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Health-related interventions among night shift workers: a critical review of the literature [1]

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1 Appendix

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MeSH terms and key words used in search strategy

Medline

- Shift work$.mp. shiftwork$.mp, night work$.mp, night shift.mp., evening work$.mp, split shift work$.mp, rotating shift work$.mp, non-day shift work$.mp, health worker.mp., healthcare worker.mp., paramedic$.mp. or exp Allied Health Personnel, emergency medical tech$.mp., Physicians/, Nurses/, Manufacturing work$.mp., Hospitality work$.mp, armed forces, mp., armed personnel.mp, Military Personnel/, Police$.mp. or exp Police/, Astronauht.mp. or exp Astronauts/, flight attendant$.mp. , steward$.mp., air crew.mp., or pilots.mp.

AND

- *Light/ bright light.mp, dim light.mp, exp Lighting/, controlled light exposure, mp., light intensity.mp, blue light.mp, phototherapy.mp. or exp Phototherapy/, light exposure.mp., Darkness/, goggles.mp, dark goggles.mp, sunglasses.mp, blue blockers.mp, short wavelength.mp, light exposure.mp., Modafanil.mp., adrafinil.mp, armodafinil.mp, Melatonin/ad, tu [Administration & Dosage, Therapeutic Use], Caffeine/ad, ae, ct, sd, tu, th [Administration & Dosage, Adverse Effects, Contraindications, Supply & Distribution, Therapeutic Use, Therapy], stimulants.mp., Exp Relaxation Therapy/ or stress management.mp, Exp Counsling/ or counseling.mp, physical activity.mp., exp Exercise/ or exp Exercise Therapy, Diet.mp or exp Diet/, meal.mp, weight loss.mp. or exp Weight Loss/, Low energy emission therapy.mp, Nap$.mp, Exp "Personnel staffing and scheduling"/ or work schedule.mp, schedule change.mp., schedule modification.mp., shift system.mp., shift change.mp., shift rotation.mp, shift length.mp, work schedule flexibility.mp,. , Working conditions.mp, workload/or working time directive.mp, exp Primary Prevention/ or prevention.mp; health promotion.mp. or exp health promotion/

AND

- Work schedule tolerance.mp. or exp Work Schedule Tolerance/, circadian adaptation.mp., circadian rhythm adaptation.mp., circadian alignment.mp., circadian adjust$.mp., phase shift.mp., phase delay.mp., Exp Sleep/ or sleep.mp., sleep-wake cycle.mp., rest-activity cycle.mp., Melatonin.mp. or exp Melatonin/, dim light melatonin onset.mp., urinary 6-sulfatoxymelatonin.mp., Cortisol.mp., Cancer.mp. or exp Neoplasms/, diabetes.mp. or exp Diabetes Mellitus/, cardiovascular disease.mp. or exp Cardiovascular Diseases/, heart disease.mp. or exp Heart Diseases/, exp Metabolic Syndrome X/ or metabolic syndrome.mp.

EMBASE

- Shift work$.mp. or exp shift worker/, shiftwork$.mp., exp night work/ or night work$.mp., night shift work$.mp., evening work$.mp., split shift work$.mp., rotating shift work$.mp., alternating shift work$.mp., non-day work$.mp., Healthcare worker.mp.; emergency medical tech$.mp., paramedical personnel/ or paramedic$.mp.; *physician/ or *nurse, Manufacturing worker.mp. or exp industrial worker/, Hospitality worker.mp., Armed forces.mp.; military personnel.mp. or exp soldier/; armed personnel.mp; police$.mp. or exp police/, Astronaut.mp. or exp cosmonaut/; flight attendant$.mp. or exp airplane crew/; airplane pilot/ or pilots.mp.

AND

- Exp phototherapy/ or exp light exposure/ or bright light.mp. or light/; dim light.mp; lighting.mp. or exp illumination/; darkness/; controlled light exposure.mp.; light intensity.mp. or exp light intensity; blue light.mp. or exp blue light/, Goggles.mp.; dark goggles.mp; sunglasses.mp.; blue-blockers.mp; short wavelength.mp., exp melatonin/ct, ad, dv, do, dt, po [Clinical Trial, Drug Administration, Drug Development, Drug Dose, Drug Therapy, Oral Drug Administration], exp caffeine/ct, ad, do, dt, po, th [Clinical Trial, Drug Administration, Drug Dose, Drug Therapy, Oral Drug Administration, Therapy]; stimulants.mp., exp Modafinil/ or modafanil.mp; Armodafinil.mp. or exp armodafinil/; adrafinil.mp. or exp adrafinil/, Stress management.mp. or exp stress management/; counseling.mp. or exp counseling/, Exercise.mp. or exercise/; physical activity.mp. or exp physical activity/, Diet.mp. or exp diet/; Meal.mp. or meal/, Weight loss.mp. or exp weight reduction/, Low energy emission therapy.mp., Nap$.mp., Exp Work schedule/ or schedule change.mp.; schedule modification.mp.; shift system.mp.; shift change.mp.; shift length.mp. or exp working time/; work schedule flexibility.mp., shift rotation.mp. Workload/ or working time directive.mp.; exp work environment/ or working conditions.mp., *health promotion/ or *health program or *prevention

AND

- circadian adaptation.mp.; circadian rhythm adaptation.mp.; circadian alignment.mp.; circadian adjust$.mp.; phase shift.mp.; phase delay.mp., Sleep-wake cycle.mp. or exp sleep waking cycle/; rest-activity cycle.mp.; *sleep/, Melatonin.mp. or exp melatonin/; dim light melatonin onset.mp.; urinary 6-sulfatoxymelatonin.mp. or exp 6 hydroxymelatonin o sulfate/, Cortisol.mp, Cancer.mp. or exp Neoplasms/, diabetes.mp. or exp Diabetes Mellitus/, cardiovascular disease.mp. or exp Cardiovascular Diseases/, heart disease.mp. or exp Heart Diseases/, exp Metabolic Syndrome X/ or metabolic syndrome.mp.

