

Supplementary material for “Interventions to Mitigate Fatigue in Shift Workers: A Systematic Review”

Supplementary Table 1: Search strategies reported for three databases (PubMed, Web of sciences, Scopus)

Search Strategy for PubMed :
[Title/Abstract]=((shiftwork OR "shift work" OR "shift work schedule" OR "work cycle" OR "job cycle" OR "night work" OR "night job" OR "night shift" OR "nightshift" OR "work pattern" OR "work flow" OR workflow OR "long work hours" OR "extended hours" OR "extended work" OR "work table" OR "irregular shift" OR "quick return" OR "swing shift" OR "work rhythm" OR "work schedule tolerance" OR "split shift") AND (fatigue OR "comprehensive fatigue" OR tiredness OR "mental fog" OR "brain fog" OR "alertness" OR "vigilance" OR "alert fatigue" OR wakefulness OR "mental fatigue" OR "physical fatigue") AND (control OR design OR manage OR intervention OR "short rest periods" OR strategy OR strategies OR program OR prevent)) Filters: English
Search strategy for Web of Science :
(TS=(((((shiftwork OR “shift work” OR “shift work schedule” Or “work cycle” OR “job cycle” OR “night work” OR “night job” OR “night shift” OR “nightshift” OR “work pattern” OR “work flow” OR workflow OR “long work hours” OR “extended hours” OR “extended work” OR “work table” OR “irregular shift” OR “quick return” OR “swing shift” OR “work rhythm” OR “work schedule tolerance” OR “split shift”) AND (fatigue OR “comprehensive fatigue” OR tiredness OR “mental fog” OR “brain fog” OR “alertness” OR “vigilance” OR “alert fatigue” OR wakefulness OR “mental fatigue” OR “physical fatigue”) AND (control OR design OR manage OR intervention OR “short rest periods” OR strategy OR strategies OR program OR prevent)))) AND (LA==(“ENGLISH”)))
Search strategy for Scopus :
TITLE-ABS-KEY (((shiftwork OR "shift work" OR "shift work schedule" OR "work cycle" OR "job cycle" OR "night work" OR "night job" OR "night shift" OR "nightshift" OR "work pattern" OR "work flow" OR workflow OR "long work hours" OR "extended hours" OR "extended work" OR "work table" OR "irregular shift" OR "quick return" OR "swing shift" OR "work rhythm" OR "work schedule tolerance" OR "split shift") AND (fatigue OR "comprehensive fatigue" OR tiredness OR "mental fog" OR "brain fog" OR “alertness” OR “vigilance” OR "alert fatigue" OR wakefulness OR "mental fatigue" OR "physical fatigue") AND (control OR design OR manage OR intervention OR "short rest periods" OR strategy OR strategies OR program OR prevent))) AND (LIMIT-TO (LANGUAGE , "English"))

Supplementary table 2: Data extracted from 89 included articles is listed in the following table, sorted by year. Main outcomes are color-coded for faster review.

Author / Year	Country	Sample */ Job	Work shift (During the intervention)	Aim	Method / Intervention	Tools	Main outcome
Wyche et al. 2025	United States	82 Nurses	Night	To measure the impact of a mindfulness or physical activity intervention on hospital night shift nursing teams' quality of life	Mindfulness or physical activity intervention was implemented during 16 weeks	ProQOL-21/ PROMIS/ Sleep hygiene/ Role Related meaning scales for staff (RRMSS)	Improvements in sleep and reductions on compassion fatigue followed by raised satisfaction. (Reduced fatigue)
Kubo et al. 2025	Japan	35 (25 females) Geriatric caregivers	Early (06:00 to 03:00) Day (08:00 to 05:00) Late (11:00 to 08:00) Night (04:00 to 10:00)	To investigate how shift patters, such as backward rotation or consecutive shifts, affect sleep outcomes	AI-driven shift scheduling app created a shift schedule after incorporating these requirements using meta-heuristic algorithms based on integer programming and lab search method	Aura ring Gen3 (sleep tracker)/ Fatigue checker app including VAS and PVT on smartphone	Better sleep outcomes and Reduction in number of backward rotations, but no significant difference in VAS and fatigue outcomes. (No effect on fatigue)
Konya et al. 2025	Japan	62 Nurses	16h night shift	To examine the effects of taking a nap or break immediately after a long night shift on fatigue recovery and sleep episodes among nurses	30 min nap was taken right after a 16h night shift before going home from work.	Fatigue scale/ Actigraphy/ Accelerometer/ Sleep diary/ Sleep monitoring device	Fatigue immediately reduced after taking the nap. But no impact on other sleep parameters. (Reduced fatigue)
Cohen et al. 2025	United States	8 (5 females) Emergency medicine	Night	To improve perceived fatigue level and measured sleep metrics	Participants worked a new shift system called (casino shift: 08:00 p.m. to 04:00 a.m.) for a month followed by a control month	Shiftwork disorder screening questionnaire/ Occupational fatigue exhaustion recover scale (OFER)/ Actigraphy/ SAFTE fatigue model	Intervention Increased sleep quantity and efficiency, improved energy levels, and reduced perceived fatigue (Reduced fatigue)
Chabal et al. 2025	United States	42 Navy submarine crew	Day (04:00 to 12:00) Swing (12:00 to 20:00) Midnight (20:00 to 04:00)	To assess whether light treatment devices will serve as an unobtrusive and feasible countermeasure for circadian misalignment	Light intervention for 12-14 days which participants in intervention group instructed to wear blue blocking glasses for 2 hours prior to sleep and blue-light glasses right after waking up	ESS/ PSQI/ Insomnia severity index/ POMS/ Actigraphy/ Sleep logs	Circadian phase better got aligned with the work schedule in case group. Fatigue and sleep loss were improved during the intervention. (Reduced fatigue)
Al Maawali et al. 2025	Canada	18 Residents	On call – Night float	To further explore the experience of residents and faculty in a trial of an NF system on clinical teaching unit of a pediatric hospital	The new call model was implemented four months into the academic year. 18 transcripts were read and coded and negotiated by research team.	Interviews	Compared to the traditional 24h call model, respondents indicated that they slept more and felt less fatigued on the new NF rotation (15h). (Reduced fatigue)
Van Elk et al. 2024	Netherlands	210 (40 females) Healthcare workers	Night	To evaluate both the effects and the implementation of PerfectFit@night program using mixed methods	Single group pre-post study design for 3 months using power nap bed, healthy food, and a workshop on healthy rostering + interactive e-learning and sleep coaching	Bergen shift work sleep questionnaire (BSWSQ)/ PSQI/ Need for recovery scale/ short fatigue questionnaire (SFQ)/ Work ability index	No changes in sleep quality, sleep duration, and insomnia. Need for recovery and fatigue were decreased significantly after the intervention. (Reduced fatigue)

ProQOL-21: professional quality of life scale - PROMIS: patient reported outcome measurement information system - VAS: visual analog scale - PVT: psychomotor vigilance test - SAFTE: sleep, activity, fatigue, and task effectiveness model - ESS: Epworth sleepiness scale - PSQI: Pittsburgh sleep quality index - POMS: profile of mood states.

