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Review article

A systematic review of physical activity-based interventions in shift workers☆

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ABSTRACT

Shift workers are at increased risk of a range of chronic diseases and there is evidence to suggest that these risks can be ameliorated by physical activity. Little is known however about the efficacy of physical activity interventions in shift workers. The aim was therefore to critically review the literature to improve understanding of the efficacy of physical activity promotion initiatives for this occupational group.

A systematic review of randomized controlled trials of physical activity in shift workers was conducted in 2016–2017 following the Preferred Reported Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. Only seven studies were found.

None of the studies measured changes in physical activity behaviour or reported on the timing or setting of the intervention protocols. Instead, most focused on health-related outcomes including body composition, fitness and sleep. Almost all provided physical activity 'prescriptions' with walking or 'aerobic activity' as the primary intervention mode and most reported significant improvements in one of the outcome measures.

Although the findings suggest that physical activity may mitigate intermediate risk factors associated with non-communicable diseases (NCD) in shift workers, the studies offer little insight into physical activity behaviour change in this occupational group. Future research should assess actual changes in physical activity behaviour, and its determinants, as well as the reach and uptake of intervention strategies in this challenging population group.

1. Introduction

Shift work is characterized as work outside the normal 9:00 am–5:00 pm period (Atkinson et al., 2008). Schedules vary due to organizational factors, such as the number of consecutive working days and the frequency and direction of the shift rotation (Brum et al., 2015). The length of each shift can differ (6–12 h) (Harrington, 2001) as can the number of rest days between shifts. The variability of shift work causes disruptions in homeostasis leading to adverse health outcomes. Common repercussions associated with shift work include inadequate sleep (Åkerstedt and Wright Jr, 2009), poor diet (Antunes et al., 2010) and insufficient physical activity (Atkinson et al., 2008). These intermediate consequences cause elevations in biological risk factors, which contribute to the development of many non-communicable diseases. Shift workers are at increased risk of developing metabolic syndrome (Canuto et al., 2013) and diabetes (Knutsson and Kempe, 2014) and are at 48% and 40% greater risk of developing breast cancer (Megdal et al., 2005) and cardiovascular diseases (CVD) (Boggild and Knutsson, 1999) respectively. The risk of CVD morbidity (17%) and mortality (20%) is higher for shift workers than non-shift workers and after five years of shift work, the risk increases by 7.1% (Torquati et al., 2017). As one-fifth of the global work force is now involved in shift work (Pati et al., 2001), it is important to include these workers in health promotion and disease prevention initiatives.

Physical activity has been associated with a number of health benefits including improved cardiovascular fitness, musculoskeletal functioning and body composition (Warburton et al., 2006). To achieve these health benefits, current global guidelines recommend a minimum of 150 min of moderate intensity physical activity each week (World Health Organization, 2010). This amount of activity has significant protective effects on the development of CVD, diabetes and some cancers, and reduces the risk of all-cause mortality (Arem et al., 2015; Lee et al., 2012).

Despite these well-documented health benefits, many shift workers fail to achieve the recommended physical activity guidelines and consequently, the majority of shift workers are insufficiently active. In a

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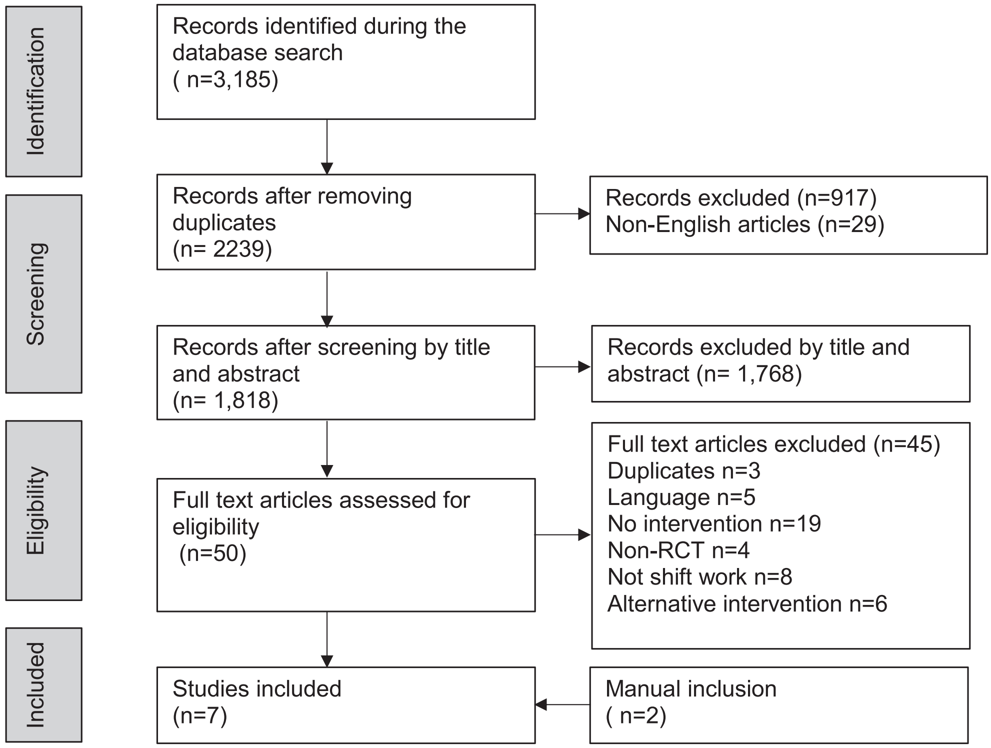