CINAHL

- (MH "Shiftwork") or "shiftwork" or (MH "Shift workers") or "shift work" or "night work' or "night shift work" or "evening work" or "split shift work" or "rotating shift work" or "alternating shift work" or "non-day work", (MH "Health personnel") or "health worker" or "healthcare worker" or (MH "Nurses") or (MH "Emergency medical technicians") or "emergency medical tech$" (MH "Physicians") or "paramedic", "Manufacturing worker" or "industrial worker", "Hospitality worker", "Armed forces" or (MH "military personnel") or "soldier" or (MH "police") or "police" , "Astronaut" or "flight attendant" or "airplane crew" or (MH "Pilots")

AND

- (MH “Phototherapy”) or “phototherapy” or (MH “Lighting”) or “light exposure” or “bright light” or (MH “light”) or “dim light” or “ darkness” or “controlled light exposure” or “light intensity” or “blue light”, “Goggles” or “dark goggles” or “sunglasses” or “blue-blockers” or “short wavelength”, (MH “melatonin”) or “melatonin”, (MH “Caffeine”) or “caffeine” or “stimulant”, (MH “Modafinil”) or “modafanil” or “armodafinil” or “adrafinil”, (MH “Stress management”) or “stress management” or (MH “counseling”)or “counseling”, (MH “Exercise”) or “exercise” or (MH “physical activity”) or “physical activity”, (MH “Diet”) or “diet”; (MH “meal planning”) or “Meal”, (MH “Weight loss”) or “weight loss”, “Low energy emission therapy”, “Nap$”, “Work schedule” or “schedule change” or “schedule modification” or (MH “Personnel staffing and scheduling”) or (MH “Flexible scheduling”) or “shift system” or “shift change” or “shift length” or “working time” or (MH “Work environment”) or “shift rotation” or (MH “ Workload”) or “working time directive”, (MH “Health promotion”) or “health promotion” or “prevention”

AND

- (MM “Circadian Rhythm”) or “circadian adaptation”; “circadian rhythm adaptation”; “circadian alignment”; (MH “Phase Angle”) OR “phase shift”; “phase delay”, “Sleep-wake cycle” or ‘rest-activity cycle”; (MH “sleep”) or “sleep”, (MM “Melatonin”) or “melatonin”; “dim light melatonin onset”; “urinary 6-sulfatoxymelatonin”, “Cortisol”, (MH “Neoplasms”) or “Cancer”; (MH "Diabetes Mellitus, Type 2") OR (MH "Diabetes Mellitus") OR "diabetes"; (MM "Cardiovascular Diseases") OR (MM "Cardiovascular Risk Factors") OR "cardiovascular disease", (MM "Metabolic Syndrome X") OR "Metabolic syndrome"

Inclusion criteria

• All workers on permanent night or rotating shifts at the time of intervention AND
• Implemented an intervention for 7 or more consecutive days and evaluated it AND
• Designed to improve one or more health outcomes related to chronic disease:
  • Sleep quantity and quality (objective and subjective measurement tools)
  • Markers of circadian disruption or circadian adaptation (melatonin, cortisol, body temperature, uric acid, norepinephrine, epinephrine)
  • Markers of chronic disease risk (cholesterol, triglycerides, glucose, HbA1C, c-reactive protein, blood pressure)
  • Risk factors for chronic disease (physical activity, unhealthy diet, tobacco use, alcohol consumption, overweight or obesity)

Exclusion criteria

• Interventions conducted among non-shift workers (e.g. healthy volunteers) OR
• Interventions conducted among workers with extreme work schedules or workers who cross time zones (e.g. astronauts, pilots, flight attendants, air crew, military/soldiers) OR
• Interventions conducted in simulated work environments and conditions OR
• Literature reviews, commentaries, editorials, opinion pieces, policy document, consensus statement OR
• Absence of both pre- and post-intervention main outcome measures OR
• Designed to improve any one or more of the following outcomes:
  • Organizational-related (e.g. profit, turnover, absenteeism, job satisfaction, productivity, performance, alertness, vigilance)
  • Workplace injuries
  • Sleepiness
  • Fatigue
  • Mental health, mood, well-being, work-life balance, psychological stress, burnout
  • Attitudes towards intervention

