 (1.2)	-	N/A	N/A	**DM:** MAAS **PA:** intentions, behaviour **Other:** SRHI	DM not correlated with PA, but positively correlated with attitude and perceived behavioural control; DM moderated the intention-PA relationship	Weak
Clevenger et al. (2017) [65]	CS	754 (47)	Range 8-13	Percentile 69.2 (29.3)	N/A	N/A	**DM:** CAMM **PA:** PAQ-C **Other:** none	PA not associated with DM	Moderate
Fanning et al. (2018) [66]	CS	148 (60)	55.7 (10.1)	35.5 (6.7)	N/A	N/A	**DM:** MAAS **PA:** SDSCA **Other:** none	DM not associated with exercise	Weak
Gao & Shi (2015) [67]	CS	1354 (62)	18.3 (-)	-	N/A	N/A	**DM:** MAAS **PA:** IPAQ **Other:** none	DM positively associated with PA	Weak
Gilbert & Waltz (2010) [20]	CS	269 (68.8)	20.9 (-)	-	N/A	N/A	**DM:** FFMQ **PA:** IPAQ **Other:** ECS	DM positively correlated to MPA, VPA, self-efficacy for making time for exercise and self-efficacy for resisting exercise relapse	Weak
Grinnell et al. (2011) [68]	CS	75 (89.3)	18.1 (0.1)	80% healthy, 16% overweight, 4% obese	N/A	N/A	**DM:** MAAS **PA:** IPAQ **Other:** WRBQ	DM not correlated with PA, but positively correlated with self-regulation and outcome expectations of PA, and negatively correlated with personal barriers of PA	Weak
Kangasniemi et al. (2014) [69]	CS	108 (79)	43 (5.2)	**More active:** 23.4 (2.8) **Less active:** 28.3 (5.7)	N/A	N/A	**DM:** KIMS **PA:** accelerometer **Other:** AAQ-2	DM positively correlated with MVPA, but not correlated with HEPA; physically active group scored higher on DM and psychological flexibility than less active group	Moderate

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Author (year)	Design	Participants			Intervention	Control	Measures[†]	Main findings	Study quality
		N (% female)	Mean years (SD)	Mean BMI (SD)					
Loucks et al. (2015) [70]	CS	382 (57)	47 (-)	-	N/A	N/A	**DM:** MAAS **PA:** IPAQ **Other:** none	DM level positively associated with PA	Moderate
Martin et al. (2013) [71]	CS	159 (100)	18-80 (-)	24.9 (4.5)	N/A	N/A	**DM:** MAAS **PA:** exercise frequency **Other:** MEQ	DM and mindful eating positively correlated with yoga, but negatively correlated with aerobic exercise	Weak
Murphy et al. (2012) [72]	CS*	441 (100)	19.06 (3.6)	-	N/A	N/A	**DM:** MAAS **PA:** LTEQ **Other:** none	DM not correlated with exercise frequency	Weak
Roberts & Danoff-Burg (2010) [73]	CS	553 (69.6)	18.8 (2.1)	-	N/A	N/A	**DM:** FFMQ **PA:** WLI **Other:** PSS	DM positively correlated with daily PA, weekly PA, and PA enjoyment; DM-PA was partially mediated by stress	Weak
Ruffault et al. (2016) [74]	CS	280 (58.2)	21 (2.7)	21.9 (2.8)	N/A	N/A	**DM:** MAAS **PA:** IPAQ **Other:** BREQ-2	DM not correlated with PA, but positively correlated with PA motivation; DM moderated PA-intrinsic motivation	Weak
Ruffault et al. (2017) [75]	CS	100 (48)	33.49 (11.6)	-	N/A	N/A	**DM:** MAAS **PA:** IPAQ **Other:** AAQ-2	PA not correlated with DM, but positively correlated with acceptance	Weak
Sagui-Henson et al. (2018) [76]	CS	233 (53.2)	39.6 (12.3)	-	N/A	N/A	**DM:** FFMQ **PA:** IPAQ **Other:** AAQ-2, PSS	DM not correlated with PA; mindfulness-PA was fully mediated by psychological flexibility and reduced stress	Weak
Slonim et al. (2015) [77]	CS	207 (67.1)	21.8 (3.6)	-	N/A	N/A	**DM:** FFMQ **PA:** HPLP-II **Other:** none	PA positively correlated with DM	Weak