Fig. 1. Flow diagram of study results.

cross sectional survey of 1206 production line workers in Brazil, 64% reported that they were not engaging in 150 min of activity per week (Garcez et al., 2015). In another cross-sectional study of 551 English nurses, 49% reported that they did not meet the recommended guidelines (Malik et al., 2011). Moreover, low levels of physical activity have been reported in samples of shift workers in the U.S.A. (Chin et al., 2016), Canada (Neil-Sztramko et al., 2016), India (Ram et al., 2014) and Iceland (Škrbina and Zurc, 2016), suggesting that inactivity among shift workers may be of global concern. However, a recent study has shown that objectively measured leisure time and occupational physical activity levels are similar in Dutch hospital workers (Loef et al., 2016). Notwithstanding, it is generally agreed that demanding work schedules, reduced access to facilities and circadian rhythm disruption (Atkinson and Davenne, 2007) may explain the observation that shift workers are less physically active than their non-shift working counterparts (Puttonen et al., 2009; Vandelanotte et al., 2015).

Worksite physical activity interventions have been shown to positively influence many aspects of workers' health including: physical activity behaviours, stress levels and musculoskeletal functioning (Conn et al., 2009; Proper et al., 2003; To et al., 2013). Moreover, worksite physical activity interventions can increase employee productivity and reduce health care costs (Van Dongen et al., 2011). Growth in this field of health promotion research is illustrated by the fact that a 2007 meta-analysis identified 206 worksite physical activity interventions, compared with only 26 interventions in a 1998 review. Although the latter review reported that the effectiveness of such interventions was largely unrealized (Dishman et al., 1998), Conn et al. (2009) found significant positive effects on physical activity behaviours, anthropometric measures, cardiovascular fitness, work attendance and job stress. However, neither review provided details of shift schedules or working hours of the employees. Therefore, despite the potential reach and benefits of worksite physical activity interventions, their utility for shift workers remains unclear.

Considering that many shift workers have high levels of inactivity, and are therefore at increased risk of poor health, the overall aim of this study was to synthesize and critically review the available literature on physical activity-based interventions in shift workers.

2. Methods

2.1. Design

A systematic review of physical activity interventions for shift workers was conducted following the Preferred Reported Items for Systematic Review and Meta-Analysis (PRISMA) guidelines (Moher, 2010).

2.2. Search strategy

Four electronic databases were searched for articles published from 1988 to 2017: PubMed, EMBASE, Scopus, CINAHL. Key search terms relating to target population (e.g. ‘shift work’, ‘night shift’) exercise (e.g. ‘exercise’, ‘physical activity’) and intervention (e.g. ‘workplace intervention’, ‘worksite physical activity program’) were considered. A full list of the search terms is provided in the supporting documentation (see Appendix A).

2.3. Inclusion criteria

The following inclusion criteria were applied: (a) randomized control trials (RCT) or RCT protocols; (b) with shift workers as the target population; and (c) physical activity as the *primary* intervention component. (Studies in which the main focus was weight loss, with physical activity as one intervention component were excluded.) Only peer reviewed journal articles written in English language were considered for selection.

2.4. Screening/selection

Articles were screened for inclusion by two independent reviewers (HF, TKA) using a three-stage process. In stage one, both reviewers excluded articles by title. In stage two, abstracts were screened and

Table 1

Characteristics of the study populations (in alphabetical order of first author).