Figure 1: search strategy and study selection

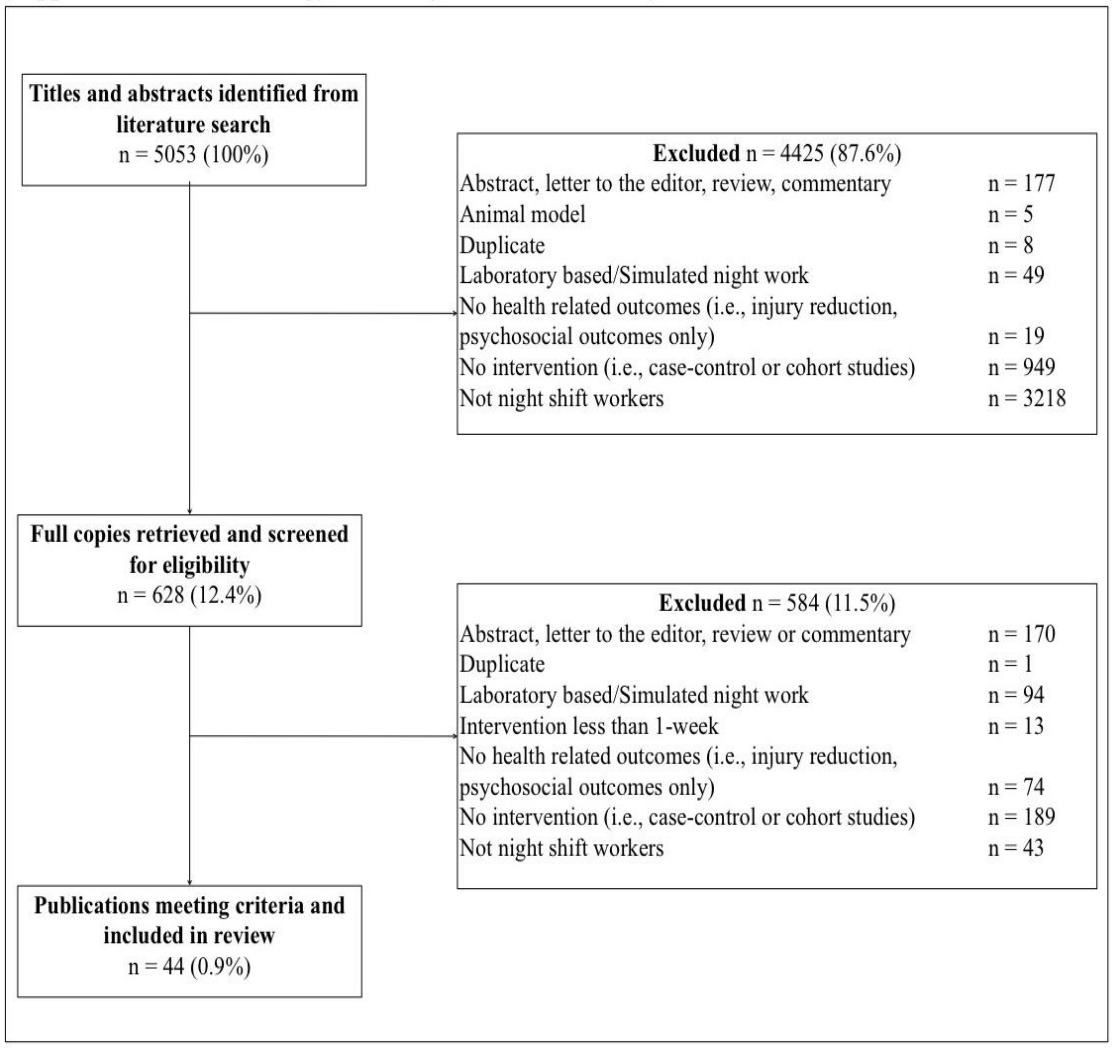

Table A. Controlled light exposure interventions

Author/Year	Primary Aim	N	Sample	Shift system	Intervention	Length	Design	Outcome Measures	Results			Quality
									Treatment		Control	
Bjorvatn 1999 (23)	To promote adaptation to night shift and readjustment to day	7	M oil rig workers (North Sea), age 29-47, > 8 y SW, good health	12-h shifts, one-week blocks; (DD---NN----)	30 min BL exposure (10 000 lux) 3h before habitual wake time; first 4 nights and first 4 days off	One rotation (14 night shifts)	Single-arm, pre-post intervention	During night shifts - Time in bed (min) - Sleep latency (min) - Total sleep time (min) - Sleep quality (Likert, 1-5) Days off - Time in bed (min) - Sleep latency (min) - Total sleep time (min) - Sleep quality (Likert, 1-5)	 +8.0 +1.2 +7.8 +0.0 +25.9 +6.5 +20.3 +0.4		n/a	17
Bjorvatn 2007 (24)	To assess effects of bright light and melatonin in shift workers complaining of problems	17	M=16, F=1, oil rig workers (North Sea) mean age 42, report problems adjusting to SW	2-weeks on 12-h shift (one week nights, 1830-0630), second week days (0630-1830) followed by 3-4 weeks off.	1) 30 min BL (10 000 lux), before the start of the nadir (0000-0500 on nights, 1200-1430 on days) 2) 3 mg melatonin 1h before bed 3) Placebo capsule For the first four days of night and day shifts	14-days of work	3-arm randomized cross-over design	During night shifts Subjective sleep (diary) - Sleep onset latency (min) - Total sleep time (min) - Sleep efficiency (%) - Sleep quality (1-5) Objective sleep (Actiwatch) - Sleep onset latency (min) - Total sleep time (min) - Sleep efficiency (%) Days off Subjective sleep (diary)	BL 9[a] 392 86 3.1 6 419[a] 88	Melatonin 13[b] 405[b] 87 86 9[b] 416 87	Placebo 14 386 86 3.1 6 403 86	20

								- Sleep onset latency (min)	17	19	19	
								- Total sleep time (min)	318	355[b]	340	
								- Sleep efficiency (%)	80	87[b]	83	
								- Sleep quality (1-5)	2.8	2.8	2.7	
								Objective sleep (Actiwatch)				
								- Sleep onset latency (min)	7	15[b]	6	
								- Total sleep time (min)	367	355	348	
								- Sleep efficiency (%)	87	86	85	
Boivin 2002, 2004 (27, 28)	To promote circadian rhythm adaptation to night-shift	15	M=6, F=9 full-time nurses (hospital, Montreal, Canada), mean age 41.7; No sleep disorders	8-h night shifts (≥ 8 shifts/15 days)	1) BL exposure (~2000 lux) during first 6-h of 8-h shift, centered 1:07 ± 0:30 min before midpoint of peak melatonin concentration; 2) Neutral gray density lens goggles during commute home	Mean = 12 shifts (19 days)	Two-arm RCT with cross-over (n=4)	Phase angle (hours)				15
								- Core body temp. (degrees C)	-0.06[a, b]		+5.31	
								- Salivary melatonin (pg/mL)	-2.05[a, b]		+4.31	
								Phase shift				
								- Core body temp. (t_{min}, h)	+9.32[a, b]		+4.09	
								- Salivary melatonin (t_{mid}, h)	+11.31[a, b]		+5.08	
James 2004 (31)								Salivary cortisol				12
								- Phase angle (h)	-1:47[b]		+7:17[a]	
								- t_{mas} (h)	+10:04[a, b]		+3:03	
								- t_{min} (h)	-12:34[a, b]		+3:41	
								- 24h mean concentration (ug/dL)	+0.03		+0.02	
Boivin 2012a (25)								After night shift				17
								- Time in bed (h, Actigraph)	-0:37		-1:37	
								- Total sleep time (h, PSG)	7:06[b]		6:36	
								- Sleep efficiency (h, PSG)	92%		88%	
Boivin 20012b (26)	To promote circadian rhythm adaptation on rotating shift	15	M=7, F=8 full time police officers (Montreal, Canada), mean age 29.8; No	35-d roster (EEE--DDDD--NNNNNNN--------EEEE--	1) Intermittent BL "as much as workload permitted" 2) Orange-tinted	7 night shifts	Two-arm RCT with cross-over (n = 2)	*Before/After night shift*				18
								- UaMT6s t_{mid} (h)	-7.07[a]		-5.75[a]	
								- UaMT6s total (ng)	+1671		+268	