* = Female subjects are not mentioned in the article

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Shriane et al. 2024	Australia	58 (28 females) Paramedics	Forwards rotating shift Day/afternoon/evening/night + 3.5 days Off	To trial a sleep health-based mobile intervention including sleep hygiene advice tailored for shiftworkers	Utilizing a mobile app “SleepFit” for sleep education for shiftworkers in a 14-day intervention.	Self-reported sleep scale/ Fatigue severity scale (FSS)/ ESS/ Insomnia severity scale (ISI)/ Sleep hygiene index (SHI)/ Diary	Despite Significant reduction in insomnia severity and improvement in sleep hygiene, the effects on fatigue and sleep duration were inconsistent. (No effect on fatigue)
Salzman et al. 2024	United States	128 Missileers	14/14 7/7/7 with: 16 on/ 8 off or 24/12 or 24/24 or 12/12	To improve and alert schedule to enhance mission readiness, personnel effectiveness, quality of life, and retention	Circadian rhythm management, fatigue mitigation measure plus nutritional and fitness recommendation.	Self-reported missileer survey/ 3-minute PVT/ Armed forces longitudinal technology application (AHLTA)	Fatigue decreased over the period of the study. Misses decreased due to the intervention. (Reduced fatigue)
Ebina et al. 2024	Japan	196 (177 females) Healthcare workers	Rotating	To examine the impact of breakfast intervention on autonomic nerve function in healthcare workers who skip breakfast	Breakfast including Frugra cereal was provided five times or more per week for four weeks.	Chalder fatigue scale (CFS)/ HRV/ ECG/ Acceleration photoplethysmography (APG)	The CFS score significantly decreased after four weeks. Autonomic nervous system activity was improved by consumption of breakfast cereal. (Reduced fatigue)
Djupedal et al. 2024	Norway	1314 (1120 females) Healthcare workers	LWH with quick returns	To investigate the effect of a work schedule with abated quick returns on symptoms of insomnia, daytime sleepiness, and work-related fatigue.	A 6-month shift schedule with as few quick returns as possible were implemented and compared with usual schedule of control group.	Bergen insomnia scale/ ESS/ revised Swedish occupational fatigue inventory (rSOFI)	Larger reduction in symptoms of insomnia, less daytime sleepiness, No effects on work- related fatigue. (No effect on fatigue)
Cyr et al. 2023	Canada	57 (48 females) Nurses	2D2O3N2O2D3O	To assess the effects of combined evening light intervention on fatigue, performance, sleep, and mood.	On night shifts, participants would wear dark sunglasses in the prior morning, optional nap in the afternoon and receive 40 minutes of bright light at home before starting the shift.	Questionnaires	Fewer work errors, reduction in fatigue rate and sleepiness, small improvement in sleep were observed but nothing on mood detected. (Reduced fatigue)
Bessman et al. 2023	United States	47 (8 females) Navy watchfloor staff	12h rotating (4D:4O:4N cycle)	To assess both the efficacy and feasibility of two spectrally engineered lighting interventions in mitigating night-shift sleepiness and fatigue.	Within-subject crossover trial (two 16- day blocks) comparing: (1) short- wavelength enriched (SW+) vs. (2) short-wavelength attenuated (SW-) light boxes during 12-h shifts, combined with post-shift blue- blocking glasses and daytime sleep masks.	KSS/ 3-minute PVT/ Wrist Actigraphy/ Sleep diary/ Home- Ostberg ME scale/ QOL index/ health and performance scale (HPQ)	On-shift sleepiness was significantly reduced under SW-, alongside lower caffeine intake and higher perceived performance/QOL. SW+ significantly improved sleep quality, sleep bout length, and reduced WASO. fatigue symptoms decreased under both lighting conditions, though objective PVT performance did not differ. (Reduced fatigue)

HRV: heart rate variability - ECG: electrocardiogram - KSS: Karolinska sleepiness scale - QOL scale: quality of life scale

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Wingelaar-Jagt et al. 2023	Netherlands	32 (5 females) Airforce crewmembers	Long work hours 4:30 p.m. to 8:00 a.m.	To determine the effect of Modafinil on vigilance	A single dose of Modafinil after 24h sleep deprivation compared with a placebo and a single dose of caffeine in 2 groups, a double-blind randomized controlled trial.	VigTrack dual task / Psychomotor vigilance task (PVT) /Stanford sleepiness scale (SSS) / Blood samples	Significant effects of modafinil and caffeine on alertness compared with placebo. Modafinil effects remain longer than caffeine. (Reduced fatigue)
Ruan et al. 2023	United States	27 (16 females) Anesthesia residents	Night	To evaluate the effect of night float rotation on sleep quantity, quality, and well-being	Night float rotation and recovery system were Compared with baseline week in sleep and fatigue by using wearable devices and surveys.	NIH PROMIS questionnaire / Fitbit	No difference was observed between daily sleep hours for night float and baseline weeks. The night float system caused less REM sleep and higher survey scores. (Increased fatigue)
Li et al. 2023	United Kingdom/Ireland	Study1:57/study 2: 34 Air traffic controllers*	8-h rotating (5-day roster)	To examine fatigue across 5 rotating shifts and assess Quick Coherence Technique (QCT) biofeedback to mitigate fatigue.	Study 1: Hourly fatigue tracking across 5 shifts. Study 2: 30-min biofeedback-guided Quick Coherence Technique (QCT; paced breathing at 6 breaths/min).	SSS / Sleep diary / Inner Balance ear sensor / Kubios HRV software / Diary and score sheet for fatigue	Fatigue accumulated at hours 6–8 and peaked on Shift 5. QCT significantly increased Mean RR, pNN50, and coherence score (27.01 to 70.56), and reduced mean HR. (Increased fatigue resilience)
Mohammadi-Nezhad et al. 2022	Iran	18 males Urban train monitoring room staff	12-hour Rotating	To examine the effect of a mento-physical program on mental recovery and mental fatigue reduction in morning room personnel	Mento-physical exercises during inter-shift breaks of 7.5h continuous work. Including deep breathing, isometric and isotonic exercises, and progressive relaxation for 30 minutes.	Questionnaire / Stroop test / digital blood pressure monitoring	Mento-physical exercises effectively decreased fatigue and reaction time in the experimental group. (Reduced fatigue) (Reduced reaction time)
Myllyla et al. 2022	Finland	15 males Navy Soldiers	24-hour 4:4 & 6:6	To compare the two-section 4:4 and 4:4/6:6 schedules in terms of sleepiness, fatigue, and stress responses	Data on sleepiness and fatigue, salivary alpha amylase, cortisol, immunoglobulin, dehydroepiandrosterone, attention, and response rate were collected for two weeks before and after the shift schedule change.	Karolinska sleepiness scale (KSS) / Salivette sampling device / Sustained attention and response task (SART) / N-back / Orthostatic test	The 4:4/6:6 system enabled a 2-hour longer daily continuous sleep period than the 4:4 system, with corresponding improvements in sleepiness and fatigue. (Reduced fatigue)
Melan et al. 2022	France	57 (17 females) Air traffic controllers	12-day Rotating (M1DE1RRRM2E2NRRR)	To investigate the effect of both shift schedule arrangements and traffic load on ATCOs' sleep, fatigue, and alertness	A Retrospective study using a questionnaire to assess the effect of a modified schedule for ATCOs. In addition, the impact of traffic density over five weeks will be evaluated.	Self-administrated questionnaire	The intervention reduced sleep, and alertness and increased the need for recovery from fatigue. (Increased fatigue)
Kubo et al. 2022	Japan	30 Nurses *	Evening: 15:45 to 0:30 Night: 0:00 to 8:45	To examine the benefits of extending the restart break in fatigue and stress after two consecutive night shifts	A non-randomized controlled cross-over trial of Planning an off-duty day between night and evening shifts to extend the rest time for the nurses.	Sleep log / Questionnaire / PVT / Mattress sensor / Stress biomarkers / Maastricht questionnaire	The extended restart break after consecutive night shifts can moderately decrease occupational fatigue and stress. (Reduced fatigue)
Hoshi et al. 2022	Japan	27 (26 females) Nurses	Night	To investigate the impact of dark environments on fatigue sleepiness and performance	A non-randomized open-label trial to compare dark (110 lux) with well-lit (410 lux) work conditions over a 4-month study period.	Self-administrated questionnaire	Fatigue and sleepiness were higher in dark room lighting than in bright room conditions. Darkroom lighting did not ameliorate fatigue and sleepiness during night shifts. (Increased fatigue)

ATCOs: air traffic controllers - M1DE1RRRM2E2NRRR: morning shift type1, day shift, evening shift type 1, rest, morning shift type 2, evening shift type 2, night shift