Author Year Country	Sample size Gender (M/F)	Occupation Shift schedule	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	SBP (mm Hg)	DBP (mm Hg)
Atlantis et al. 2006 Australia	42 M = 20 F = 22	Casino staff 2-month shift rotation consisting of: daytime work (12 noon to 8 pm), night work (8 pm to 4 am) and morning work (4 am to 12 noon)	Ex = 21–52 Con = 20–54			< 30.0 = 35 > 30.0 = 9		
Atlantis et al. 2006 Australia	44 M = 20 F = 24	Casino staff 2-month shift rotation consisting of: daytime work (12 noon to 8 pm), night work (8 pm to 4 am) and morning work (4 am to 12 noon)	Ex = 29 ± 7 Con = 32 ± 7		Ex = 77.2 ± 17.2 Con = 80.3 ± 24.1	Ex = 26.8 ± 5.9 Con = 27.7 ± 7.3		
Harma et al. 1988 Finland	75 F	Nurses and nursing aids Irregular schedule (7) day shifts, (5) evening shifts and (3) night shifts over a 3-week period	Ex = 24.6 ± 6.8 Con = 35.7 ± 6.5	Ex = 161.9 ± 6.6 Con = 163.9 ± 5.3	Ex = 60.3 ± 7.1 Con = 63.6 ± 7.9		Ex = 124.4 ± 14.9 Con = 120.8 ± 10.4	Ex = 82.0 ± 10.4 Con = 80.4 ± 7.9
Harma et al. 1988 Finland	75 F	Nurses and nursing aids Irregular schedule (7) day shifts, (5) evening shifts and (3) night shifts over a 3-week period	Ex = 24.6 ± 6.8 Con = 35.7 ± 6.5	Ex = 161.9 ± 6.6 Con = 163.9 ± 5.3	Ex = 60.3 ± 7.1 Con = 63.6 ± 7.9		Ex = 124.4 ± 14.9 Con = 120.8 ± 10.4	Ex = 82.0 ± 10.4 Con = 80.4 ± 7.9
Kim et al. 2015 Republic of Korea	30	Not reported	Ex = 35.7 ± 6.6 Con = 35.8 ± 4.2	Ex = 172.8 ± 6.9 Con = 175.4 ± 5.8	Ex = 87.3 ± 15.2 Con = 90.3 ± 11.2	Ex = 29.3 ± 2.2 Con = 29.0 ± 3.1		
Lim et al. 2015 South Korea	30 M	Not reported Night-shift worker	Ex = 56.80 ± 1.82 Control = 58.33 ± 1.88	Ex = 167.6 ± 2.98 Con:170.7 ± 6.33	Ex = 65.73 ± 3.91 Con = 68.08 ± 8.50	Ex = 23.36 ± 1.42 Con = 23.3 ± 2.32	Ex = 133.1 ± 4.33 Con = 131.5 ± 2.97	Ex = 89.07 ± 4.46 Con = 85.47 ± 3.25

Legend: BMI, Body Mass Index; DBP, Diastolic Blood Pressure; F, female; M, male; SBP, Systolic Blood Pressure.
Atlantis (1) 70% Experiment were shift workers 75% control were shift workers.
Atlantis (2) Entire population shift workers.

Table 2
Details of the physical activity and multi-component interventions.