			drugs, medical or psychological conditions	DD--)	goggles from sunrise to start of daytime sleep			- Salivary melatonin acrophase (h) - Salivary melatonin amplitude (pg/mL) *During night shift* Daytime mean uaMT6s	-5.93 -2.13 + [b]	-4.52 -2.03 x	
Budnick 1995 (29)	To determine effectiveness of BL at home to alter circadian pacemaker, improve sleep and performance	13	M=11, F=2 industrial technicians (Chemical company, Baytown, Texas), median age 35	12-h shifts, 16-day rotation (DDDD----NNNN----)	1) Ambient light increased to 1 500 lux; 2) Scheduled BL (5000-8000 lux standing; 4000-6000 lux sitting) for at least 50% of shift	6 work cycles (96 days)	Single-arm, pre-post intervention	Hours of sleep (log book) Urinary melatonin	x x	n/a	13
Figueiro 2001 (30)	To improve performance and sense of well-being	21	F day (n=12) and night (n=9) NICU nurses (South Bend, Indiana), age 25-38; >6 months on same shift	12-h permanent day or night shift	1) 15 min of BL (2300-4000 lux) at start, middle, end of shift; 2) BL with dark goggles (sham intervention)	2 weeks	Non-randomized intervention BL on day/ night shift	Tympanic temperature throughout night shift	x	n/a	9
Kakooei 2010 (32), Zamanian 2010 (38)	To compare hormonal levels, body temp. before/after BL	34	F nurses (University hospital, Shiraz, Iran), mean age 27; No history of psychiatric disorders	Irregular 3-shift system, day, evening and night	BL (4500 lux) during two 45-min breaks on night shift,	30 days	Single-arm, pre-post intervention	Plasma melatonin (mean concentration, pg/mL) Body temperature t_{peak} (h) Plasma cortisol (mean concentration, ug/dL)	-7.29 [a] +3:00 [a] +1.75 [a]	n/a	12, 8
Lowden 2004 (33)	To determine effectiveness of short term BL exposure	18	M=17, F=1 Industrial operators (Truck production plant, Sweden), mean age 36.2, mean 5.4 y SW	5 shifts (morning, evening, night), 2 off for 4-wks	BL (2500 lux) during two self-chosen breaks	4 weeks	Two-arm RCT with cross-over	Sleep (Actiwatch) - Bed time (h) - Sleep time (h) - 24-total sleep (h) - Sleep efficiency (%) Melatonin (mean concentration,	 07:44 6:43 6:53 [b] 90.4	 07:44 6:28 x 89.5	18

								pg/mL)	15.02 [b]	18.10	
Sasseville 2009 (34)	To determine effect of blue-blockers to promote circadian rhythm	28	M=13, F=15 mail distribution center workers (Quebec City, Canada), age 25-55; Good health, no travel > 1 time zone in past month	Permanent night shift, (NNNNN--)	Blue-blocker goggles worn when commuting home and before night shifts	Two weeks	Single-arm pre-post intervention	Sleep (Actiwatch) - Time before bedtime (min) - Time in bed (h) - Total sleep time (h) - Sleep efficiency (%) - Movement and Fragmentation Index (%)	 -9 +0:17 +0:32 [a] +2.0 [a] -1.7 [a]	n/a	16
Sasseville 2010 (35)	To evaluate effect of goggles on performance & circadian adaptation	4	M sawmill workers (Quebec City, Canada), mean age 44.8; Healthy, no smoking, drugs/sleep medication, extreme chronotypes or travel >2 time zones in past month	3-week rotation (DDDDD--NNNNN--EEEEE--)	1) Environment supplemented with blue-green light (200 lux) 2) Blue-blockers on commute home and when outside before 1600h	1 week	Single-arm, pre-post intervention	Phase shift of salivary melatonin (h) Bed time (h) Time in Bed (h) Total Slept Time (h) Sleep efficiency (%) Sleep latency (h)	-2:02 +0:14 +0:05 +0:40 [a] +3.7 -0:18 [a]	n/a	12
Tanaka 2011 (36)	To assess effects of workday BL on sleep, fatigue, safety and performance	61	F nurses (Teaching hospital, Japan), mean age 29.7; No eye/mood disorders, sensitivity to BL, headaches	Rapidly rotating shift schedule: (DDD-NN-)	10 min of BL (5444-8826 lux) on day-shift workday mornings in staff lounge	One month (one-week washout)	Two-arm RCT with crossover	Night sleep (VAS) Alcohol consumption	6.30 [b] x	5.94	21
Thorne 2010 [(32)]	To assess effectiveness of BL after night shift in promoting circadian adaptation and improving	10	M oil rig workers (North Sea), mean age 46-49, BMI >28	1900-0700h for 14 or 21 consecutive days in the summer of 1800-0600 for 14 consecutive days in winter	1) One hour of BL (~3000 lux), timed to phase advance the circadian system 2) Sunglasses worn from wake prior to bright	21 days	2-arm intervention (some randomized, some not)	Rate of aMT6s adaptation (h/day) Objective sleep (Actigraphy) - Sleep onset (h) - Sleep offset (h) - Sleep duration (h)	2.16 22.85 5.78 6.18	2.00 23.45 6.19 5.95	18

	sleep				light exposure			- Sleep efficiency (%) - Fragmentation index - Sleep latency (h) Subjective sleep (Diary) - Sleep onset (h) - Sleep offset (h) - Sleep duration (h) - Sleep efficiency (%) - Fragmentation index - Sleep latency (h) - Sleep quality (1-9 Likert)	86.7 [a] 27.2 0.21 22.92 6.51 6.99 0.14 1.3 0.31 4.6	79.4 30.7 0.38 22.91 6.66 7.26 0.13 1.5 0.32 5.1	

[a] Significant difference before-after intervention, $p < 0.05$

[b] Significant between groups

Note: + = positive change - = detrimental change, x = no change

Legend: BL, Bright Light; BMI, Body Mass Index; D, Day shift; E, Evening shift; F, Female; h, hours; M, Male; N, Night shift; PSG, Polysomnography; RCT, Randomized Controlled Trial; SSS, Stanford Sleepiness Scale; -, off work; t_{mid}, time of midpoint; t_{max}, time of maximum; VAS, Visual Analogue Scale