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Author (year)	Design	Participants			Intervention	Control	Measures[†]	Main findings	Study quality
		N (% female)	Mean years (SD)	Mean BMI (SD)					
Tsafou et al. (2016) [78]	CS	398 (50.3)	41.28 (13.3)	25.2 (4.5)	N/A	N/A	**DM:** MAAS **PA:** IPAQ, satisfaction **Other:** SRHI, MFPA	DM not correlated with PA, but positively correlated with PA satisfaction; state mindfulness-PA was mediated by PA satisfaction	Weak
Tsafou et al. (2016) [79]	CS	305 (51.1)	40.7 (13)	25.2 (4.5)	N/A	N/A	**DM:** FFMQ, MAAS **PA:** IPAQ **Other:** MFPA, PA satisfaction	DM positively correlated with PA when measured by the MAAS only; DM-PA relationship was mediated first by state mindfulness and then by PA satisfaction	Weak
Ulmer et al. (2010) [80]	CS	226 (65)	49.96 (14.7)	26.6 (5.7)	N/A	N/A	**DM:** MAAS **PA:** IPAQ, exercise maintenance, perceived success in meeting exercise goals **Other:** AAQ-9, FMI, WBSI	Participants who scored higher on DM and state mindfulness were less likely to skip exercise	Weak
Kang et al. (2017) [81]	LGT**	67 (61.2)	33.4 (13.0)	28.0 (6.8)	Computerized health message intervention + daily text messages	N/A	**DM:** MAAS **PA:** IPAQ, accelerometer **Other:** BREQ-2, PANAS	DM predicted self-reported VPA and exercise motivation (1m only), but not MPA, walking, or objectively measured PA; DM-PA motivation was mediated by negative affect and shame	Moderate
Carlson et al. (2004) [82]	COH	42 (78.6)	54.5 (10.9)	-	MBSR 90min x 8w + 3h retreat	N/A	**DM:** none **PA:** times/w **Other:** none	PA frequency increased from pre- to post-intervention	Moderate
Cox et al. (2018) [83]	COH	23 (82.6)	19.3 (1.1)	24.8 (5.0)	10min audio mindfulness script during 30min treadmill test	N/A	**DM:** none **PA:** RPE **Other:** valence, SMS-PA, PACES	State mindfulness, affective valence, and PA enjoyment was higher and RPE was lower in mindfulness condition	Moderate

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Author (year)	Design	Participants			Intervention	Control	Measures[†]	Main findings	Study quality
		N (% female)	Mean years (SD)	Mean BMI (SD)					
Goodwin et al. (2012) [84]	COH	16 (68.8)	56.42 (12.7)	-	ABBT 4 x 90min (with psychoeducation on heart-healthy behaviours)	N/A	**DM:** PHLMS **PA:** IPAQ **Other:** PAAAQ, values and goals clarity	Participants made moderate increases in PA from pre- to post-treatment; PA change associated with PHLMS-acceptance and values/goals clarity	Moderate
Lucas et al. (2015) [85]	COH	17 (100)	61.1 (7.0)	33.8 (6.5)	MIM+D 1h x 8w + 6w home practice (with dietary counselling)	N/A	**DM:** FFMQ, MAAS **PA:** PAQ, accelerometer, SPPB **Other:** none	There were small to moderate increases in DM (MAAS only), PA (self-reported walking only), and physical performance	Moderate
Salmoirago-Blotcher et al. (2013) [86]	COH	174 (61)	47 (10.3)	-	MBSR 2.5h x 7w + all-day class at 6w + 45min/d home practice	N/A	**DM:** FFMQ **PA:** HBQ **Other:** none	Participants in the "sedentary" category decreased from pre- to post-intervention; increase in activities aimed to improve flexibility and overall strength/flexibility score	Moderate
Ingraham et al. (2016) [87]	CCT	266 (100)	≥40 (-)	-	Mindfulness-based workshops 2h x 12w (with PA psychoeducation)	TAU 12-16w (n=106)	**DM:** none **PA:** IPAQ **Other:** MEQ	PA increased from pre- to post-intervention (TAU > MBI); mindful eating increased in the mindfulness group	Weak
Butryn et al. (2011) [88]	RCT	54 (100)	23.1 (3.8)	25.1 (5.6)	ACT-based workshop 2x2h, held 2w apart	Education workshop 2x2h, held 2w apart (n=19)	**DM:** PHLMS **PA:** athletic centre visits **Other:** PAAAQ	Athletic centre visits increased from pre- to post-intervention (ACT > control); PAAAQ and PHLMS-awareness increased (ACT=control)	Moderate
Davis (2008) [89]	RCT	71 (88.7)	45.1 (8.3)	32.9 (3.7)	SBWL 30min x 24w + MMT	SBWL (n=24) or SBWL + resistance training (n=23)	**DM:** MAAS **PA:** PPAQ **Other:** none	PA increased at 3m (MBI = control) and at 6m (SBWL plus resistance only); DM increased in all groups	Moderate
Fletcher (2012) [90]	RCT	72 (83.3)	52.6 (11.8)	35.5 (SE = 0.1)	ACT 1 x 6h	Waitlist (n=31)	**DM:** FFMQ **PA:** IPAQ **Other:** AAQ-2, PAAQ	PA increased from pre- to post-intervention (ACT = control)	Moderate