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Helmhout et al. 2022	Netherlands	87 (5 females) Security guards	Night	To evaluate the effectiveness of glasses that emit blue light in reducing general fatigue and stress levels of night workers	A randomized controlled cross-over trial in which During 5 weeks, participants were exposed to blue-light emitting glasses for 30 minutes each night. Followed by a five-week control condition.	Need for recovery scale / Checklist for individual strength / Stress level.	Blue light exposure using light-emitting glasses for security guards during night shifts showed no direct effect on the reduced need for recovery and overall fatigue and stress levels. (No effect on fatigue)
Ha et al. 2022	Korea	57 females Nurses	8-hour Rotating	To develop and examine the effectiveness of a mobile wellness program on daily steps, sleep quality, exercise, fatigue, and wellness.	A pilot cluster-randomized study of 12 weeks using a mobile wellness program for nurses in addition to subjective and objective measuring by Fitbit and Questionnaires.	Pittsburgh sleep quality Index (PSQI) / Fitbit / Self-efficacy for exercise / Behavioral regulation in exercise questionnaire (BREQ) self-rated fatigue item	Mobile wellness programs using Fitbit, online exercise using Zoom, online health coaching, and motivational text messages effectively promoted physical activity and sleep quality for nurses; self-rated fatigue was also significantly reduced. (Reduced fatigue)
Dahlgren et al. 2022	Sweden	207 (188 females) Nurses	8-hour Rotating	To examine if a proactive recovery intervention can prevent the development of sleep problems, burn-out, and fatigue	RCT of a Group-administrated proactive recovery program including interviewing sessions focused on enhancing beneficial strategies for sleep and recovery to mitigate stress and fatigue based on motivational techniques.	Insomnia severity index (ISI) / KSS / Shirom-Melamed burnout questionnaire (SMBQ) / Work interference with personal life index (WIPL) / Somatic symptoms scale (SSS8) / Perceived stress scale (PSS) / Dysfunctional beliefs and attitudes about sleep scale (DBAS)	Somatic symptoms, fatigue, and burnout over a short period were reduced, but there were no effects on sleep quality and insomnia symptoms and no effect on perceived stress and tension. (Reduced fatigue for a short period)
Baek et al. 2022	Korea	54 females Nurses	8-hour Rotating	To develop a smartphone-based home workout program for shiftwork nurses	Encouraging participants to exercise regularly using the home workout application for 18 weeks. Text message, counseling, and environmental improvements.	ISI / Korean version of multidimensional fatigue scale / Connor Davidson resilience scale/performance measurement scale	fatigue was significantly decreased in the intervention group, musculoskeletal cases were less, fatigue resilience was increased (Reduced fatigue)
White et al. 2021	United States	72 General surgery residents *	24-hour extended shift	To evaluate the efficacy and feasibility of an employer-subsidized rideshare program in mitigating post-shift fatigued driving hazards.	An 8-week "Safe Ride" pilot providing 100% reimbursement for round-trip rideshares (Uber/Lyft) to eliminate driving under acute sleep deprivation following 24-h shifts.	Rideshare reimbursement tracking logs / resident experience survey	Successfully eliminated 63 post-call fatigued commutes. Residents reporting, they "never" fell asleep or almost asleep behind the wheel rose significantly from 17.2% to 63.9%. (Reduced fatigued driving)
Van Woerkom et al. 2021	Netherlands	95 (78 females) Nurses	Night 10:30 p.m.-7:30 a.m.	To investigate the effects of a napping facility and therapy glasses on fatigue and well-being at the end of the night shift	A quasi-experimental of implementing a Napping facility – allowing taking a 20-minute nap whenever it was most convenient to the participants in an innovative nap facility in a separate room.	Fatigue assessment scale (FAS), Everyday Feeling questionnaire (EFQ)	Night shifts of nurses had access to both facilities which were associated with less fatigue and more well-being among them. (Reduced fatigue)
Sakai et al. 2021	Japan	34 (27 females) Nurses	Rotating Morning: 8:15-17:00 Night: 16:15-9:15	To investigate the benefit of an intervention based on food to improve the sleep quality of nurses	A before and after the design of 2 weeks of intervention included 3 nights. Participants began to consume "Food with Function Claims" which contained Asparagus extract. Several subjective and objective measures were used to assess the results.	PSQI / VAS for sleep quality & fatigue / Actigraphy / PVT / Utrecht work engagement scale (UWES) / Work functioning impairment scale (Wfun) / Kessler psychological distress scale (k-6)	Significant improvement in PSQI and UWES was observed. The feeling of fatigue was reduced. Reaction time and sleep efficiency got better. There were no significant results in impaired work functioning. (Reduced fatigue)

RCT: randomized control trial

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Longman et al. 2021	United Kingdom	89 (1 female) Truck drivers	24-hour	To examine the effect of nature exposure on the levels of acute and chronic fatigue, anxiety, and depression	Participants were issued with two accelerometers to wear over eight days following a health assessment and completing daily logs. They also had the opportunity to spend time in nature during their trips.	Daily log / Online survey / Hospital anxiety and depression scale (HADS) / OFER-15	Drivers who had exposure to nature at least once a week exhibited less chronic or acute fatigue. No significant differences were measured for anxiety or depression. (Reduced fatigue)
Han et al. 2021	Korea	38 Nurses *	12-hour Rotating NNOODD	To conduct a scheduled nap intervention as a countermeasure for fatigue and drowsiness in the middle of 12 the shift	A 30-minute sleep education session was designed to help nurses recognize the importance of sleeping and resting, to correct personal sleep and habits. Following the design of a 30-minute nap in their shiftwork and a dark separate room.	Infrared Oculography / Work Diaries / Johns Drowsiness Scale (JDS) / 10 score scales for work demands, fatigue, sleepiness, work pace, quality of care	Subjective and objective measures successfully showed a reduction in fatigue among nurses who take naps during 12-hour shifts. (Reduced fatigue)
Brunet et al. 2021	Canada	70 (68 females) Nurses	8-hour & 12-hour Fixed days Fixed nights Rotating	To assess the influence of physical activity and step count on work characteristics and mood states	A randomized controlled cross-over trial of a 6-week intervention phase about individual, friend, or team-based PA using a Tractivity program, and monitoring its effects on mood states and work-related characteristics.	Tractivity program / Profile of mood states (POMS)	Nurses who work rotating shifts and perform clinical work showed smaller improvements in moderate-to-vigorous physical activities. None of the mood state scores were associated with initial levels or rates of change in average daily step count. (No effect on fatigue)
Barger et al. 2021	United States	20 Nasa flight controllers *	Night	To evaluate the effect of a combined short-wavelength-enriched white light and exercise on fatigue	Passive exposure to Blue-enriched polychromatic lighting for three 20-minute intervals, which included 10 min exercise and occurred before and during shift	Wrist actigraphy / KSS / PVT / VAS for fatigue	More alertness, happiness, and faster reaction times were observed due to the intervention. (Reduced fatigue)
Cho et al. 2021	Korea	59 (55 females) Nurses	Extended Morning work	To examine the effect of meridian acupressure on stress, fatigue, anxiety, and self-efficacy	15-min Meridian acupressure on six meridian points for 3 days after the day shift between 3-5 p.m.	Questionnaire / Stress scale / Fatigue scale / State anxiety inventory (SAI) / Self-efficacy scale	Meridian acupressure significantly decreased the stress, fatigue, and anxiety of shiftwork nurses. (Reduced fatigue)
Olson et al. 2020	United States	33 (25 females) Nurses	12-hour Rotating DDOONNNOODDOOO Some nurses had 8-hour night shifts	To reduce some of the negative consequences of shiftwork by using a light-based intervention	40-min exposure to bright light from a portable light box before night shifts and light avoidance using sunglasses after those shifts followed by ideal sleep and nap.	NASA-TLX / Multidimensional fatigue inventory (MFI) / Perceived stress scale (PSS) / Daily fatigue short form (DFSf) / Logbook	Less fatigue, fewer work errors, better and longer sleep, and more positive mood were observed during the study implementation. (Reduced fatigue)
Patterson et al. 2019	United States	83 (48 females) Air medical emergency service	12-hour Rotating	To determine the impact of Sleep track- txt2 intervention on-air medical clinicians' fatigue.	A randomized trial setting in which participants receive queries about fatigue, sleepiness, and difficulty with concentration via SleepTrackTXT and if they report high levels, they receive immediate response suggesting behavioral strategies to mitigate.	PSQI / Chalder fatigue Questionnaire (CFQ) / Schedule attitudes survey (SAS) / Epworth sleepiness scale (ESS) / OFER / Sleep fatigue alertness behavior (SFAB)	Positive short-term impact on self-rated fatigue during 12-hour shifts has appeared. The intervention did not impact longer-duration shifts or sleep quality. (Reduced fatigue)

D: Day, O: Off, N: Night – OFER-15: occupational exhaustion recovery survey 15-items scale – NASA-TLX: national aeronautics and space administration's task load index