Author Design Participants	Duration Frequency Intensity	Intervention description	Outcome Variable	Results Intervention/control			
Harma et al. RCT Ex = 49 Con = 26	D = 16 weeks F = 2–6 days/week I = 60–70% Age-group average HR max	● Individual exercise plan ● Jogging, swimming, skiing running, walking or gymnastics ● Training diary of HR recordings checked by physical educator at 3 week intervals	Fitness				
			VO^2 max (l-min^{-1} kg^{-1})	+1.9[a,b]		−0.3	
			MS (#sit ups/30 s)	+2.9[a,b]		+0.5	
			Body composition				
			Weight (kg)	−0.6[a]		−0.5	
			Skinfolds (mm)	−2.5[a]		−0.4	
			Sleep				
			Sleep length (h) morning	+0.2[a]		0.0	
			Sleep length (h) evening	+0.3[a,b]		0.0	
			Sleep length (h) night	+0.4[a]		+0.1	
			Sleep quality (h) morning	−3.9[a]		−0.4	
Harma et al. RCT Ex(A) = 26 Ex(B) = 23 Con = 26	D = 16 weeks F = 2–6 days/week I = 60–70% Age-group average HR max	● Individual exercise plan ● Jogging, swimming, skiing running, walking or gymnastics ● Training diary of HR recordings monitored by physical educator at 3 week intervals	Temperature				
			Day mesor (°C)	−0.11[a]		−0.05[a]	
			Night mesor (°C)	−0.09[a]		−0.06[a]	
			Day amplitude (°C)	−0.08[a]		−0.01[a]	
			Night amplitude (°C)	+0.03[a]		+0.05[a]	
			Day acrophase (h/min)	+1:11[a]		+1:46[a]	
			Night acrophase (h/min)	+0:57		−0:06	
Lim et al. RCT Ex = 15 Con = 15	D = 10 weeks F = 3 days/week I = 60–79% individual HR max	● Supervised exercise program ● Brisk walking ● Aerobic exercise: 30 min Three 10 minute sessions separated by > 4 h rest	Biological risk factors				
			Cathepsin S (μ/L)	−0.48[a]		+0.13	
			Cathepsin L (μ/L)	−0.96[a]		+0.25	
			Cathepsin K (μ/L)	−0.30[a]		+0.19	
			MCP-1 (μ/L)	−15.27[a]		+3.00	
			Body composition				
			Weight (kg)	−0.37[a]		+0.11	
			BMI (kg/m^2)	−0.10		+0.04	
			Fat mass (kg)	−0.13[a]		+0.09[a]	
			Percent body fat (%)	−0.07		+0.10	
			Fat free mass (kg)	−0.24		+0.02	
Atlantis et al. RCT Ex = 19 Con = 23	D = 24 weeks F = ≥3 days/week I = Wk 1: 50–60% Wk 2: ≥75% Age predicted HR max	● Supervised exercise with behaviour modification program ● Treadmill, bicycle, stepper or rowing ergometer combined with whole body weight training ● Aerobic exercise: 20 min/day, 3 days/week Weight training: 30 min/day, ≥3 days/week ● Behaviour seminars relating to exercise, diet and ergonomics offered on 5 occasions with optional 60 min one-on-one counselling session 1 day/month ● All participants received manuals with lecture material and rewards were provided as incentive for intervention compliance	Body composition				
			Weight (kg)	+0.1 (5.9)		+0.5 (2.7)	
			BMI (kg/m^2)	0.0 (1.9)		+0.1 (1.3)	
			Waist circumference (cm)	−4.3 (7.5)		−1.1 (3.4)	
			Fitness				
			VO^2 max (l-min^{-1} kg^{-1})	+11.2 (7.2)		+4.1 (8.1)	
Atlantis et al. RCT Ex = 14 Con = 18	D = 24 weeks F = ≥3 days/week I = Wk 1: 50–60% Wk 2: ≥75% Age predicted HR max		Sleep quality				
			PSQI	B = 6.3 ± 2.8	A = 4.2 ± 2.0	B = 6.7 ± 3.1	A = 5.6 ± 2.9
			Poor sleep category				
			Pre	64%		50%	
			Post	14%		44%	

(continued on next page)

Table 2 (*continued*)

Author Design Participants	Duration Frequency Intensity	Intervention description	Outcome Variable	Results Intervention/control			
		● Supervised exercise with behaviour modification program ● Treadmill, bicycle, stepper or rowing ergometer combined with whole body weight training ● Aerobic exercise: 20 min/day, 3 days/week Weight training: 30 min/day, ≥3 days/week ● Behaviour seminars relating to health and sleep hygiene offered on 5 occasions with optional 60 min one-on-one counselling session 1 day/month ● All participants received manuals with lecture material and rewards were provided as incentive for intervention compliance					
Kim et al. RCT Ex = 9 Con = 15	D = 4 weeks F = Ex: 2 days/week Con: 5 days/week I = N/R	● Exercise and deep abdominal ultrasound therapy program ● Aerobic exercise: 30 min Resistance training: 20 min 10 min cool down ● Ultrasound therapy was utilized in the experimental group 3 days/week for 30 min per session	Body composition				
			BMI (kg/m^2)	B = 29.3 ± 2.2	A = 27.6 ± 4.5	B = 29.0 ± 3.1	A = 28.2 ± 3.1
			Body fat mass (kg)	B = 34.85 ± 5.2	A = 23.49 ± 7.8[a]	B = 33.9 ± 7.8	A = 25.0 ± 6.6
			Lean body mass	B = 63.4 ± 8.4	A = 60.0 ± 13.9	B = 60.3 ± 12.4	A = 61.4 ± 7.0
			Biological risk factors				
			TC (mg/dL)	B = 180 ± 25.6	A = 169.5 ± 31.6	B = 194.8 ± 32.8	A = 182.6 ± 28.1
			LDL-C (mg/dL)	B = 100.6 ± 26.3	A = 109 ± 33.3	B = 113.4 ± 36.3	A = 122.0 ± 33.9
			HDL-C (mg/dL)	B = 41.7 ± 6.6	A = 47.5 ± 11.1[a]	B = 46.0 ± 9.7	A = 48.812.7
Suni et al. RCT protocol Ex (A) = Pilates Ex (B) = BC Ex (C) = Pilates and BC Con (D)	D = 24 weeks F = Wk 1–8: 2 days/week Wk 8–16: 1 day/week I = N/R	● Supervised group exercise classes/behavioural counselling program ● Wk 1–8: two supervised Pilates classes/week Wk 8–16: one supervised Pilates class/week and one at home fitness class using a video, disk or booklet ● Behavioural counselling sessions relating to low back pain provided to groups B and C only ● Ten group sessions lasting 45 min ● Participants receive folders of lecture material ● 6 month, 12 month, 24 month follow up					

Legend: A, after; B, baseline; BC, behavioural counselling; BMI, Body Mass Index; D, duration; F, frequency; HDL, high density lipoprotein; HR, heart rate; HR max, heart rate maximum; I, intensity; LDL, low density lipoprotein; MS, muscular strength; PSQI; Pittsburgh Sleep Quality Index, RCT, randomized control trial; TC, total cholesterol; Temp, temperature; VO_2max, maximal oxygen consumption; Pittsburgh Sleep Quality Index: 19 point scale, < 6 poor sleep category: decrease denotes change favouring outcome.