Table B. Change in shift schedule interventions

Author/Year	Primary Aim	N	Sample	Shift system	Intervention	Length	Design	Outcome Measures (Tool)	Results			Quality
									Treatment		Comparison	
Boggild 2001 (39)	To examine the effect of a change in schedule biomarkers of heart disease	101	Full/part-time nurses/nursing aides (Hospitals, Nothern Juland, Denmark), median age 35-42; wards willing to change schedules	2-3 shift rotation, flexible/ irregular scheduling	1) I4, adoption of four ergonomic principles 2) I3, adoption of three ergonomic principles (regularity; fewer consecutive shifts; more weekends off; two types of shifts)	6 months	Three-arm, quasi-experimental intervention		I4	I3		17
								TChol (mmol/L)	-0.1	+0.2	0.0	
								TG (mmol/L)	-0.1	0.0	0.0	
								HDL (mmol/L)	+0.1 [b]	0.0	-0.1	
								LDL (mmol/L)	-0.2 [b]	0.0	+0.1	
								Total:HDL ratio	-0.3 [b]	-0.3	+0.1	
								Sleep quality (Subjective)	x	x	x	
								Lifestyle (Exercise, smoking, alcohol consumption)	x	x	x	
Hakola 2001 (40)	To compare two shift systems on sleep and wakefulness	16	M steel factory workers (Finland), young (age 30-39) and old (age 44-56)	Slow backward rotating; (EEE-MMMNNN-----)	Fast forward rotating system; (MMEENN-----)	1-year	Single-arm pre-post intervention	Sleep quality (SSI)				9
								- Morning shift	+ [a]		n/a	
								- Evening shift	x			
								- Night shift	x			
								Sleep Length (Actigraph)	x			
								Sleep Efficiency (Actigraph)	+			
Hakola 2010 (41)	To determine effectiveness of new shift system on health and	75	M=4, F=71 nurses (Hospital, Finland),	8-day rotation; (-EMEMNN-)	1) Fewer quick transitions from evening to morning	1-year	Single-arm, pre-post intervention	Sleep length (SSI, h)	+ [a]		n/a	18
								Leisure-time activity (SSI)	+ [a]			

	wellbeing by age group		mean age 46		shift 2) Forward shift rotation						
Harma 2006 (42)	To determine effects of intervention on sleep-wakefulness, well-being and social life	140	M airline maintenance workers (Helsinki, Finald); mean age 36 (<45) and 50 (>45);	Continuous backward rotating three-shift system (EEE--MMM--NNN--)	Rapidly forward rotating shift system (MEN--)	6 months	Two-arm, non-randomized intervention	Sleep (Actigraph) - Sleep length - Sleep efficiency - Sleep fragmentation	 + [b] + [b] - [b]	n/a	16
Hossain 2004 (43)	To determine the effects of a change in shift system on sleep and performance	58	M=56, F=2 underground mine workers (Timmins, Canada), mean age 40.3; no medication or illness; mean 17.6y of SW	Backward rotating, 8-h, 3-shift system (NNNNN--EEEEE--DDDDD--)	Backward rotation, 10-h, 2-shift system (DDDD---NNN---)	1 year	Single-arm, pre-post intervention	During night shift (PSG) - Sleep duration (h) - Sleep quality (1-5) During day shift (PSG) - Sleep duration (h) - Sleep quality (1-5) Days off (PSG) - Sleep duration (h) - Sleep quality (1-5)	 -0.2 -1.2 [a] -1.1 [a] +0.4 -0.2 +0.4 [a]	n/a	17
Karlson 2009 (44)	To improve subjective health and well-being through a change in shift schedule	118	M=98, F=20) manufacturing plant workers (Lund, Sweden), mean age 44.6	Continuous, fast forward-rotating 24-h schedule (MMAANN----)	Slower, backward rotating schedule: (MMM---NNN---AAA--)	9 months	Two-arm, non-randomized intervention	Sleep disturbances (KSQ) Health - Self-rated (single-item) - Symptom Checklisk-35 - LSHCI	-0.3 [a, b] +0.6 [a, b] -0.15 [a, b] -0.14 [a, b]	+0.05 +0.05 -0.10 -0.07	15
Knauth	To determine whether quick	14	Steel manufacturin	Discontinuous (NNNNNN-	Quick, forward	10 month	Two-arm, non-	Subjective Health	x	x	13

1998 (45)	forward rotation has an advantage over backward rotation	3	g plant workers (Germany), mean age 35.6-39.8 y	EEEEEE-MMMMMM-) or continuous NNNNNNN--EEEEEEE--MMMMMMM---) backward rotating shift	rotation shift Discontinuous (---MMM-MMMEEE-NNN----EEENNN-) or continuous (MEENN---)	s	randomized intervention	Sleep time/disturbances Leisure time	x x	x x	
Lowden 1998 (46)	To determine the effect of changing from an 8-h, 3-shift system to a rapidly rotating 12-h, 2-shift system	14	M= 12, F=2 chemical plant workers, mean age 37	35-day, 8-h schedule (-AMMMM---NNNNAA---AAMMM----NNNAA---)	Rapidly rotating , 12-hour schedule (NN-----DD--NN----DDD--NN-----DD---)	10 months	Pre-post intervention (also included day shift group, not reported here)	Subjective sleep (diary) - Bed time - Time of rising - Sleep length	 x x x	n/a	12
Mitchell 2000 (42)	To examine the effect of a change in shift on performance, health and well-being, sleep, mood, absence and accident	15	M electrical power station workers, mean age 44	8-h rotating,3-shift system over 4 weeks (AAAAAAA--DDDDDDD-NNNNNNNN----)	12-h rotating shift day and night shifts (16-week schedule)	10 months	Single group, pre-post intervention	Sleep (diary) - After day shift (h) - After night shift (h) - Day off (h) Sleep quality (VAS)	 +0.55 +1.50 +0.05 + [a]	n/a	17
Orth-Gomer 1982, 1983 (48, 49)	To evaluate the effects of a new shift on coronary risk factors, well-being, sleep and urinary catecholamine	45	M police officers (Stockholm, Sweden), mean age 30; No heart disease or other chronic	Backwards rotating shift of night, evening, mid-day, morning and early morning shifts	Forward rotating shift	4 weeks (no wash-out)	Two-arm intervention with cross-over	Fasting cholesterol TG Gl Uric acid Epinephrine/Norepinephrin	+ + [b] + [b] + x	+ + + + -	18