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Fowler et al. 2019	United States	22 males Military air traffic controllers	Rapidly rotating shift of Morning and evening shifts in every week	To assess the use of video game play in ATCOs' cognitive and physiological alertness	In a counter-balanced, within-subject design study of gaming experience over 4 weeks, participants play games for 20 to 60-min in their shift break.	Oculomotor assessment / SSS/perceived fatigue.	Video game shift breaks significantly decreased the levels of perceived fatigue as an effective fatigue countermeasure in high-vigilance occupations such as air traffic control. (Reduced fatigue)
Holzinger et al. 2019	Austria	184 (19 females) Railway workers	Various Including night work	To measure the effect of a 2-day sleep coaching seminar on sleepiness and sleep-related variables	A 2-day sleep coaching seminar was conducted to improve sleep quality and coping strategies which can be implemented in daily routine	PSQI / ESS / Gestalt therapy / Cognitive behavioral therapy	2-Day sleep coaching was beneficial with improvements in PSQI scores. However, some variables like daytime sleepiness were not changed significantly. (No effect on fatigue)
James et al. 2018	Canada	61 (22 females) Royal Canadian Mounted police	Various 8-hour to 12-hour Day shift and rotating	To evaluate the efficacy of fatigue management training in improving sleep health	A repeated measures design of a fatigue management program and advisory with self-reported data before and 4 weeks after the training.	PSQI / World health organizational quality of life (WHOQOL) / Psychological distress scale	Positive effects on sleep health, satisfaction, insomnia, and the incidence of headaches were observed during the study. (Reduced fatigue)
Leedo et al. 2017	Denmark	59 (52 females) Physicians – Nurses - Assistants	8-hour Rotating	To examine the effect of increased reach of healthy meals and water at work on healthcare staff	8-week randomized Cross-over trial of receiving a self-selected keyhole-labeled lunch, snack, and bottled water during each shift throughout the intervention period.	Body composition analyzer / GO-NO-GO test / POMS / Dietary intake records	Healthy meals affect dietary intake and increased water consumption which may associated with beneficial effects on fatigue, vigor, and total mood in workers. (Reduced fatigue)
Sparrow et al. 2016	United States	106 (6 females) Commercial motor vehicle drivers	Night	To investigate the efficacy of the new hours-of-service restart provision break including two night-time sleeps.	Naturalistic field study of measuring sleep and fatigue of 106 commercial motor vehicle drivers whose schedule breaks were changed during two consecutive duty cycles.	PVT-B test / Actigraphy / KSS	Having at least two night-time periods in the break provides a greater opportunity for sleep recuperation and helps fatigue mitigation. (Reduced fatigue)
Smith-miller et al. 2016	United States	1697 (1481 females) Nurses	Rotating Long work hours	To identify the barriers and facilitators in a fatigue management plan and its effects on nursing work	12 weeks of a duty-free break with a minimum of 30-minute period within 8 or 12 hours in separate rooms from work without communication devices.	OFER / Focus groups	Reducing work-related fatigue and high involvement of workers in changing the work culture. (Reduced fatigue)
Flindall et al. 2016	United Kingdom	24 (5 females) Medical undergraduates	Long work hours	To evaluate the impact of modafinil on free and cued recall of fatigued clinicians	RCT of the effect of Modafinil vs placebo on continuous performance between two conditions of free and cues tasks.	ESS / Dual 2-back task / Case history memorization task / PVT	Modafinil attenuated fatigue and improved free recall. (Reduced fatigue)
Patterson et al. 2015	United States	100 (29 females) Emergency medical clinicians	12-hour	To assess the impact of a mobile phone test message intervention for reducing intra-shift fatigue	A randomized trial of 90 days of text messaging to participants measured fatigue-related factors and promoted their alertness by giving pieces of advice.	PSQI / CFQ / ESS / OFER / SFAB	Participants reported lower mean fatigue and sleepiness at all new shift plans compared to controls. (Reduced fatigue)
Parshuram et al. 2015	Canada	47 Academic surgical ICU residents *	12-hour	To compare the effects of 3 resident schedules in the ICU on patient safety, resident well-being, and quality of care.	Residents in 2 ICUs were randomly assigned (in 2-month rotation blocks from January to June 2009) to in-house overnight schedules of 24, 16, or 12 hours	7-point Stanford sleepiness scale / Acute Physiologic Assessment of chronic health evaluation for Patients (APACHE) II	No significant differences were found among the 3 commonly used resident work schedules in rates of adverse events and resident insomnia. No program protects against fatigue or burnout overnight. (No effect on fatigue)

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Van Drongelen et al. 2014	Netherlands	502 (34 females) Airline pilots	Long work hours	To evaluate if mHealth program intervention can improve health-related behavior, and reduce sleep problems	The intervention group was given access to both the mobile application with tailored advice and a website with background information. The control group was directed to a website with standard information about fatigue.	Online questionnaires / Need for recovery scale / Jenkins sleep scale / PSQI / General perceived health scale SF-36 / Work-home interference-Nijmegen (SWING) /Morningness-Eveningness questionnaire (MEQ)	Offering tailored advice through a <i>mHealth</i> intervention reduced self-reported fatigue over a 6-month period compared to other minimal interventions like using website consultation for control group. (Reduced fatigue)
Signal et al. 2014	New Zealand	52 Flight crew members *	Long work hours	To examine the uptake and effects of fatigue mitigation by sleep advisory for a trip to and returning long-range flight.	Subjects are scheduled for an ultra-long-range flight with advisory material and rest breaks. Subjective and objective tasks were completed by all 4 team members during each flight.	Questionnaire / sleep-duty diary / Samn-perelli fatigue scale/event marker / KSS / PVT	Structured napping and sleep-mitigation guidance prevented the expected increase in fatigue on the return leg of an ultra-long-range flight, with fatigue levels on the outbound and return legs not significantly different. (Reduced fatigue)
Punja et al. 2014	Canada	40 (32 females) Nursing students	Rotating or permanent overnight	To compare the efficacy of Rhodiola rosea with placebo for reducing fatigue in nurses	Subjects randomized to take 364mg of either Rhodiola rosea or identical placebo at the start of their wakeful period and up to one additional capsule within the following four hours daily over 42 days	Questionnaire / VAS for fatigue	Among nursing students on shiftwork, a 42-day course of R. Rosea compared with placebo worsened fatigue; however, the results should be interpreted with caution. (Increased fatigue)
Oriyama et al. 2014	Japan	15 females Nurses	Day (8:30-17:15 or 8:00-16:45) Evening (16:00-0:45 or 16:30-1:15) Night (0:00-8:45 or 0:30-9:15)	To determine the effects of two 15-minute naps on nurses who work at night in 3 shifts	Providing conditions for nurses to take two 15-minute naps during work shifts followed by electrocardiography and fatigue evaluation	Electrocardiogram (ECG) / VAS for fatigue	Taking two short naps may effectively reduce tension and prevent a brief increase in HF (high-frequency ratio) values by suppressing sympathetic nervous activity in the morning. (Reduced fatigue)
Ernst et al. 2014	Austria	30 (9 females) Physicians – residents	Night (8:00-4:30)	To investigate the effects of a working schedule including sleep fragmentation and extended work hours in the clinical care environment	A randomized cross-over trial of implementing a working schedule included 24 hours of working on call and its effects on fatigue using Saccadometry and urinary biomarkers' measurement.	Event diary / Saccadometry / The d2-test	Physicians' emotional state and cognitive and oculomotor performance seem to be influenced independently by sleep interruptions. The discrepancy between subjective feeling and objective cognitive impairments posed a risk for performing complex manual and cognitive tasks. (Increased fatigue)
Tempesta et al. 2013	Italy	54 (37 females) Medical interns	Night	To show whether taking a long nap can counteract the negative effect of sleep deprivation on the executive skills of residents	Participants were Separated into three groups Nap, Wake, or Sleep. Measures were conducted while the first group was required to take an optional nap during the night shift and the second group had to work all their shift. The third group was day workers.	KSS / Go-No go test / Task switching / Subjective rating for fatigue-inertia- Vigor-Activity	Taking a long nap proved to be effective in ameliorating the deterioration in executive skills that accompanies night work in interns. (Reduced fatigue)