[a] Significant difference before and after intervention $p < 0.05$.

[b] Significant difference between groups.

Table 3
Modified Delphi quality assessment tool.

Criteria	Answer
1. Was a method of randomization preformed	Yes/no/don't know
2. Was the treatment allocation concealed prior to baseline testing?	Yes/no/don't know
3. Were the group characteristics similar at baseline?	Yes/no/don't know
4. Were eligibility criteria specified?	Yes/no/don't know
5. Was the outcome assessor blinded?	Yes/no/don't know
6. Was the care provider blinded?	Yes/no/don't know
7a. Was there adequate measurement of shift work?[a]	Yes/no/don't know
7b. Is there relevant information on shift work schedules, patterns and duration included?	Yes/no/don't know
8. Were point estimates and measures of variability presented?	Yes/no/don't know
9. Did the analysis include an intention-to-treat analysis?	Yes/no/don't know

[a] Defined as: evening or night shifts, rotating shifts, split shifts, on-call or casual shifts or 24 hour shifts.

excluded, as shown in Fig. 1. In stage three the full text articles were read and screened for inclusion (see Fig. 1).

2.5. Data extraction

Data from selected studies were extracted and synthesized into tabular format. Participant characteristics and information relating to sample size, occupation, age and anthropometric measures are reported in Table 1. Information relating to study design and structure, study duration, intervention description, outcome measures and results are summarized in Table 2.

2.6. Quality assessment

The quality of eligible studies was assessed using a modified version of the scoring criteria developed by Verhagen et al. (1998) (Table 3). Of the nine criteria, one was excluded (i.e. blinding of the patient) due to the inability to blind whether a participant has been allocated to the physical activity intervention or comparison group. Further adaptations to the quality score included the addition of two criteria specific to shift work: (a) adequate measurement of shift work (b) inclusion of information relating to shift work schedules, as suggested by Proper et al. (2016). Study quality was assessed independently by two reviewers (HF, TKA). The criteria were scored 'yes' (1 point), 'no' (0 point) or 'unclear' (0 point). All criteria were weighted equally and the score was calculated by summing all items on the checklist. Individual assessments were discussed and in cases of uncertainty, papers were referred to the third author (WJB). Consensus was achieved prior to final scoring and studies were considered "high quality" if they scored > 8/10 (80%).

3. Results

The results of the systematic search process are shown in Fig. 1. The initial literature search yielded 3185 results. After removal of duplicates and exclusion of 29 non-English records, 2239 articles were screened by title. The main reason for exclusion by title was because the study was of non-shift workers. Abstracts of 1818 articles were reviewed and 50 full text articles were assessed for eligibility. The main reason for exclusion by abstract related to study design (non-RCT). Seven articles published between 1988 and 2016 met the inclusion criteria. In two cases an intervention was outlined in two separate publications. As each reported a different outcome, both papers from each study were included (Atlantis et al., 2006a; Atlantis et al., 2006b; Harma et al., 1988a,b).

3.1. Quality assessment

Quality assessment scores ranged from 30% to 75% and are outlined in Table 4. Of the seven studies included, none were considered "high quality". Five studies adequately measured shift work but only four provided details of shift schedules and patterns.

3.2. Study population

Participant characteristics are presented in Table 1. Studies were conducted in Australia, Finland, and North Korea. Sample sizes ranged from 30 to 75 participants with ages from 20 to 58 years. Five studies reported night-shift work as part of the shift rotations (Atlantis et al., 2006a; Atlantis et al., 2006b; Harma et al., 1988a,b; Lim et al., 2015) and the other two reported shift work, without describing the roster (Kim et al., 2015; Suni et al., 2016). Of the four studies that specified occupation, participants were casino staff (dealers, ushers, cleaners etc.) (Atlantis et al., 2006a; Atlantis et al., 2006b) and nurses and nursing aids (Harma et al., 1988a,b). Another study of nursing personnel was not included in the table because participants' demographic characteristics were not provided (Suni et al., 2016).