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Author (year)	Design	Participants			Intervention	Control	Measures[†]	Main findings	Study quality
		N (% female)	Mean years (SD)	Mean BMI (SD)					
Gotink et al. (2017) [91] (*follow-up of Younge et al. 2015 [92]*)	RCT	324 (46.3)	**MBI:** 43.2 (14.1) **Control:** 43.2 (13.7)	**MBI:** 25.9 (4.6) **Control:** 25.7 (4.7)	TAU + 12w online MMT	TAU (n=109)	**DM:** none **PA:** 6-min walk test (6MWT), HR **Other:** PSS	Improvements in the 6MWT and HR in the mindfulness group were not significant at 12m	Moderate
Grossman et al. (2017) [93]	RCT	163 (100)	**Fibromyalgia:** 54.1 (9.1) **Control:** 53.4 (6.0)	-	MBSR 2.5h x 8w	Waitlist or matched intervention 2.5h x 8w (n=33)	**DM:** none **PA:** HR, accelerometer **Other:** none	PA and HR decreased from pre- to post-intervention (MBSR = control)	Strong
Ivanova et al. (2015) [94]	RCT	39 (100)	23 (5)	-	ACT 1 x 40min	Short video of PA goals 1 x 40min (n=21)	**DM:** none **PA:** HR, RPE **Other:** PACES	There was a significant group by time interaction for exercise tolerance time, RPE, and perceived exercise enjoyment (ACT > control)	Moderate
Meyer et al. (2018) [95]	RCT	49 (82)	51.9 (11.1)	31.3 (7.8)	MBSR 2.5h x 8w + 6h retreat + home practice	Aerobic Exercise Training (AET) 2.5h x 8w + 6h retreat + home practice (n=14) or control (n=17)	**DM:** none **PA:** accelerometer **Other:** none	Seasonal declines in PA did not differ between groups (MBSR = AET = control); MVPA bouts of ≥10min increased in the AET group only	Moderate
Miller et al. (2012) [96]	RCT	52 (63.5)	**MB-EAT-D:** 53.9 (8.2) **SC:** 54.0 (7.0)	**MB-EAT-D:** 36.2 (1.2) **SC:** 36.1 (1.2)	MB-EAT-D 2.5h x 8w + 2.5h x 2w +1 and 3m follow-up (with PA and health psychoeducation)	"Smart Choices" (SC) Diabetes self-management 2.5h x 8w + 2.5h x 2w +1 and 3m follow-up (n=25)	**DM:** none **PA:** MPAQ **Other:** none	PA increased from pre- to post-intervention at 1m (MB-EAT-D = control); no change in PA at 3m	Moderate
Moffitt & Mohr (2015) [97]	RCT	59 (83.1)	**ACT:** 43.5 (12.2) **Control:** 43.9 (10.3)	**ACT:** 32.0 (7.1) **Control:** 31.7 (6.0)	ACT DVD + 12w walking programme building up to 3000 steps in 30min x 5d/w	12w walking programme building up to 3000 steps in 30min x 5d/w (n=27)	**DM:** none **PA:** IPAQ, pedometer **Other:** AAQ, PA goals	Average step count and PA classifications increased from pre- to post-intervention (ACT > control); participants in the ACT group were more likely to reach PA goals	Moderate

Table 1. Characteristics of the reviewed studies.

