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CLINICAL REVIEW

Longitudinal studies of sleep, physical activity and nutritional intake in shift workers: A scoping review

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SUMMARY

Shift work is known to be associated with poor health outcomes, however our understanding of health behaviours (sleep, physical activity and nutritional intake) longitudinally in shift workers is currently limited. Systematic searches of four data bases were conducted. Using PRISMA-ScR guidelines we report a scoping review of 15 eligible studies. Of the included studies, 11 studies examined sleep outcomes, three examined physical activity and two examined nutritional intake. The number of follow ups conducted in each study varied from one to six, with the majority of studies reporting one follow up. Study length varied from six months to 16 years. Findings suggest that shift workers have stable but largely insufficient sleep longitudinally. Many shift workers, particularly inexperienced shift workers, are additionally experiencing poor sleep quality. There is limited data longitudinally on physical inactivity and nutrition intake, but included studies indicate that shift workers may also be physical inactive and with some poor nutritional intake (i.e., high levels of saturated fat intake). Longitudinal studies of shift work with multiple follow-ups are needed to address the current gaps in literature. The evidence that shift workers may be susceptible to poor health behaviours longitudinally is important as it provides a means by which strategies and interventions can be targeted, at both individual and organisational levels, to assist in better long term health outcomes.

Introduction

There is consistent demand for many workforces to operate outside traditional 9am to 5 pm h. Approximately 21% of the European [1], 17% of the United States [2] and 16% of the Australian workforce [3] are regularly engaged in shift work. While shift work is present in many forms of nonstandard work hours, it can be defined as “work [that] usually encompasses work time arrangements outside of conventional daytime hours, which includes fixed early morning, evening, and night work, as well as roster work and rotating three shift work” [4]. Shift work is unavoidable in occupations where working around the clock is necessary, such as health, emergency services and transport. Shift work is also attractive to businesses and workers as it can decrease running costs, increase productivity and improve flexibility for workers [2,5]. Despite shift work being necessary, a substantial body of evidence suggests that this pattern of work is associated with increased health risks such as cardiovascular disease [6,7], metabolic disorder [8], and some cancers [9,10].

Shift work negatively impacts health through circadian misalignment and sleep loss [4], and through suboptimal health behaviours [4,11,12]. Health behaviours are defined as intentional or unintentional actions taken by an individual which may promote or detract from health [13]. Poor health behaviours, also known as lifestyle or behavioural risk factors, include insufficient or poor sleep, physical inactivity and suboptimal nutritional intake, as well as tobacco smoking and alcohol consumption. Such behaviours are linked to chronic disease and increased mortality risk [14–16] and each are modifiable. However, of these health behaviours, sleep, physical activity and nutritional intake are an important triad. As fundamental biological needs, sleep, physical activity and nutritional intake uniquely impact individuals on a day to day level. These three health behaviours all co-occur daily and engagement in

Abbreviations: CASP, Critical Appraisal Skills Programme; EEG, Electroencephalogram; GSDS, General Sleep Disturbance Scale; KCAL, Kilocalorie; KSQ, Karolinska Sleep Questionnaire; PRISMA-ScR, Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews; PSG, Polysomnography; SSI, Standard Shiftwork Index.

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each behaviour may influence one or both of the other behaviours [17]. In the simplest terms, under normal conditions, all individuals must engage in some level of sleep, physical activity and nutritional intake daily in order to survive, thus these three behaviours have crucial influence on an individual's health.

Sleep is a basic human need which plays a crucial role in many waking functions [18]. Broadly, healthy adults are estimated to need approximately 7–9 h of quality sleep per 24 h [19]. Insufficient and poor sleep quality is associated with increased risk of chronic disease and mortality [15,16]. Physical activity refers to any movement of the body that results in energy expenditure including exercise (planned, structured with the goal of improving or maintaining physical fitness), occupational physical activity, sports, household or other daily activities [20]. Public health recommendations for adults are a minimum of 150 min of moderate-intensity or 75 min of vigorous-intensity physical activity per week [21]. Insufficient physical activity is associated with increased mortality risk, and an estimated 8.3% of deaths in America are attributable to insufficient physical activity [22]. Further, insufficient physical activity is estimated to be responsible for between 6% and 10% of disease burden for coronary heart disease, type 2 diabetes, breast cancer and colon cancer worldwide [23]. Nutritional intake refers to the intake of nutrients, usually via food consumption, required for sustenance or avoid a deficiency nutritional state [24]. Nutritional intake and dietary guidelines are extensive and varied. Existing dietary guidelines suggest adults should consume approximately 2080 calories per day (subject to height, weight and physical activity level), $\geq$ four and a half cups of fruit and vegetables per day, $\geq$ two 3.5-oz servings of fish per week, six servings of wholegrains per day, <1500 mg sodium per day, $\leq$450 kcal sugar-sweetened beverages per week, $\leq$ two serves of processed meats, no more than 100 or 150 calories of sugar for women and men respectively [21,24]. Lastly, saturated fat intake should be limited to less than 7–10% of total energy intake [21,24]. High sodium intake, low omega-3 intake and high trans fatty acids are associated with increase mortality [14], higher sugar intake is associated with coronary heart disease [25], while excessive total calorie, saturated fat intake and sugar intake is associated with increased risk of obesity [25–27].