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Barger et al. 2012	United States	32 Phoenix Mars lander mission staff *	8-hour Rotating	To evaluate the effectiveness of a combined short-wavelength-enriched white light and exercise in reducing fatigue overnight	The 78-day intervention used a blue light box in the workplace while participants were required to live and work on Mars Day. Subjective and Objective data were gathered during the study.	Sleep-work diary / Wrist actigraphy / Regular performance test	The combined sleep/fatigue education and short-wavelength light program supported adaptation to the Mars day and alleviated circadian misalignment, sleep loss, and fatigue, though the relative contribution of education versus light exposure could not be isolated due to the lack of a randomized design. (Reduced fatigue)
Lowden et al. 2012	Sweden	23 (2 females) Power plant control room staff	Rotating NNN+MMA	To test whether a new dynamic light exposure would improve alertness and adaptation to a rotating shift	In a Crossover design, operators worked under two conditions of experimental week and control week to assess their sleep, fatigue, and comfort in objective and subjective tests.	Sleep-wake diary / KSS / Other ratings for sleepiness	It seems that appropriate dynamic light in rooms without windows during the dark Nordic season may promote alertness, sleep, and better adaptation to quickly rotating shiftwork. (Reduced fatigue)
Estrada et al. 2012	United States	18 (1 female) Helicopter pilots	Long work hours	To determine which three doses of modafinil can help performance and facilitate adapting from the night shift	Comparison of prescription of Modafinil, dextroamphetamine, and placebo in 4h intervals during 40h sustained operation scenario.	Actiwatch / Motion sickness questionnaire (MSQ) / POMS / Evaluation of risks questionnaire (EVAR) / PVT / Balloon analog risk test (BART)	Modafinil appears to be a good alternative to dextroamphetamine for enhancing cognitive functions because it is well-tolerated and has fewer side effects. (Reduced fatigue)
Zamanian et al. 2010	Iran	34 (30 females) Nurses	Night	To assess the effects of bright light on physiological rhythms of the body and alertness during shift work	Two break times during night shifts with exposure to bright light (BL) for 4 consecutive weeks with plasma indicators, body heat, sleepiness & fatigue measurements.	KSS / VAS for fatigue	These results demonstrate that photic stimulation in a hospital setting can have a powerful influence on the adjustment of the circadian system. (Reduced fatigue)
Scott et al. 2010	United States	47 (45 females) Nurses	12 & 10-hour Rotating	To evaluate the feasibility of a fatigue mitigation program for improving sleep duration, and quality, reducing sleepiness	A prospective design with a pre and post-test repeated measures approach to explore the feasibility of a fatigue countermeasure program for nurses (FCMPN) consisted of education, service regulation, scheduling, work resetting, and ergonomic design.	PSQI / ESS / Logbook	Initial findings support the feasibility of using a program (FCMPN) for mitigating fatigue, improving sleep, and reducing errors among hospital staff nurses. (Reduced fatigue)
Powell et al. 2010	New Zealand	125 Pilots *	Night	To investigate the effect of adding an extra day of layover on fatigue	An additional day's layover period is included in the flight schedule of pilots and compared with their controlled flying duty followed by subjective assessments of fatigue.	Samn-perelli fatigue scale / Personal digital assistant (PDA) / KSS / VAS	Adding an extra night's layover had different effects depending on the type of operation. In such cases, the additional day free of duty may be of greater benefit when taken after returning to home base. (Reduced fatigue)
Hesselink et al. 2010	Netherlands	4600 Steel company workers *	8-hour Rotating Old: NNN—EEE— MMM— New: MMEE—NN—	To show how a shift roster change can affect Musculoskeletal symptoms, fatigue, and work relationships.	Shift roster changes from backward to forward, from slow rotation to fast rotation, and from 2 days off to 3 days after night work and evaluation of its effects on health parameters of work including fatigue.	Sickness absence data / Occupational accidents on Corus site/ health complaints including tiredness	The effects are mainly positive: 0/6% less absence in the first year. Less fatigue is associated with age. The benefit was more among the older workers. (Reduced fatigue)

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Karlson et al. 2009	Sweden	185 (31 females) Manufacturing factory workers	8-hour Initial: MMAAN---- New: MMM--NNN--- AAA	To examine the effects of a change in shift schedule on subjective health, sleep, and fatigue	Shift rescheduling from a fast forward-rotating 24-hour roster to a new slow backward-rotating schedule with 8h monthly fewer duty hours with a follow-up after 15 months.	KSS / Swedish occupational fatigue inventory / self-rated health scale/job content questionnaire / Lund subjective health complaints inventory	Most dimensions of work were improved (subjective health, sleep and fatigue, recovery ability, satisfaction, work-family interface, control, and support) for shift workers. Day workers showed no development. (Reduced fatigue)
Tvaryanas et al. 2009	United States	66 Pilots of remotely piloted aircraft *	8-hour rotating	To present the results of a follow-up survey 1 year after shift modification	Effects of a 6W:3F change in shift plan with a monthly, clockwise rotation system for both pilots and sensor operators were assessed by multiple surveys 1 year after the implementation.	Physical and mental fatigue scale / individual strength concentration subscale (CON) / FAS / WHOQOL / Maslach burnout inventory / Emotional exhaustion subscale / ESS	The results demonstrate a persistent problem with chronic fatigue in the population, likely reflective of continued inadequate opportunities for recovery and restorative sleep. (No effect on fatigue)
Viola et al. 2008	United Kingdom	94 (45 females) Office workers	Long work hours	To investigate the effects of exposure to blue-enriched white light during daytime work hours	Crossover design study of working 4 weeks under white light condition followed by 4 weeks under blue-enriched white light. The data was collected using subjective measures.	PSQI / Horne-Östberg questionnaire / 7-point Likert workplace scale	Exposure to blue-enriched white light during daytime work hours improves subjective alertness, performance, and evening fatigue. (Reduced fatigue)
Mitra et al. 2008	Australia	233 Emergency department doctors*	Morning: 8:00-17:30 Afternoon: 14:00-23:30 Night: 23:00-8:30	To analyze the effects of breaks on tiredness and fatigue as well as effects on departmental performance	A 30-minute uninterrupted break followed by education sessions and posters and a subjective analysis of fatigue in the workplace.	VAS / Objective fatigue severity scale	Significant improvements in some key performance indicators. However, the quantification of tiredness and fatigue remained a challenge due to the lack of standardized tools to measure these parameters. (Reduced fatigue)
Ferguson et al. 2008	Australia	17 males Coastal pilots	Long work hours	To examine the impact of brief, unscheduled naps during work periods on alertness and vigilance	The use of frequent opportunistic short naps to manage fatigue during pilot shifts. Data was gathered by actigraphy and palm PVT test.	Wrist activity monitors and Actiware software / PVT / Sleep and work diary.	The napping strategies, together with the management of pre-ship sleep opportunities, act to reduce the chance of accumulating significant sleep deprivation. (Reduced fatigue)
Smith et al. 2007	Australia	9 (6 females) Nurses and medics	Night	Examine the effects of a brief nap on both subjective and objective indices of alertness during the first night on schedule.	Implementation of a 30-minute nap break during the night shift in their usual work environment and assessment of workload, fatigue, and vigilance.	Prior-sleep log / Caffeine consumption log / after-nap questionnaire / NASA-TLX / VAS for sleepiness / PVT	A brief nap during the first night on shift can limit the deterioration of performance across the night. Improvement in subjective alertness and in specific measures of psychomotor performance persist until the end of the night shift. (Reduced fatigue)
Smith-Coggins et al. 2006	United States	49 (33 females) Physicians – Nurses	Night	To evaluate the influence of a 40 min nap opportunity at 3 a.m. on cognitive and psychomotor performance	Controlled nap intervention of 40-minute naps at 3 a.m. in consecutive night shifts and polysomnography, memory task, drive simulation with fatigue and sleepiness assessment.	PVT / Polysomnography / POMS / KSS	Intervention caused performance improvement and less fatigue, but worsened memory and had no effect on driving. (Temporarily reduced fatigue)
La Pine et al. 2006	New Zealand	28 (21 females) Nurses	12-hour/8-hour Rotating	To investigate the effect of a homeopathic remedy on the night shift in ICU	Participants took a homeopathic remedy or placebo tablets in a double-blinded trial in 3 consecutive night shifts.	Scanning visual test / 10-point fatigue scale / Standard shiftwork index (SSI) / Vigilance task	No significant difference in alertness and reaction time, and neither is for subjective measures. (No effect on fatigue)
Arora et al. 2006	United States	38 Medical interns*	Long work hours Extended shifts	To assess the effects of a call-night nap on resident sleep and fatigue	Assigned to a nap schedule from midnight to 7 a.m. for 2 weeks of the month and the following 2 weeks constituting a standard schedule.	Actigraphy / SSS/fatigue scale/paging log/interviews	Allowing a nap during extended duty hours can increase sleep and decrease fatigue for residents. (Reduced fatigue)
Rosekind et al. 2006	United States	29 males Flight crew members	Long work hours	To determine whether sleep and performance would be enhanced with the implementation of an alertness management program	Implementation of an alertness management program included education, strategies, healthy sleep, and scheduling with actigraphy and vigilance measures.	PDA daily diary / Educational CD / Actigraphy / PVT test / Fatigue scale	The 3.5-hour educational CD improved PVT test scores, fatigue, reaction times, and performance metrics showed significantly better in the intervention condition. (Reduced fatigue)