3.3. Physical activity interventions

Details of the physical activity interventions are outlined in Table 2. The duration of the interventions ranged from four weeks to six months, and most included aspects of 'exercise' prescription, such as frequency of two to six days per week, at moderate to vigorous intensity (Atlantis et al., 2006a; Atlantis et al., 2006b; Harma et al., 1988a,b; Lim et al., 2015).

Six of the seven studies 'prescribed' aerobic activity (Atlantis et al., 2006a; Atlantis et al., 2006b; Harma et al., 1988a,b; Kim et al., 2015; Lim et al., 2015) with the most common modes being walking (Atlantis et al., 2006a; Atlantis et al., 2006b; Harma et al., 1988a,b; Kim et al., 2015), jogging (Harma et al., 1988a,b), or rowing (Atlantis et al., 2006a; Atlantis et al., 2006b). Two interventions incorporated a combination of both aerobic and resistance training (Atlantis et al., 2006a; Atlantis et al., 2006b). For example, Atlantis et al. (2006a) prescribed 20 min of aerobic activity followed by 30 min of resistance training exercises to activate chest, back, biceps, triceps, shoulders, calves, quadriceps and hamstring muscle groups. Each exercise was performed for a maximum of 15 repetitions using machines or free weights. The number of sets ranged from 2 to 10, each separated by 30–120 second rest. Four interventions were supervised (Atlantis et al., 2006a; Atlantis et al., 2006b; Lim et al., 2015; Suni et al., 2016). Only one included scheduled follow up assessments, which were at 6, 12 and 24 months (Suni et al., 2016).

Both studies conducted by Harma et al. (1988a,b) and the study conducted by Lim et al. (2015) focused solely on physical activity, while three others focused on physical activity, but also offered behavioural counselling to address additional concerns such as sleep (Atlantis et al., 2006b), general health (Atlantis et al., 2006a) and low back pain (Suni et al., 2016). One intervention also offered ultrasound therapy and in this study, Kim et al. (2015) used physical activity in both the treatment and control groups.

Table 4
Quality assessment scores of selected studies.

Criterion	Atlantis et al., 2006a	Atlantis et al., 2006b	Harma et al., 1988a	Harma et al., 1988b	Kim et al., 2015	Lim et al., 2015	Suni et al., 2016[b]
1. Was a method of randomization preformed?	Y	Y	Y	Y	Y	Y	Y
2. Was the treatment allocation concealed prior to baseline testing?	N	N	N	N	N	N	Y
3. Were the group characteristics similar at baseline?	Y	Y	Y	Y	Y	Y	N/A
4. Were eligibility criteria specified?	Y	Y	Y	Y	N	Y	Y
5. Was the outcome assessor blinded?	D/K	D/K	D/K	D/K	D/K	D/K	Y
6. Was the care provider blinded?	D/K	N	D/K	D/K	D/K	D/K	Y
7a. Was there adequate measurement of shift work?[a]	Y	Y	Y	Y	N	Y	N
7b. Is there relevant information on shift work schedules, patterns and duration included?	Y	Y	Y	Y	N	N	N
8. Were point estimates and measures of variability presented?	Y	Y	Y	Y	Y	Y	N/A
9. Did the analysis include intention-to-treat analysis?	Y	Y	Y	Y	N	D/K	Y
	70	70	70	70	30	50	75
	7/10	7/10	7/10	7/10	3/10	5/10	6/8

Legend: D/K, don't know; N, no; Y, yes.
[a] Defined as: evening or night shifts, rotating shifts, split shifts, on-call or casual shifts or 24 hour shifts.
[b] Study scored out of eight points.

3.4. Body composition

Four of the seven studies examined the effect of physical activity on body composition (Atlantis et al., 2006a; Harma et al., 1988b; Kim et al., 2015; Lim et al., 2015). Of these, three identified a significant decrease in bodyweight from baseline to post-intervention (Atlantis et al., 2006a; Harma et al., 1988b; Lim et al., 2015) and four reported a decrease in Body Mass Index (BMI) (Atlantis et al., 2006a; Harma et al., 1988b; Kim et al., 2015; Lim et al., 2015).

Fat mass was measured pre- and post-intervention in two studies and both reported significant reductions in the experimental groups and no change in the control groups (Kim et al., 2015; Lim et al., 2015). In one study, there was an inverse relationship between the amount of physical activity and the magnitude of reduction in skinfold measurements (Harma et al., 1988b). In another study, there was a decrease in waist circumference following the intervention (Atlantis et al., 2006a).

3.5. Fitness

The two studies that measured maximal oxygen consumption showed improvements from baseline to post-intervention (Atlantis et al., 2006a; Harma et al., 1988b). Further, Harma et al. (1988b) found significant differences in muscular strength favouring the experimental group.