Author (year)	Design	Participants			Intervention	Control	Measures†	Main findings	Study quality
		N (% female)	Mean years (SD)	Mean BMI (SD)					
Palmeira et al. (2017) [98]	RCT	73 (100)	**Kg-Free:** 42.0 (8.8) **TAU:** 42.7 (8.4)	**Kg-Free:** 34.8 (5.3) **TAU:** 33.7 (4.8)	TAU + Kg-Free intervention based on mindfulness, ACT and compassion 2.5h x 10w + 2 x 2.5h (with health psychoeducation)	TAU (n=37)	**DM:** FFMQ **PA:** 3-item questionnaire **Other:** none	PA increased from pre- to post-intervention with higher overall PA (Kg-Free > TAU); no between-group differences for DM were found post-intervention	Moderate
Salmoirago-Blotcher et al. (2018) [99]	RCT	53 (59)	**HE-MT:** 14.6 (0.3) **HE-AC:** 14.5 (0.4)	**HE-MT:** Percentile 66.5 (30.8) **HE-AC:** Percentile 69.4 (31.3)	Health education 4d/w x 2w + modified MBSR 45min x 8w (HE-MT)	Health education 4d/w x 2w + attention control 1 x 8w (HE-AC) (n=23)	**DM:** none **PA:** PAR **Other:** none	MVPA post-intervention was higher among males and those with higher MVPA at baseline (HE-MT > HE-AC)	Moderate
Tapper et al. (2009) [100]	RCT	62 (100)	41 (13)	31.6 (6.1)	ACT-based workshop 3 x 2h over 3w	Normal diet (n=31)	**DM:** none **PA:** BPAT **Other:** AAQ-2	PA increased from pre- to post-intervention (ACT > control); those that still used workshop principles at 6m had greater increases in PA	Weak
VanBuskirk et al. (2014) [101]	RCT	87 (55.2)	56.25 (11.9)	-	ACT 90min x 8w	CBT 90min x 8w (n=41)	**DM:** none **PA:** accelerometer **Other:** none	No change in PA (ACT = CBT)	Moderate
Younge et al. (2015) [92]	RCT	324 (46.3)	**MBI:** 43.2 (14.1) **TAU:** 43.2 (13.7)	**MBI:** 25.9 (4.6) **TAU:** 25.7 (4.7)	TAU + 12w online MMT	TAU (n=109)	**DM:** none **PA:** 6-min walk test (6MWT), HR **Other:** none	Heart rate, but not the 6MWT, improved at 12w (MBI > TAU)	Moderate

*. Cross-sectional data drawn from a longitudinal study.

**. Longitudinal data drawn from an intervention study.

†. Only measures directly related to mindfulness and/or PA are reported.

Design. CS = cross-sectional study; CCT = controlled clinical trial; COH = cohort study; LGT = longitudinal study; RCT = randomised controlled trial.
Measures. AAQ = Acceptance and Action Questionnaire; BMI = Body Mass Index; BPAT = Brief Physical Assessment Tool; BREQ-2 = Revised Behavioural Regulation in Exercise Questionnaire; CAMM = Child and Adolescent Mindfulness Measure; DDS = Drexel Defusion Scale; ECS = Exercise Confidence Survey; FFMQ = Five-Facet Mindfulness Questionnaire; FMI = Frieberg Mindfulness Inventory; HBQ = Health Behaviour Questionnaire; HPLP-II = Health Promoting Lifestyle Profile II; IPAQ = International Physical Activity Questionnaire; KIMS = Kentucky Inventory of Mindfulness Skills; LTEQ = Leisure-Time Exercise Questionnaire; MAAS = Mindful Attention and Awareness Scale; MEQ = Mindful Eating Questionnaire; MFPA = Mindfulness in Physical Activity; MPAQ = Modifiable Physical Activity Questionnaire; PAAAQ = Physical Activity Acceptance and Action Questionnaire; PAAQ = Physical Activity Acceptance Questionnaire; PACES = Physical Activity Enjoyment Scale; PAR = Physical Activity Recall; PAQ = Paffenbarger Physical Activity Questionnaire; PAQ-C = Physical Activity Questionnaire for Children; PHLMS = Philadelphia Mindfulness Scale; PPAQ = Paffenbarger Physical Activity Questionnaire; RPE = Rating of Perceived Exertion; SDSCA = The Summary of Diabetes Self-Care Activities; SMS-PA = State Mindfulness Scale for Physical Activity; SPPB = The Short Physical Performance Battery; SRHI = Self-Report Habit Index; WBSI = White Bear Suppression Inventory; WLI = Weight and Lifestyle Inventory; WRBQ = Weight Related Behaviours Questionnaire.
Interventions. ABBT = Acceptance-Based Behaviour Training; ACT = Acceptance and Commitment Therapy; CBT = Cognitive Behavioural Therapy; MB-EAT-D = Mindfulness-Based Eating Awareness Training for Diabetes; MBSR = Mindfulness Based Stress Reduction.
Other. BMI = body mass index; DM = dispositional mindfulness; HEPA = health-enhancing physical activity; HR = heart rate; MBI = mindfulness-based intervention; MMT = mindfulness meditation training; MPA = moderate intensity physical activity; MVPA = moderate to vigorous intensity physical activity; PA = physical activity; SBWL = standard behaviour weight loss programme; TAU = treatment as usual; VPA = vigorous intensity physical activity.