FAS: fatigue assessment scale – ICU: intensive care unit - PDA: personal digital assistant – CD: compact disc

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Chung et al. 2004	United States	N/A Post-graduate residents	Long work hours Before: mean 97 hours/week After: mean 78 hours/week	To meet the new requirement of obligatory cuts in educational components of residents' perception	Reducing external rotations, transitions, and integrating rotations to bring the monthly average of 80 hours in residents with 6-month follow-up.	Survey / 0 to 10 scales to physical fatigue, sleep deprivation, learning efficiency, and satisfaction	Reducing work hours cannot be accomplished without reducing educational components. Unlike junior residents, seniors felt less fulfilled with the new system. (Increased fatigue)
Yoon et al. 2002	Korea	12 females Nurses	Night	To assess whether melatonin administration effects are enhanced by attenuating morning sunlight exposure	Melatonin administration in the night shift followed by morning sunlight exposure with glasses.	Sleep log / VAS / Continuous performance task (CPT) / POMS	The intervention improved sleep time, a marginal improvement in alertness, and a modest benefit in adaptation to the night shift were observed. But there was no effect on performance. Sunlight exposure also did not affect the variables mentioned. (Mildly reduced fatigue)
Purnell et al. 2002	New Zealand	24 males Aircraft maintenance engineers	12-hour Night	To assess the effects of napping in a 12h shift overnight on performance, alertness, and sleep	Participants were given the opportunity of a 20-minute nap between 1 to 3 a.m. on each of their two overnight shifts.	VAS / Three subjective fatigue rating / Reaction time task / Mackworth clock vigilance task / Actigraphy/sleep diary	Short-duration naps in the workplace can counteract performance deficits associated with the first night shift. (Reduced fatigue for a short period)
Smith et al. 2001	United Kingdom	102 Police officers *	8-hour Rotating Before: 6N-6R-4E-2R-3M-2R-3E-2R-4M-2R After: 4N-3R-3M-2R-4E-2R-3N-3R-4M-2R-3E-2E.	To examine the effects of a change in rota upon sleepiness and fatigue and potential age-related issues	Splitting the run of 7 consecutive night shifts into blocks of 3 and 4 within the rota cycle and 6 months of follow-up after the change.	Critical flicker fusion frequency (CFFF) / VAS for fatigue / Caffeine intake measurement	The change in rota had little effect but the age factor may play a substantial role in responses to night work. (Increased fatigue in elders)
Khai et al. 2001	Vietnam	34 Oxygen factory workers *	12-hour Rotating	To build practical support measures in a small enterprise to improve work conditions	Actions on risks associated with night and shift work such as environmental changes and facility improvement.	Work monitoring / 30-item fatigue questionnaire / Time analysis / advisory meeting	Positive interaction between workers and managers improved work conditions. This measure can be applied in other industries. (Reduced fatigue)
Chaikittiporn et al. 2001	Thailand	30 (12) Glass factory workers	8-hour Rotating	To examine the working conditions of shift workers in multinational enterprises using local resources	Implementing better lighting, smooth and even floors, machine covers, resting corners, heat barriers, and reducing overtime work and evaluation of their effect on sleep and fatigue.	Time-budget study / Direct work observation/walkthrough survey / 30-item fatigue questionnaire	Direct observation methods associated with the time-budget study helped identify practical action points and strengthen workplace initiatives. (Reduced fatigue)
Bonnefond et al. 2001	France	12 males Industrial plant workers	Night	To test whether napping during the night could be acceptable in night work.	Participants were authorized under certain conditions to use individual sleeping areas for a maximum of 1 hour on the night shift.	Daily questionnaire inspired by sleep diaries / Purpose-designed questionnaire / Interviews	A short nap during the night shift can be considered a positive way to counteract the low level of vigilance that normally occurs during the late part of the night. (Reduced fatigue)
Akerstedt et al. 2001	Sweden	41 (35 females) Nursery personnel	9-hour & 6-hour workday, 39h a week	To investigate the effects of weekly hours reduction on subjective health and well-being	Three points of measuring with 1 year in between, before reduction, and 1 and 2 years after at each point questionnaires and clinical investigation.	Questionnaire / Karasek-Theorell scale / Social support index	A reduction of weekly work hours from 39 to 30 hours greatly improves time for family, friends, and social activities and results in moderate improvement of fatigue, sleep, and heart-respiratory complaints. (Reduced fatigue)

Note: N: Night, R: Rest, E: Evening, M: Morning

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Tucker et al. 1999	United Kingdom	602 (12 females) Various companies	12-hour Rotating	To explore the effects of the distribution of rest days in a 12-hour shift system	Distribution of rest days in a 12-hour system for case groups between their day and night shift change and assessing sleep, alertness, fatigue, well-being, and social distribution.	Survey of shiftwork (SOS) / Shift change plan	Chronic fatigue and alertness levels among workers on 12-hour systems that incorporated breaks between the day shift and the night shift indicated that those systems were somewhat better than systems in which the block of night shifts followed immediately after the day shifts (with no complete days off in between), although the effects were only bordering on significance. (No effect on fatigue)
Wright et al. 1998	United States	15 (3 females) Emergency physicians	8-hour Rotating	To determine the effects of exogenous melatonin after intermittent night shifts on fatigue	Subjects were given Melatonin 5mg or placebo for 3 consecutive nights right after the subjects' night duty.	VAS for recovery / POMS / KSS / Neuropsychologic task battery	No beneficial effect of melatonin on sleep quality, tiredness, or cognitive function in emergency physicians after night shift duty was observed. (No effect on fatigue)
Smith et al. 1998	Australia	72 males Sewage treatment plant workers	8-hour & 12-hour Rotating	To examine the impact of participatory changes in shiftwork on sleep, fatigue, mood, and satisfaction	One plant worked first on a rapid rotating 8-hour roster and then on a 12-hour shift roster and the other 2 worked continuous 12-hour shift rosters. Then the three plants were compared in terms of sleep, satisfaction, and fatigue.	Sleep diary / Survey / General health questionnaire / self-report scales	There was a decrease in physical and psychological circadian malaise. Sleep and life quality, satisfaction, and tiredness were improved during the intervention. (Reduced fatigue)
Hornberger et al. 1998	Germany	50 males Chemical industry workers	8 and 12-hour rotating Old: 4 shift system New: 5 shift system	To investigate the impact of long-term development in shift systems on the attitude, sleep, and fatigue	Changing shift system and 7-9 months and 4.5-year follow-up by measuring fatigue, sleep, and disturbance and effect on their social life	Questionnaire / Survey	Fatigue, sleep disorders, family, and social life on morning shift days all were improved. There was a positive attitude toward rotation in the short term but not in the long duration. (Reduced fatigue in a short period)
Lowden et al. 1998	Sweden	32 males Control room operators	8 to new 12-hour shift Old: 1A4M---4N2A---2A3M----3N2A--- New: 2N-----2D---3N---3D---2N-----2D---	To evaluate the effects of change from 3-shift to 2-shift system on sleep, performance, and well-being	Change in the shift schedule and 10-month follow-up with added sleep diary and reaction time tests at the start and the end of each shift.	Questionnaire / Actigraphy / Karolinska sleep diary / Sleep scoring program / Computerized visual reaction time task	The change from 8 to 12-hour shifts was positive in most respects. However, there was not any significant effect on fatigue. (No effect on fatigue)
Paley et al. 1998	United States	24 males Firefighters	Rotating DDNNOOO	To evaluate a compressed work schedule to better determine its influence on sleep and fatigue	A comparative study in which a 10h day/14h night rotating shift was introduced to the fire department to replace an 8h three-rotating shift.	SSS / Sleep log / Mood scale (NPRU)	There were no significant differences between compressed and non-compressed schedules. Subjective measures were shown an increase over the course of extended work, but the problem with shiftwork in general will remain. (No effect on fatigue)
Feyer et al. 1997	Australia	37 males Long haul truck drivers	Long work hour	To examine the nature and its impact on two-up driving operations on fatigue	Two types of driving operations were compared, single driving, involving solo drivers and then two-up drivers in terms of heart activity, fatigue, and performance.	Auditory reaction time task / Data logger / Sport tester for heart activity / Rotary shaft encoder for truck / VAS for fatigue / CFFF	The use of overnight rest in combination with two-up driving appeared to be the most successful strategy for managing fatigue across the trip. (Reduced fatigue)