	s		illness					e SBP (mmHg) DBP (mmHg) Tobacco consumption (#/8h shift) Sleep length at night (h) Day sleep after night work (h)	111.6 [b] 75.2 4.7 -0.2 -0.2	115.6 75.8 4.4 +0.1 -0.2	
Peacock 1983 (50)	To compare physiological/ psychological effects of change in shift system	75	M police officers (Dartmouth City, Canada), mean age 32.8	8 h, 12-day rotating shift (NNNEEEMMM----)	12h-8 day rotating schedule (NN-DD---)	6 months	Single-arm pre-post intervention	Physical fitness (W170 test, J/min) Resting Blood Pressure Body temperature Urinary catecholamines Sleep quality (1-7 scale)	+12.03 [a] x x NR + [a]	n/a	10
Rosa 1989 (51)	To evaluate change in variables related to shift work after a change from a 8-h to 12-h shift schedule	53	M=45, F=4 (4 unknown) Control room officers at processing plant; 71% between 25-35y (rest >35)	8-h rotating shift (DDDDD----SSSSSSS--TDDTTT--NNNNNNN--)	12-h rotating shift (TTTT ooo NNNN ooo DDD ----- o NNN ooo – DDD)	7 months	Single arm, pre-post intervention	After night shift (Diary) - Total sleep time (h) - Sleep latency (min) - Sleep quality (1-9) - Exercise bouts (%) After day shift (Diary) - Total sleep time (h) - Sleep latency (min) - Sleep quality (1-9)	 + 0.24 + 0.34 + 0.15 -15 + 0.20 + 4.22 - 0.07	n/a	13

								- Exercise bouts (%)	-13		
Rosa 1996 (52)	To improve sleep before the morning shift; To assess the effect on older workers	68	M=63, F=2 Steel plant operators (Finland), Young: mean age 31, 10y SW; Old: mean age 50, 23 y SW	10-h, backward rotating schedule; (EEEE-MMMM-NNNN---); Evenings 1400-2200, mornings 0600-1400, nights 2200-0600	One hour delay in start and end times	4 months	Single arm, pre-post intervention; also report site with no change (but different schedule)	Morning shift sleep - Subjective (SSI) - Actigraph (h) - Sleep diary Evening shift sleep - Subjective (SSI) - Actigraph (h) - Sleep diary Night shift sleep - Subjective (SSI) - Actigraph (h) - Sleep diary	 x + [a] + [a] - [a] x x x - -*		n/a	16
Viitasalo 2008 (53)	To evaluate the effects of shift change on alertness, and cardiovascular risk factors	84	M permanent airline maintenance workers (Helsinki, Finland), mean age 37-47; Healthy, no CVD, or medication for CVD, diabetes or sleep disorders	8-h, 3 shift system (EEE--MMM--NNN--)	1) Forward, rapidly rotating shift (MEN--) 2) Flexible shift system (typically EEE---MMM---NNN---) resulting in fewer work hours	7-8 months	3-arm, non-randomized intervention	TC (mmol/L) HDL (mmol/L) LDL (mmol/L) TG (mmol/L) Gl (mmol/L) HbA1c (%) CRP (mg/L) Resting SBP (mmHg)	Forward +0.3 0.0 +0.1 +0.2 -0.1 -0.2 +0.3 +2.5	Flexible 0.0 +0.1 -0.1 0.0 -0.2 -0.2 +0.3 -6	+0.1 +0.1 +0.1 +0.1 -0.2 -0.1 +0.3 x	20

								Resting DBP (mmHg) BMI (kg/m^2) Waist (cm) Waist/hip ratio Dietary Fibre (g/day) Quality of fat intake Alcohol (g/day) Physical Activity (h/week) Sleep disturbance (ESS)	x 0 +2 +0.2 -2 +1 -1 0 +	+ 0 +3 +0.2 +1 +1 +2 -0.1 +	x 0 +1 0 0 0 -1 -0.3 -	
Williamson 1994 (50)	To examine effects on health, job satisfaction and productivity	18	Computer operators (Australia), mean age 23.8, employed 1.3 y	Rotating shift system; 8 week rotation including 8=h day, afternoon and night shifts and 12-h day and night shifts	Rotating 3-shift system of 12-h day and night shifts (DDNN----)	12 months	Single-arm, pre-post intervention	Hours of sleep (Diary) - Day shift - Night shift - Rest day # of sleep periods (Diary) - Day shift - Night shift - Rest day	 + [a] + [a] - [a] - + [a] + [a]		n/a	13

[a] Significant difference before-after intervention, $p < 0.05$

[b] Significant between groups

Note: + = positive change - = detrimental change, x = no change

Legend: A, Afternoon shift; BMI, Body Mass Index; BW, Body Weight; CRP, C-Reactive Protein; CVD, Cardiovascular Disease; D, Day shift; DBP, Diastolic Blood Pressure; E, Evening shift; ESS, Epworth Sleep Scale; Gl, Glucose; HbA1C, Hemoglobin A1C; HDL, High Density Lipoprotein; KSQ, Karolinska Sleep Questionnaire; LDL, Low Density Lipoprotein; LSHCI, Lund Subjective Health Complaints Inventory; M, Morning shift; N, night shift; o, On-Call shift; PA, Physical Activity; S, Swing shift; SBP, Systolic Blood Pressure; SSI, Standard Shiftwork Index; T, Training shift; TC, Total Cholesterol; TG, Triglycerides; VAS, Visual Analog Scale; W, work; - , off work;