Relationship between dispositional mindfulness and physical activity

Nineteen cross-sectional studies [20, 63-80] and one longitudinal study [81] investigated the relationship between dispositional mindfulness and PA. Dispositional mindfulness was assessed with a variety of self-report measures, including MAAS [64, 66-68, 70-72, 74, 75, 78-81], FFMQ [20, 63, 73, 76, 77, 79], KIMS [69], and CAMM [65]. Additionally, three studies used measures of state mindfulness, including MFPA [78, 79] and FMI [80]. PA was assessed mostly with self-report questionnaires, including IPAQ [20, 67, 68, 70, 74-76, 78-81], LTEQ [72], PAQ-C [65], WLI [73], and other measures [63, 64, 66, 71, 77]. Only two studies used accelerometers to measure PA objectively [69, 81]. Most of the studies investigated total PA [20, 63, 65-68, 70-81]; one study investigated vigorous intensity PA (VPA) and sports [64]; one investigated moderate to vigorous intensity PA (MVPA) and health-enhancing PA (HEPA) [69]; and one investigated yoga and aerobic PA [71].

Cross-sectional studies. Five of 19 cross-sectional studies reported a positive correlation between dispositional mindfulness and PA [20, 67, 70, 73, 77]. Four reported a positive correlation between dispositional mindfulness and psychological factors related to PA, rather than PA [64, 68, 74, 78]. Two reported that PA was positively correlated with some mindfulness measures, but not others [79, 80] and two reported that dispositional mindfulness was positively associated with some PA measures, but not others [69, 71]. Six studies found no correlations between dispositional mindfulness and PA [63, 65, 66, 72, 75, 76].

Of the four studies reporting positive correlations with psychological factors related to PA, one study indicated that dispositional mindfulness was positively correlated with PA self-regulation and outcome expectations and negatively

correlated with perceived personal barriers of PA [68]. Another study indicated positive correlations with perceived behavioural control and attitudes related to PA [64]. The remaining two studies showed positive correlations with PA satisfaction [78] and motivation [74]. Of the two studies that found that PA was positively correlated with some mindfulness measures, one study found a positive correlation between PA and dispositional mindfulness measured using the MAAS, but not the FFMQ [79]. Another study found higher correlations of PA with the FMI than with the MAAS [80]. Of the two studies that found that dispositional mindfulness was positively associated with some types of PA, one study showed a positive correlation with yoga, but a negative correlation with aerobic PA [71]. Another study showed a positive correlation with objectively measured MVPA, but no correlation with objectively measured HEPA [69]. The strength of significant correlations among cross-sectional studies varied between .08 and .32 for mindfulness and PA and between .11 and .50 for mindfulness and psychological factors related to PA.

Longitudinal studies. One longitudinal study [81] indicated a positive correlation between dispositional mindfulness at baseline and self-reported VPA after five weeks, but no correlation with self-reported moderate PA, self-reported walking, or objectively measured accelerometer data [81].

Potential psychological factors explaining the mindfulness-physical activity relationship

Four cross-sectional studies [73, 76, 78, 79] and one longitudinal study [81] investigated potential mechanisms of the mindfulness-PA relationship by conducting mediation analyses.