A: afternoon shift – M: morning shift – N: night shift – D: day shift – O: off – NPRU: national research program for universities – CFFF: critical flicker fusion frequency

Author / Year	Country	Sample / Job	Work shift	Aim	Method / Intervention	Tools	Main outcome
Rosa et al. 1996	Finland	208 (11 females) Steel mill workers	12-hour Rotating	To evaluate a new work schedule and its special effects on older workers	Designing a schedule to improve sleep before the morning shift and alertness during the morning by delaying shift start and end times.	SSI / Actigraphy / Daily sleep diary / NIOSH fatigue test battery / Computerized testing for fatigue and alertness	One-hour delay in shift starting times can improve sleep before the morning shift. It also reduces sleepiness and improves waking fatigue, but there is a trade-off for night and evening. (Reduced fatigue)
Kandolin et al. 1996	Finland	45 females Midwives	8-hour Rotating	To find measures that reduce the strain of irregular shifts and maintain work capacity in healthcare	An extensive survey was followed by a 6-month intervention in shift scheduling with the participation of workers.	Questionnaire / SSI / Occupational stress questionnaire (OSQ) / interview	There was a decrease in mental strain and stress levels especially among the elderly workers. Social interaction also improved besides fatigue. (Reduced fatigue)
Williamson et al. 1996	Australia	27 males Truck drivers	Long work hours	To investigate the relationship between staged driving and fatigue and the impacts of the 12-hour 900-km trip on fatigue.	Three different regimes which were equated for length and start time were compared. Staged trip, single trip, and flexible trip.	Custom-built data logger for heart rate and speed variability / Subjective fatigue scale / CFFP / PVT / Reaction time task / Performance task	None of the driving regimes prevented fatigue and the pattern of fatigue experienced during the trips appeared to be related to pre-trip fatigue levels. (No effect on fatigue)
Stewart et al. 1995	United States	18 (5 females) NASA flight agents	9-hour & 13-hour Night and early morning	To promote adjustment to shiftwork schedules by using light treatment	Designing and testing light-treatment protocol for NASA personnel during the prelaunch week which continued during the mission and several days afterward.	VAS about performance / SSS / Owl-Lark questionnaire / Sleep log	Work speed, concentration, and alertness were higher after the treatment. Performance got easier and sleep quality increased. Also, the levels of arousal and difficulty were lower during the study. (Reduced fatigue)
Barton et al. 1994	United Kingdom	363 (26 women) Industrial workers	8-hour Rotating	To reduce shiftwork problems with shift design and identify its effects on fatigue, well-being, sleep, and work satisfaction	Changing from delaying shift system to advancing system with 2 months before and 6 months after change survey.	SSI / Psychological well-being questionnaire (GHQ-12) / 10-item questionnaire for fatigue/sleep log	Social disruption decreased and in contrast, sleep difficulties were increased during the advancing system. No effect on fatigue was observed during the study period. (No effect on fatigue)
Matsumoto et al. 1994	Japan	28 males Computer operators	8-hour Rotating Day: 7:00-15:00 Evening: 15:00-22:00 Night: 22:00-7:00	To investigate the effectiveness of naps in facilitating recovery from night-shift fatigue	Comparison of two conditions with nap and without nap in two different companies in terms of sleepiness and fatigue.	SSS / Subjective fatigue scale / Intensity scale for feelings	It was found that a nap taken during the night shift to some extent aids recovery from fatigue. (Increased recovery from fatigue)
Harma et al. 1988	Finland	75 females Nurses	Day & Evening 8-hour Night 10-hour	To explore the effects of physical training on health, sleep, and adaptation	The controlled physical training program lasted for 4 months. Assessments were conducted before and after the intervention in the laboratory and field.	Submaximal cycle ergometer test / Maximal test after intervention / Sit-up test / Training diary / Quality of sleep questionnaire	Maximal oxygen consumption and muscle strength increased during the training period. Heart rates at work were decreased, physical fitness and sleep length were increased and there was a reduction in fatigue during the night shifts. (Reduced fatigue)

SSI: short sleep index - NIOSH: national institute for occupational safety and health - GHQ: general health questionnaire

Supplementary Table 3: Risk of Bias assessment Table Based on Downs and Black (1998) quality checklist.

Risk-of-bias assessment of all 92 studies identified for critical appraisal, using the Downs and Black (1998) quality checklist. Domain-level sub scores are reported for reporting quality, external validity, internal validity, confounding/selection bias, and statistical power (maximum total score = 28). Overall quality was stratified as excellent (26–28), good (20–25), fair (15–19), or poor (≤ 14). Study design (RCT, non-randomized, etc.) is indicated for each study. Three studies with scores < 14 quality scores (Kerin et al., 2005; Wootten, 2000; Rosenberg et al., 1995) were excluded from the narrative synthesis, yielding the final 89 studies reported in the Results.

NO.	First Author	Year	Article type	D&B score*	Reporting	External validity	Internal validity	Confounding (Selection bias)	Power	Quality Rating
—	—	—	Max**	28	11	3	7	6	1	-
1	Wyche	2025	RCT	15	7	2	4	1	1	Fair
2	Kubo	2025	Cross-over non-randomized	18	10	1	4	2	1	Fair
3	Konya	2025	Quasi-Experimental	20	9	3	4	3	1	Good
4	Cohen	2025	Pilot quasi-experimental	16	9	2	2	2	1	Fair
5	Al Maawali	2025	Qualitative thematic analysis	14	6	1	4	2	1	Poor
6	Chabal	2025	Quasi-experimental	21	11	1	5	4	0	Good
7	Van Elk	2024	Quasi-experimental	20	9	1	5	4	1	Good
8	Shriane	2024	RCT	21	9	1	5	5	1	Good
9	Djupedal	2024	RCT	23	11	2	5	5	0	Good
10	Salzman	2024	Quasi-experimental	15	7	2	4	2	0	Fair
11	Ebina	2024	Pretest-posttest	17	11	2	3	1	0	Fair
12	Cyr	2023	RCT	23	10	2	5	5	1	Good
13	Bessman	2023	Quasi-experimental	22	11	1	6	4	0	Good
14	Wingelaar	2023	RCT	27	10	3	7	6	1	Excellent
15	Ruan	2023	Quasi-experimental	22	10	2	5	4	1	Good
16	Li	2023	Quasi-experimental	21	9	3	4	4	1	Good
17	Myllyla	2022	Quasi-experimental	20	9	3	4	3	1	Good
18	Mohammadi	2022	Quasi-experimental	16	7	2	3	3	1	Fair
19	Melan	2022	Quasi-experimental-repeated measure	18	9	3	3	2	1	Fair
20	Kubo	2022	Cross-over non-randomized	19	9	2	3	4	1	Fair
21	Hoshi	2022	Pretest-posttest	14	6	3	3	2	0	Poor
22	Helmhout	2022	RCT – Cross-over	23	11	3	3	5	1	Good

Risk of Bias assessment Table (Continue)

NO.	First Author	Year	Article type	D&B score*	Reporting	External validity	Internal validity	Confounding (Selection bias)	Power	Quality Rating
—	—	—	Max**	28	11	3	7	6	1	-
23	Ha	2022	RCT	25	9	3	6	6	1	Good
24	Dahlgren	2022	RCT	24	9	3	5	6	1	Good
25	Baek	2022	Pretest-posttest	19	9	2	3	4	1	Fair
26	White	2021	Pretest-posttest	16	6	2	4	3	1	Fair
27	Van Woerkom	2021	Quasi-experimental	17	8	3	4	2	0	Fair
28	Sakai	2021	Pretest-posttest	17	9	2	3	2	1	Fair
29	Longman	2021	Cross-sectional	23	10	3	3	6	1	Good
30	Han	2021	Pretest-posttest	20	9	3	3	4	1	Good
31	Cho	2021	Pretest-posttest	19	8	3	3	4	1	Fair
32	Brunet	2021	RCT	19	7	3	4	4	1	Fair
33	Barger	2021	Quasi-experimental	21	8	3	5	4	1	Good
34	Olson	2020	Quasi-experimental	22	10	3	5	3	1	Good
35	Patterson	2019	RCT	19	7	2	5	4	1	Fair
36	Holzinger	2019	Pretest-posttest	14	6	3	2	3	0	Poor
37	Fowler	2019	Pretest-posttest Cross-over	16	6	3	4	2	1	Fair
38	James	2018	Pretest-posttest Pilot	19	9	3	4	2	1	Fair
39	Leedo	2017	RCT	22	8	3	4	6	1	Good
40	Sparrow	2016	Interventional field study	21	10	3	5	2	1	Good
41	Smith-Miller	2016	Interventional field study	20	8	3	4	4	1	Good
42	Flindall	2016	RCT	20	7	2	5	5	1	Good
43	Patterson	2015	RCT	25	10	3	6	5	1	Good
44	Parshuram	2015	RCT	22	9	3	4	6	0	Good
45	Van Drongelen	2014	Quasi-experimental	25	10	3	5	6	1	Good
46	Signal	2014	Interventional field study	20	9	3	4	3	1	Good