Table C. Behavioral interventions

Author/ Year	Primary Aim	N	Sample	Shift system	Intervention	Length	Design	Outcome Measures (Tool)	Results		Quality
									Treatment	Control	
Bonnefond 2001 (55)	To test the effect of napping on work demand, quality of life and sleep; to test acceptability to shift workers	12	M electric power plant workers, mean age 37, mean 11.3y SW	5-shift rotating shift system; morning, afternoon, night, shifts plus day and half day training	Short rest period of 1-h between 23:30-03:30h (Control group enrolled but lost to follow-up)	1 year	Single arm, pre-post intervention	Sleep duration following night shift (minutes, Diary)	-13.8	n/a	10
Harma 1988a (57)	To determine the effects of physical training on fitness, fatigue, sleep and psychosomatic symptoms	75	F nurses/nursing aides (Hospital, Kuopio, Finland), age 20-49; 1.5y SW	38h/week, irregular rotation of 8-10h day, evening and night shifts	Physical training program targeting circulatory and muscular systems (jogging, running, swimming, skiing, walking and gymnastics); 2-6x/week, 60-70% maximum heart rate	4 months	2-arm RCT (2:1)	VO_2 max (ml/kg/min) Strength (# sit-ups/30s) Body Weight (kg) Body composition (skinfolds, mm) Subjective Sleep (Diary) Sleep Length – Morning (h) Sleep Length – Evening (h) Sleep Length – Night (h) Sleep Quality – Morning Sleep Quality – Evening Sleep Quality - Night	+1.9 [a, b] +2.9 [a, b] -0.6 [a] -2.5 [a] +0.2 [a] +0.3 [a, b] +0.4 [a] -0.3 [a] 0.0 -0.4	-0.3 +0.5 -0.5 -0.4 0.0 0.0 +0.1 -0.4 +0.2 -0.5	18
Harma 1988b (56)	To determine effects of physical training							Body Temperature Mesor (° C)			18

	on alertness, short term memory and body temperature							- Day shift - Night shift Body Temperature Amplitude (° C) - Day shift - Night shift Body Temperature Acrophase (h/min) - Day shift - Night shift	-0.11 [a] - 0.09 [a] -0.08 [a] +0.03 [a] +1:11 [a] +0:57	-0.05 [a] -0.06 [a] -0.01 [a] +0.05 [a] +1:46 [a] -0:06	
Morgan 2011 (58, 59)	To determine the feasibility and efficacy of a work-based weight loss program	110	M aluminum plant workers (Tomago Aluminum plant, Newcastle, Australia) mean age 44.4; BMI 25-40, no major medical problems in the last 5y; no contraindications to exercise or recent weight loss	Four shifts (schedule not reported)	Group-based lifestyle intervention for weight loss based on Social Cognitive Theory; one-on-one information session, study website, resource booklet, pedometer and financial incentive;	14 weeks	2-arm RCT	Body weight (kg) Waist circumference (cm) BMI (kg/m^2) SBP (mmHg) DBP (mmHg) Physical Activity (MET minutes) Current PA Level (GLTEQ) Workday PA (GLTEQ) Dietary Intake (FFQ) - Fruit - Vegetables - Bread - Milk - Cola	-4.0 [a, b] -4.4 [a, b] -1.3 [a, b] -7.3 [a] -3.7 [a] +0.4 [a, b] +0.4 [a, b] +0.8 [a] + 0.5 [a] 0.0 -0.8 [a] -0.6 +0.4 [b]	+0.3 +1.5 +0.1 -1.3 -2.5 +0.1 -0.2 +0.4 +0.1 -0.1 -0.2 -0.1 -0.	27

								- Diet drinks - Soda drink Alcohol risk score	+0.7 +0.4 [b] +0.1	-0.1 -1.1 -0.1	
Smith-Coggins 1997 (60)	To test the effectiveness of a broad literature-based intervention to enhance adaptation to night rotations	6	M emergency department attending physicians (Stanford Univeristy Hospital, Stanford Connecticut), mean age 34	10-16 shifts/month equally divided into day, evening, and night shifts 8-9 hours long	Two-hour education session about sleep physiology and sleep hygiene; education about countermeasure strategies to maintain alertness and performance during work; regular work schedule	3-4 weeks	2-arm, double-blind, RCT with cross-over (1 month washout)	Subjective sleep (Log) Total sleep time (h, PSG) REM sleep time (min, PSG)	x +0:42 +21.74 [a]	x +1:08 [a] NR	17

[a] Significant difference before-after intervention, $p < 0.05$

[b] Significant between groups

Note: + = positive change - = detrimental change, x = no change,

Legend: BMI, Body Mass Index; BP, Blood Pressure; F, Female; FFQ, Food Frequency Questionnaire; GLTEQ, Goodin Leisure Time Exercise Questionnaire; HR, Heart Rate; M, Male; MET, Metabolic Equivalent; PA, Physical Activity; PSG, Polysomnography; RCT, Randomized Controlled Trial; VO_2max, Maximal oxygen consumption;

Table D. Pharmacological interventions

Author/ Year	Primary Aim	N	Sample	Shift system	Intervention	Length	Design	Outcome Measures (Tool)	Results			Quality
									Treatment		Control	
Bjorvatn 2007 (24)	To assess effects of bright light and melatonin in shift workers complaining of problems	17	M=16, F=1, oil rig workers (North Sea) mean age 42, report problems adjusting to SW	2-weeks on 12-h shift (one week nights, 1830-0630), second week days (0630-1830) followed by 3-4 weeks off.	1) 30 min BL (10 000 lux), before the start of the nadir (0000-0500 on nights, 1200-1430 on days) 2) 3 mg melatonin 1h before bed 3) Placebo capsule For the first four days of night and day shifts	14-days of work	3-arm randomized cross-over design	During night shifts	BL	Melatonin	Placebo	20
								Subjective sleep (diary)				
								- Sleep onset latency (min)	9[a]	13[b]	14	
								- Total sleep time (min)	392	405[b]	386	
								- Sleep efficiency (%)	86	87	86	
								- Sleep quality (1-5)	3.1	86	3.1	
								Objective sleep (Actiwatch)				
								- Sleep onset latency (min)	6	9[b]	6	
								- Total sleep time (min)	419[a]	416	403	
								- Sleep efficiency (%)	88	87	86	
								Days off				
								Subjective sleep (diary)				
								- Sleep onset latency (min)	17	19	19	
								- Total sleep time (min)	318	355[b]	340	
								- Sleep efficiency (%)	80	87[b]	83	
								- Sleep quality (1-5)	2.8	2.8	2.7	
								Objective sleep (Actiwatch)				
								- Sleep onset latency (min)	7	15[b]	6	