Cross-sectional studies. One of the four cross-sectional studies indicated that stress partially mediated the relationship between dispositional mindfulness and PA, suggesting that mindfulness is related to lower stress, which in turn contributes to increased PA [73]. This was confirmed in a second study that indicated that the mindfulness-PA relationship was mediated by stress and psychological flexibility [76]. Another study found that satisfaction mediated the relationship between state mindfulness and PA [78], but dispositional mindfulness was not correlated with PA. A follow-up study found that the relationship between dispositional mindfulness and PA was mediated sequentially by state mindfulness followed by PA satisfaction [79].

Longitudinal studies. Findings from the longitudinal study indicated that negative affect and shame mediated the relationship between dispositional mindfulness at baseline and PA motivation after five weeks, but no relationship was found for PA [81].

The effect of mindfulness-based interventions on physical activity

Of the 20 studies that employed a MBI to target PA, five were cohort studies (no control group) [82-86], one was a non-randomised controlled clinical trial [87], and 14 were RCTs [88-101]. Five studies compared usual care with a mindfulness component to

a usual care-only group [89, 91, 92, 97, 98]; eight studies compared a MBI to another intervention [87, 88, 93-96, 99, 101]; and two studies compared a MBI to a no-treatment control group [90, 100].

MBIs included ACT [88, 90, 94, 97, 100, 101], Acceptance-Based Behaviour Therapy (ABBT) [84], MBSR [82, 86, 93, 95, 99], Mindfulness-Based Eating Awareness Training for Diabetes (MB-EAT-D) [96], Mindfulness in Motion (MIM) [85], non-standardised mindfulness training [83, 87, 89, 91, 92], and an intervention that combined mindfulness and acceptance training [98]. The intervention duration ranged from a single session [94] to 24 weeks [89] and session length varied from 10 minutes [83] to six hours [90]. The follow-up period ranged from none [83, 84, 86, 87, 89, 90, 93-95, 97, 98] to a 12-month follow-up [91, 92].

PA components were present in 14 MBIs and included PA education [87, 96, 97] and recommendations [96, 97], mindfulness and acceptance-based techniques targeting psychological factors related to PA [84, 87, 88, 90, 94, 100], and PA exercises, such as mindful movement [85, 87, 95] and yoga [82, 85, 89, 91, 92]. PA outcomes included PA frequency [82, 84-90, 93, 95-101], tolerance [83, 91-94], maintenance [100], enjoyment [83, 94], strength [85, 86], and flexibility [86]. Only nine studies measured PA objectively [85, 88, 91-95, 101].

Of the 20 MBIs, three cohort studies [82-84] and five RCTs [94, 97-100] showed significant positive between-subjects effects on PA. Three studies showed significant positive within-subjects effects on PA, but found no differences between the MBI and a control group [89, 90, 96]. Two cohort studies [85, 86] and two RCTs [88, 92] showed positive effects for some PA outcomes. Three RCTs found no effect on PA outcomes in either group [91, 93, 101] and two RCTs showed better outcomes following the standard intervention than the MBI [87, 95].

Of the eight studies that showed significant positive between-subjects effects of a MBI on PA, four employed acceptance-based interventions [84, 94, 97, 100]; one employed another MBI that did not include MMT [83]; one employed a MBI that combined acceptance-based techniques and MMT [98]; and two employed traditional MBIs with an element of MMT [82, 99]. Of the three studies that showed significant positive within-subjects effects on PA, but found no differences between groups, one employed an acceptance-based intervention [90] and two employed traditional MBIs with an element of MMT [89, 96]. Of the four studies that showed effects for some PA outcomes, two studies showed improvements in PA in the short term only [88, 92]; one showed improvements in self-reported walking only [85]; and one showed improvements in some types of PA (e.g., activities aimed at improving flexibility), but not others (e.g., activities aimed at improving strength) [86]. Of these interventions, one was acceptance-based [88] and the remaining were MBIs with an element of MMT [85, 86, 92]. Of the three RCTs that found no effect on PA outcomes in either group, one employed an acceptance-based intervention [101] and two employed traditional MBIs with an element of MMT [91, 93]. Both RCTs that found better results of a standard intervention employed traditional MBIs with an element of MMT [87, 95]. Of the 15 MBIs that reported positive effects on PA outcomes, 12 studies included PA components. Specifically, five targeted psychological factors related to PA [84, 88, 90, 94, 100]; three included PA education and recommendations [96, 97, 99]; and four included yoga [82, 85, 89, 92]. Of the remaining five RCTs, one included yoga [91] and one included yoga and PA education [87].