3.6. Sleep

Sleep quality, assessed using self-report, was the main outcome in two studies (Atlantis et al., 2006b; Harma et al., 1988b). Harma et al. (1988b) found significant baseline to post-intervention improvements in sleep duration and quality among shift workers following a morning shift. Atlantis et al. (2006b) reported improvements in self-reported sleep quality in both the experimental and control groups; these improvements were more marked for those who were classified as poor sleepers.

3.7. Biological risk factors

The effect of physical activity on biological risk factors was examined in two studies. Kim et al. (2015) reported improvements in total cholesterol (TC), and in low and high density lipoproteins (LDL, HDL), while Lim et al. (2015) reported improvements from baseline to post-intervention for the following cardiovascular biomarkers: Cathepsin S, Cathepsin L, Cathepsin K, and Chemotactic protein-1.

3.8. Body temperature

One study examined the effects of physical activity on circadian rhythms, through the measurement of body temperature. Harma et al. (1988a) found a decrease in core temperature in both the intervention and control groups, however, the decrease was more pronounced in the intervention group.

4. Discussion

The aim of this study was to synthesize and critically review the available literature on physical activity-based interventions in shift workers. Only seven studies were located and the researchers reported a diverse range of outcome measures relating to body composition (Atlantis et al., 2006a; Harma et al., 1988b; Kim et al., 2015; Lim et al., 2015), fitness (Atlantis et al., 2006a; Harma et al., 1988b), and sleep (Atlantis et al., 2006b; Harma et al., 1988b). Due to the heterogeneous explanatory and outcome measures and the tools used to assess these, we could not conduct a meta-analysis. Instead, we provided the results as a narrative review. None of the studies assessed changes in physical activity behaviours and overall, the studies provided insufficient details about imperative intervention characteristics (i.e. setting and timing).

The majority of the studies reported improvements in one or more NCD risk factors, such as body weight (Atlantis et al., 2006a; Harma et al., 1988b; Lim et al., 2015), BMI (Atlantis et al., 2006a; Kim et al., 2015; Lim et al., 2015), fat mass (Harma et al., 1988b; Kim et al., 2015; Lim et al., 2015) and serum cholesterol concentration (Kim et al., 2015). The findings suggest improvements in anthropometric and biological risk factors that are similar to those reported in other workplace physical activity interventions (for example using pedometers) with non-shift workers, in both educational and government settings (Chan et al., 2004; Haines et al., 2007; Walker et al., 2014). Considering that shift work is an independent predictor of increased BMI (Antunes et al., 2010) and body weight gain (Proper et al., 2016), even small improvements in anthropometric and biological risk factors (as seen here) are encouraging, because they are associated with reduced risk of morbidity and mortality (Kruk, 2007).

Similarly, our review found that cardiorespiratory fitness improved in shift workers as a result of the physical activity interventions. This is in line with findings from a larger meta-analysis of workplace physical activity interventions that did not focus on shift workers. The authors synthesized data from 38,321 participants and improvements in fitness were documented with an overall effect size of 0.57 (Conn et al., 2009). Compared with the present review, although the study populations were smaller, the effects of physical activity were in favour of the intervention groups (Atlantis et al., 2006a; Harma et al., 1988b).

Interventions designed to influence sleep improved both sleep duration and sleep quality (Atlantis et al., 2006b; Harma et al., 1988b). These findings are in line with other randomized control trials which have shown that MVPA improves sleep variables in working adults (Dishman et al., 2015; Kredlow et al., 2015). In their 2 year follow up study conducted with health care workers, Gerber et al. (2017) found that individuals who engaged in MVPA at baseline had approximately half the risk of reporting sleep complaints at the 2 year follow up. Considering that sleep disturbances are shift workers' most frequently reported health-related concerns (Costa, 2010), physical activity could be a strategic initiative for improving sleep in this population group.

Few studies reported on the timing of physical activity in relation to shift schedules or clock time. Lack of information regarding intervention timing was first acknowledged in a review of shift worker interventions in 2007 (Atkinson et al., 2008), indicating an enduring gap in knowledge. However, two studies included in the present review offered various times for physical activity, to accommodate different work schedules. For example, in the studies by Atlantis and colleagues, shift workers were free to choose between three available time slots (7–11 am, 1–3 pm and 5–7 pm) throughout the 12-week intervention (Atlantis et al., 2006a; Atlantis et al., 2006b). This is important because asynchronized work hours and irregular roster patterns make compliance with physical activity interventions difficult for most shift workers. Although provision of timing options could be a useful strategy for engaging shift workers in future physical activity promotion initiatives, it is acknowledged that standardized timing strategies may be required in circumstances where researchers want to investigate specific physiologic responses which show circadian variation (Baehr et al., 1999; Eastman et al., 1995).