Risk of Bias assessment Table (Continue)

NO.	First Author	Year	Article type	D&B score*	Reporting	External validity	Internal validity	Confounding (Selection bias)	Power	Quality Rating
—	—	—	Max**	28	11	3	7	6	1	-
47	Punja	2014	RCT	24	10	3	6	4	1	Good
48	Oriyama	2014	Quasi-experimental	18	10	1	4	3	0	Fair
49	Ernst	2014	RCT	20	9	3	4	4	0	Good
50	Tempesta	2013	Pretest-posttest	21	8	3	5	4	1	Good
51	Barger	2012	Interventional field study	21	9	3	5	3	1	Good
52	Estrada	2012	RCT	17	7	3	3	3	1	Fair
53	Lowden	2012	Quasi-experimental	20	9	3	4	3	1	Good
54	Zamanian	2010	Pretest-posttest	15	6	3	4	2	0	Fair
55	Scott	2010	Pretest-posttest	22	9	3	5	4	1	Good
56	Powell	2010	Comparative study	19	8	3	3	4	1	Fair
57	Hesselink	2010	Comparative study	20	8	3	5	3	1	Good
58	Tvaryanas	2009	Pretest-posttest	21	8	2	5	5	1	Good
59	Karlson	2009	Pretest-posttest	19	8	3	4	3	1	Fair
60	Viola	2008	Quasi-experimental	21	10	3	4	3	1	Good
61	Mitra	2008	Pretest-posttest	16	7	3	3	2	1	Fair
62	Ferguson	2008	Quasi-experimental	19	8	3	4	3	1	Fair
63	Smith	2007	Cross-over non-randomized	22	9	3	4	5	1	Good
64	Smith-Coggins	2006	Pretest-posttest	21	7	3	5	5	1	Good
65	Rosekind	2006	Quasi-experimental	14	5	1	4	3	1	Poor
66	La Pine	2006	RCT	20	7	2	6	4	1	Good
67	Arora	2006	Pretest-posttest	19	7	3	4	4	1	Fair
68	Kerin	2005	Quasi-experimental	9	2	1	3	3	0	Poor
69	Chung	2004	Interventional field study	15	5	1	5	3	1	Fair
70	Yoon	2002	Clinical trial - not randomized	21	9	3	6	2	1	Good
71	Purnell	2002	Pretest-posttest	16	7	3	3	3	0	Fair
72	Smith	2001	Comparative study	19	8	3	4	3	1	Fair

Risk of Bias assessment Table (Continue)

NO.	First Author	Year	Article type	D&B score*	Reporting	External validity	Internal validity	Confounding (Selection bias)	Power	Quality Rating
—	—	—	Max**	28	11	3	7	6	1	-
73	Khai	2001	Quasi-experimental	15	7	3	2	3	0	Fair
74	Chaikittiporn	2001	Quasi-experimental	14	4	3	4	3	0	Poor
75	Bonnefond	2001	Quasi-experimental	14	7	1	3	3	0	Poor
76	Akerstedt	2001	Quasi-experimental	19	8	3	4	3	1	Fair
77	Wootten	2000	Pretest-posttest	11	3	2	3	2	1	Poor
78	Tucker	1999	Quasi-experimental	19	7	3	5	3	1	Fair
79	Wright	1998	RCT	24	10	3	6	4	1	Good
80	Smith	1998	Pretest-posttest	17	8	3	3	2	1	Fair
81	Paley	1998	Quasi-experimental	15	6	3	2	3	1	Fair
82	Lowden	1998	Pretest-posttest	20	8	3	4	4	1	Good
83	Hornberger	1998	Pretest-posttest	16	8	2	3	2	1	Fair
84	Feyer	1997	Quasi-experimental	18	7	3	4	3	1	Fair
85	Williamson	1996	Interventional field study	15	7	2	2	4	0	Fair
86	Rosa	1996	Pretest-posttest	17	7	3	4	2	1	Fair
87	Kandolin	1996	mixed-methods / quasi-experimental	15	6	2	4	2	1	Fair
88	Stewart	1995	Pretest-posttest	19	8	3	4	3	1	Fair
89	Rosenberg	1995	Comparative study	11	5	1	3	2	0	Poor
90	Matsumoto	1994	Pretest-posttest	17	7	2	3	4	1	Fair
91	Barton	1994	Pretest-posttest	21	10	3	4	3	1	Good
92	Harma	1988	Quasi-experimental	21	9	2	4	5	1	Good

* Downs and Black score: excellent (26–28), good (20–25), fair (15–19), and poor (≤ 14).

** Max: maximum total or section score in Downs and Black quality assessment checklist.

Supplementary Table 4: Inter-rater agreement (Cohen's kappa) on quality threshold classification.

Inter-rater agreement between Rater 1 [M.R.] and Rater 2 [N.R.] on whether each of the 92 studies met the pre-specified quality threshold (Downs & Black score ≥ 14 , "acceptable" vs. < 14 , "poor") was evaluated using Cohen's kappa.

- Rater 1 [M.R.] classified 86 of 92 studies as eligible for retention (≥ 14).
- Rater 2 [N.R.] classified 89 of 92 studies as eligible for retention (≥ 14).

Rater 1 vs Rater 2

	R2: Yes	R2: No	Total
R1: Yes	86	0	86
R1: No	3	3	6
Total	89	3	92

- $P_o = (86+3)/92 = 0.9674$
- $P_e = (86 \times 89 + 6 \times 3)/92^2 = 0.9064$
- $\kappa = 0.65 \rightarrow$ Substantial agreement

Result shows a substantial agreement for the screening reliability.

Resolution of Disagreements: The two raters disagreed on three studies near the score threshold of 14. A third reviewer [S.A.Ch.] independently evaluated these papers. Following joint review, consensus was reached that the studies met the baseline criteria for reporting and internal validity with a score of 14, and they were retained in the final synthesis.

Inter-rater agreement on quality classification. To assess the reliability of the quality-based inclusion decision, agreement between the two independent raters on whether each of the 92 studies met the pre-specified quality threshold (Downs & Black score ≥ 14 [retained] vs. < 14 [excluded]) was evaluated using Cohen's kappa. Rater 1 classified 86 of 92 studies as acceptable; Rater 2 classified 89 of 92 as acceptable. Observed agreement was 96.7% ($P_o = 0.97$), with a chance-corrected agreement of $\kappa = 0.65$, indicating substantial agreement (Landis & Koch, 1977).

Supplementary Table 5: Reasons for exclusion of three studies

Study	Reasons for exclusion
Kerin et al. 2005	Quality assessment score: 9 Study type: field report – pre and post training No focus on fatigue: aims “to reduce accidents, absenteeism, turnover, and improving morale and productivity” No data of working population: they were just referred as shift workers No actual probability values reported No data about their shift and rotation
Wootten 2000	Quality assessment score: 11 No clear aim and objective No clear method: partial intervention plus survey development and qualitative risk assessment of fatigue No clear outcome reported during the study related to fatigue
Rosenberg et al. 1995	Quality assessment score: 11 No clear description of the working population No estimate of random variation and actual probability reported Unclear methodology: no data about the measurement tools and standardization

Supplementary Table 6: Distribution of study designs across intervention categories

Study design	RCT	Crossover Non-RCT	Quasi- experimental	Pretest- posttest	Comparative	Interventional field study	Qualitative/ Mixed method
Intervention Category							
Work organization and environmental	5	2	17	11	3	5	1
Sleep and recovery	0	1	5	8	0	2	0
Lifestyle and behavior	4	0	4	4	0	0	0
Pharmacological and complementary	6	0	1	1	0	0	0
Digital and technology-assisted	4	0	3	2	0	0	0