								- Total sleep time (min) - Sleep efficiency (%)	367 87	355 86	348 85	
Bozin-Juracic[c] 1996 (61)	To determine the effects of a short vs. long elimination hypnotics in workers on a slow rotating shift system	29	Security workers age 24-58, 0.4-22.8y SW; insomnia for mean 5.4y	Slow rotating system; 7 nights (2200-0600h), 7 off, 7 morning, 7 afternoon	1) 7.5mg Zoplicone 2) 5mg nitrazepam 3) Placebo All capsules taken after work on the night shift.	7 days	3-arm intervention	Main Sleep (sleep diary) - Time in bed - Length of sleep episode - Total sleep time - Sleep efficacy - Sleep latency - Sleep quality (VAS) All Sleeps (sleep diary) - Time in bed - Sleep episode - Total sleep time - Sleep efficacy - Number of sleeps	x x treatment x day effect [a] treatment x day effect [a] x x x x x treatment x day effect [a] x			11
Cavallo 2005 (62)	To determine the effect of exogenous melatonin to reduce symptoms	45	M=16, F= 29 pediatric residents, mean age 28.6; No infants/toddlers at home, chronic illness, pregnancy, depression, use of sedatives/ hypnotic drugs in last 2 w	Night float: 2-week period of work starting at midnight to 0800 or 1000h with three nights off	Melatonin (3mg) after night shift before sleep in a dark room	2 weeks	2-arm randomized cross-over trial	All days - Sleep duration (h) - Sleep quality (VAS) - Number of awakenings Days taking melatonin - Sleep duration (h) - Sleep quality (VAS)	 6.4 64.1 2.2 6.5 62.6		 6.3 62.0 2.3 6.3 60.8	22

								- Number of awakenings	2.3	2.3	
Czeisler[c] 2005 (63)	To evaluate safety and efficacy of 200mg of modaifnil in patients with chronic shiftwork sleep disorder	209	M=122, F=87 (Various centers across the United States), mean age 38, shift schedule met defined criteria, met diagnostic criteria for SW sleep disorder	≥5 night shifts per month (≥3 consecutive); ≤12h with ≥6h between 2200 and 0800h)	Modafinil (200mg), 30-60 min prior to starting the night shift	3 months	2-arm randomized controlled trial	Sleep efficiency after night shift (%) Sleep measures (PSG) - Time in bed (min) - Time awake (min) - Time asleep (min) - Sleep latency (min) - Sleep efficiency (%) - REM sleep (min) Melatonin phase (change in hours)	+7.3 -3.0 -11.7 +1.4 +2.9 +1.4 +0.5 -0.4	+9.5 -1.7 -8.8 +4.6 +1.3 +1.2 +2.3 -0.1	24
Czeisler[c] 2009 (64)	To evaluate safety and efficacy of armodafinil in patients with at least moderate severity shiftwork disorder	254	M=135, F=119 (Various centers across the United States and Canada), mean age 39; Permanent/rotating SW with SW disorder; no history of substance abuse or sensitivity to stimulants	≥5 night shifts per month (≥3 consecutive); ≤12h with ≥6h between 2200 and 0800h)	150 mg armodafinil taken 30-60 minutes prior to each night shift (no later than 2300h)	12 week	2-arm randomized controlled trial	Night time sleep latency (min, diary) Systolic BP (mm Hg) Diatsolic BP (mm Hg) Heart rate (bpm) Daytime Sleep (PSG) - Sleep latency (min) - Sleep efficiency (%) - Total sleep time (min) - Wake after sleep onset (min)	+3.1 [a] +0.8 +0.4 +2.7 +2.9 -3.3 -19.0 +12.4	+0.4 -1.5 -0.7 +0.7 +0.2 +1.3 -2.0 -3.3	22
Erman[c] 2007 (65)	To assess effect of modafinil on patient function,	278	M=111, F=167 patients with SW sleep disorder	≥5 night shifts per month (≥3	1) 200 mg Modafinil	12 weeks	3-arm randomized controlled	Sleep (diary)			16

	quality of life we well as tolerability		(Various centers across the United States), mean age 40; No prior or concomitant medication, diagnosis of other sleep disorders	consecutive); ≤12h with ≥6h between 2200 and 0800h)	2) 300 mg Modafinil 3) Placebo 30-60 min prior to night shift		trial	- Nighttime sleep - Daytime sleep	x x	x x	
Folkard 1993 (66)	To determine the effects of melatonin for promoting sleep/wakefulness in police officers	17	M=15, F=2 police officers (Surrey, United Kingdom), mean age 29; healthy, no medication	28-day shift cycle: 4 rest days, 7 nights (2200-0600h), 2 rest, 7 late (1400-2200h), 1 rest, 7 early (0600-1400)	5 mg melatonin (or placebo) taken prior to day sleep after night shift and prior to first four regular night sleep	28 days (one full shift cycle)	2-arm randomized controlled trial	Sleep (Diary) - Time of sleep onset (h) - Time of sleep offset (h) - Sleep duration (h) - Sleep latency (min) - Sleep quality (VAS)	 0 +0:30 +0.51 [a] -2.35 +10.4 [a]	 +0:07 +0:11 +0.07 -1.30 -0.2	13
Monchesky 1989 (67)	To determine the effects of zoplicone on sleep, mood and performance	53	M=47, F=6 car assembly plant workers with insomnia(Oshawa, Canada); mean age 34.9; no hypnotic medications for 4 days, no other sleep disorders	Alternating two-week day shift (Mon-Fri, 0700-1530h) and two week night shift (Mon-Fri, 0800-0230h)	7.5 mg Zopiclone (or placebo) 30 min before bed during night shifts	14 days	2-arm randomized controlled trial	Sleep (Self-reported) - Sleep induction - Sleep duration - Sleep quality	 + [a] + +	 x x x	17

Note: + = positive change - = detrimental change, x = no change,

[a] Significant difference before-after intervention, $p < 0.05$

[b] Significant between groups, $p < 0.05$

[c] Industry-sponsored study

Note: + = positive change - = detrimental change, x = no change,

Legend: BL, Bright Light; BP, Blood Pressure; F, Female; M, Male; PSG, Polysomnography; VAS, Visual Analogue Scale;