Whereas previous studies targeting working populations have reported on various locations for interventions, such as on-site fitness facilities and office stairwells (Cheema et al., 2012; Eves et al., 2006), few of the studies included in our review provided information about the intervention setting. Initiating physical activity opportunities that are integrated into the working day and done ‘on site’, could help to mitigate the significant time constraints faced by shift workers, and would address their most commonly reported barrier to physical activity, lack of time. In addition to the incomplete reporting of intervention timing and setting, the reviewed papers provided little information about the recruitment processes, other than one study that used emails (Suni et al., 2016) and two used posters and orientation seminars (Atlantis et al., 2006a; Atlantis et al., 2006b). Failure to report on recruitment rates for physical activity interventions has previously been acknowledged in health promotion research (Marcus et al., 2010). In a systematic review of recruitment rates in workplace physical activity interventions, 76% of the included studies failed to report on participant recruitment (Ryde et al., 2013). Among studies that did report on recruitment, fewer than half the targeted employees responded to the study invitations. Low response rates were reported in the shift worker interventions which may indicate potential difficulties for recruiting shift workers to participate in physical activity interventions. For example, one shift worker study contacted 3800 employees by email, only 224 expressed interest and only 42 participated in the intervention (Atlantis et al., 2006a). In another shift worker study, of the 151 participants contacted, 119 expressed interest and only 75 volunteered to participate (Harma et al., 1988b). Moreover, the overall ‘reach’ (Glasgow et al., 1999) of the interventions was in-frequently mentioned and most studies included in our review relied on small samples of volunteer participants. Collectively, the studies provided insufficient details about the intervention characteristics. Failure to report these details makes it difficult to provide specific recommendations for future intervention design.

Notwithstanding these methodological problems, the studies provided sufficient information on the amount, type and intensity of physical activity ‘prescribed’ to shift workers, and aerobic activity prescribed at a moderate intensity was positively associated with a number of outcome measures. However, none of the studies were considered “high quality” and most failed to provide adequate details about blinding strategies, illustrating a gap in shift work intervention research.

In contrast to reviews synthesizing the outcomes of physical activity interventions in non-shift workers, none of the studies in this review measured changes in the physical activity behaviours of shift workers from baseline to post-intervention. A 2007 review conducted by To et al. (2013) found twenty physical activity interventions conducted with working populations that measured physical activity behaviours. More than half (n = 13) reported that habitual levels of physical activity increased during the intervention. They also reported on the measures used to assess the efficacy of the interventions which included questionnaires, steps per day and changes in BMI. However, in that review, workplace factors were not reported, and it is assumed that the interventions were conducted and tailored to employees working conventional 9:00 am–5:00 pm shift schedules. It is evident that much more research is required on the development, implementation and evaluation of accessible and acceptable interventions for improving physical activity behaviours of shift workers.

To the authors' knowledge, this is the first systematic review of physical activity-based interventions for shift workers, where physical activity was the primary focus of the intervention. We conducted an extensive search process which utilized four large data bases with a broad list of search terms. The decision to include one article that was a trial protocol was based on improving understanding of the strategies used to promote physical activity to shift workers, even though no results were available. The main limitations of the current review were the small number of studies included, and the small number of volunteer participants. The findings cannot therefore be generalized to all shift workers but may be used to inform future study methodology. As only peer reviewed journal articles written in English language were considered eligible, relevant publications in other languages may have been missed.

Future research conducted with larger groups of shift workers is essential for the development of pragmatic physical activity-based interventions for this target group. Investigators should report on the timing of physical activity in relation to both clock time and shift schedule, and consider the utility of the worksite as an intervention setting. Additionally, interventionists should report on recruitment strategies and rates, adherence to intervention protocols, and should use reliable and valid measures of change in physical activity behaviours, before and after the intervention.

In light of the well documented body of literature of worksite physical activity interventions for non-shift workers, and growth in shift work in many industries around the world, more research is required to evaluate the efficacy of physical activity interventions on physical activity behaviour and its determinants in shift workers. However, given their long working hours (10–12) and demanding job schedules, providing opportunities for physical activity could be difficult and simply mirroring the efforts of interventions designed for other working populations will not suffice.

5. Conclusions

This review aimed to summarize the available literature on physical activity-based interventions in shift workers. Differences in intervention components and their influences on a diverse range of outcome measures were described. The findings suggest that physical activity could be effectively used to mitigate intermediate risk factors associated with NCDs such as BMI, body weight, fat mass, cholesterol, physical fitness and sleep quality. As none of the studies measured changes in physical activity behaviours, or addressed the individual, social or environmental determinants of behaviour change, it remains unclear whether or how physical activity interventions may influence physical activity *behaviours* in shift workers.

Conflicts of interest statement

The authors declare that there are no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2018.04.004.

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