Discussion

This review is the first of its kind to investigate the relationship between mindfulness and PA. In terms of dispositional mindfulness, nine studies showed weak to moderate correlation with PA, but only one of those studies measured PA objectively. Additionally, only one study compared different types of PA, and found that dispositional mindfulness was positively correlated to yoga (r = .23), but negatively correlated to aerobic PA [71] (r = -.18). This was also seen in one intervention study that showed that a MBI only led to improvements in activities related to flexibility [86].

A possible explanation for this could be that typical exercise modes are goal- rather than process-oriented and include a relative disconnect between body and mind [102]. Conversely, some types of PA, such as yoga or Tai Chi, can be seen as geared towards mindfulness and containing mindful components [55] by being process-oriented and emphasising the mind-body connection [102]. As aerobic exercise is regularly recommended for physical health [5, 6], weight maintenance [103], and weight loss [104], this finding is of particular relevance. Mindfulness may have a different effect on different types of PA, suggesting that alternative approaches for PA promotion may be required, but more research is needed to investigate differences in various types of PA.

Several cross-sectional studies showed that mindfulness was positively correlated with psychological factors related to PA, such as habit [78, 79], satisfaction [78, 79], motivation [74, 81], and enjoyment [73], but results were mixed for PA. It is more likely that mindfulness and PA are associated through psychological factors that mediate

this relationship. This could imply that individuals who report higher dispositional mindfulness, or who learn to cultivate it, may be better able to translate PA intentions into behaviour, be intrinsically motivated to engage in PA, accept negative sensations that are likely to occur during exercise (e.g., fatigue), and enjoy the experience of exercise. This is particularly important for individuals with overweight and obesity, who often report negative attitudes towards PA [27, 31, 33, 34] and find exercise uncomfortable [25-29]. Mindfulness-based approaches have the potential to target psychological factors related to PA and therefore better prepare these individuals for sustained PA behaviour change [55]. However, whether the effect of mindfulness on psychological factors related to PA leads to an increase in PA remains to be tested in longitudinal and controlled studies.

More than half of the MBIs showed positive effects on PA outcomes, but they varied greatly in duration, session length, group size, delivery method, and content. Few studies reported follow-up data and some showed that benefits in PA gained after the intervention were not found at follow-up [88, 92, 96]. This shows a need for future MBIs to include a follow-up period to assess their long-term effectiveness. Furthermore, the included MBIs all contained additional components to MMT, such as goal setting, group discussions about PA and health, and acceptance training, which makes it unclear what the active ingredients in these interventions are [39]. The review did not find substantial evidence to suggest that MBIs with a meditation component were more effective than acceptance-based interventions without MMT, but it must be acknowledged that our methods do not allow firm conclusions to be drawn. A meta-analysis would be required to assess the relative importance of the additional meditation component in MBIs.

A previous review of the effect of mindfulness-based approaches on health behaviours in adults with overweight and obesity [105] found evidence for a small change in PA from pre- to post-intervention. However, this review only included four studies that measured PA outcomes and all four MBIs contained additional PA components. Three of those studies are also included in the current review [89, 90, 96]. The fourth was excluded as it assessed the effect of yoga, rather than a mindfulness-specific intervention on PA [106]. Cultivating mindful awareness could enhance acceptance of negative or uncomfortable thoughts and sensations that are likely to occur during PA, particularly in individuals with overweight and obesity, but its link with sustained PA needs to be verified in future studies.

The results of the current review indicate that MBIs are more likely to be successful at implementing PA behaviour change if they target psychological factors related to PA. However, evidence for the active components of MBIs is still scarce. Adding mindfulness components to standard PA interventions could improve psychological factors related to PA, such as exercise self-efficacy and acceptance of PA-related discomfort, but this needs to be determined in matched-control studies with long-term follow-ups. Evidence for the effectiveness of MBIs over standard PA interventions is at present limited and results are mixed. More research is required to establish what makes MBIs successful at increasing PA and what mechanisms are involved in the mindfulness-PA relationship.

Limitations

Despite the rigorous search criteria and study reviews conducted, this review is not without limitations. Current literature regarding the relationship between mindfulness and PA cognitions, attitudes, and behaviour is relatively scarce; more research is required before conclusions regarding the effect of mindfulness on PA can be drawn. Consequently, there are also limitations to many of the included studies.

Firstly, in terms of study quality, 18 studies (45%) were considered "weak"; 21 studies (52.5%) were considered "moderate"; and only one study (2.5%) was considered "strong". Cross-sectional studies typically lacked quality in study design, while intervention studies and RCTs suffered from selection bias and ascertainment bias (from lack of blinding). Additionally, while mediation data from cross-sectional studies provide an insight into the potential mechanisms that link mindfulness and PA, no causal inferences can be made from these observations and further prospective research is required to substantiate these findings. Secondly, study participants were predominantly white, female, healthy, and with a normal-range BMI, which may compromise the generalisability of findings to men, diverse ethnic groups, individuals with overweight and obesity, and individuals with a variety of physical and mental health concerns.

Thirdly, studies used a variety of mindfulness measures and components. Mindfulness is difficult to define [37] and operationalise [107] and thus challenging to measure [108-110]. Different scales measure different aspects of mindfulness (e.g., attention); therefore, consistency among measurement tools is required to draw

definitive conclusions. Additionally, it is unclear how validly people can report their levels of mindfulness in self-report questionnaires [108, 111], suggesting the need for future studies to measure additional constructs (e.g., attention [112], compassion [113]) that may be associated with changes in mindfulness [108]. Moreover, few studies used objective measures of PA (e.g., accelerometers). This is an important limitation considering that some studies indicated that mindfulness was related to self-report measures of PA, but not with objective measures. It is likely that some of these findings suffered from common-method variance and experimental studies are required to test the validity of results found.

Fourthly, interventions differed in length, duration, group size, session content, delivery method, and length of follow-up, making it difficult to establish which components contributed to their effectiveness. In acceptance-based MBIs (e.g., ACT and ABBT), mindfulness is only one component of a variety of other core processes and specific MMT is not included [38]. This raises the question of whether mindfulness itself is the active ingredient of such interventions [39] or if other components (e.g., acceptance or goal setting) are more likely to impact PA outcomes. Since not all studies computed a mindfulness change score (based on change in self-reported dispositional mindfulness), it was not possible to examine to what extent any PA changes were mediated by changes in mindfulness. It was, however, a purposeful decision to include studies even if they did not provide a mindfulness change score, since it is not known to what extent changes in (cultivated) mindfulness resulting from MBIs can be measured using self-report of dispositional mindfulness (thus yielding any such mediational analysis invalid) [114].

Finally, due to the limited number of RCTs conducted on mindfulness and PA, this review included uncontrolled trials, as well as longitudinal and cross-sectional studies. Although on balance the review suggests a favourable outcome for the potential of MBIs for PA, quantity of significant findings is no replacement for quantitative analysis of effect size through meta-analysis. To establish the true effect of MBIs and dispositional mindfulness on PA, further research is required to build the basis for meta-analysis of the literature. As this review demonstrated, the quality of available studies is currently too limited for conducting such an analysis.

Future directions

This review shows a need for more rigorous research that compares MBIs against matched-control conditions to establish the potential active ingredients, so that more effective PA interventions can be developed. Moreover, experimental studies are required to examine the mechanisms involved in the mindfulness-PA relationship, potentially by examining psychological factors related to sustained PA behaviour change and whether they lead to increased PA in the long term. Finally, future studies should aim to assess PA using objective measures (e.g., accelerometers or pedometers) and compare different exercise types, so that the true effect of mindfulness on PA can be established.

Conclusions

The results of this review suggest that mindfulness may be associated with PA, but evidence is currently inconclusive and more research is required to

investigate the relationship between mindfulness and PA experimentally and longitudinally. Mindfulness could potentially provide an inexpensive alternative for individuals not benefitting from existing lifestyle interventions. However, the current structure and design of MBIs seems insufficient for increasing PA. MBIs require a re-formulation in terms of PA-specificity and the identification of the active ingredients, which may be responsible for affecting PA behaviour change. MBIs may be more effective for enhancing PA if they are PA-specific and target psychological factors related to sustained PA.

Table and figure legends

Figure 1: PRISMA flowchart of study selection.

Table 1: Characteristics of the reviewed studies.

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