While each of these behaviours (sleep, physical activity, nutritional intake) represent independent risk factors for various health outcomes, as outlined above, these behaviours cluster together and interact with other [28,29]. For example, insufficient sleep is associated with increased energy intake [30], and regular physical activity is associated with benefits to sleep duration and sleep quality [31]. Furthermore, when considering these three behaviours in combination, suboptimal levels of these three behaviours together is associated with a greater risk of self-reported poor health, compared to one or two behaviours [32]. It is important that all three behaviours are examined concurrently in order to better understand the interactive relationships, in the context of shift work. Finally, given the known association between shift work and circadian misalignment, these specific behaviours are pertinent to shift workers as each health behaviour can be influenced by, or cause, disruption to circadian rhythms [33].

An existing body of evidence has examined various health behaviours in shift workers, with a strong focus on sleep. However, many studies rely on cross-sectional data which do not provide adequate evidence of the change over time between shift work, health behaviours and negative health consequences [4,11,12], and there is a need for longitudinal studies [34]. These studies can provide insight into patterns of health behaviours before disease outcomes emerge, and potentially inform direction for early intervention and prevention. Longitudinal studies may also provide insight into how health behaviours change in response to time exposed to shift work.

Understanding changes to health behaviours with exposure to shift work is important for understanding the relationship between shift work and disease outcomes. These insights are crucial if we are to inform preventive, rather than responsive, health strategies for shift workers. In that context, the purpose of the present scoping review is to examine the extent of existing longitudinal shift work research focused on the three health behaviours, summarise previous research findings, and identify gaps in the existing literature base [35]. An overarching purpose of a scoping review is to determine the coverage of research within an area [36]. Therefore, given the lack of existing literature which summarises longitudinal studies of health behaviours in shift workers, a scoping review methodology was chosen to meet the objectives of this review.

Objectives

1. To summarise existing longitudinal literature and findings on sleep, physical activity, and nutritional intake in shift workers,
2. To identify defining features which have been examined by existing studies, such as: occupations, age of workers, shift work experience, country of study, outcome measure used
3. To identify gaps in the current evidence base and provide direction for future studies.

Methods

The present scoping review has been developed using existing methodological frameworks [35,37] and is reported following PRISMA-ScR guidelines [38] (Supplementary Table 1). A team approach was adopted to discuss and develop inclusion and exclusion criteria, as well as data charting forms [37].

Protocol and registration

The protocol for the present scoping review was pre-registered on the Open Science Framework on 25/03/2021, DOI: 10.17605/OSF.IO/KS9BR.

Eligibility criteria

Inclusion and exclusion criteria (Table 1) for eligibility of studies were discussed and defined prior to registration of the review, and screening of articles. To be eligible for inclusion studies must have met the following criteria: 1) the article was a peer-reviewed article written in English, and available in full text, 2) the study examined shift workers; being workers that regularly work outside standard hours (including night shift, rotating shift, on-call, early morning, afternoon or evening shifts) [4], 3) the study examined the same individuals at a minimum of two comparable time points (e.g., not changing from day work to shift work) $\geq$ 30 days apart, 4) the outcome included at least one measure of: sleep, physical activity or nutritional intake, 5) the study presented sufficient information about changes/no change in outcomes in shift workers only (e.g., not shift workers compared to day workers).

Studies which examined individuals with a diagnosed sleep disorder or shift work disorder were excluded to avoid confounding effects from clinical sleep disorders which may have been present prior to commencing shift work. If studies examined transition to shift work (i.e., pre-shift work at baseline) and at least two time points ($\geq$30 days apart) while individuals were working shift work, the study was eligible for inclusion with examination of the time points during shift work only (i.e., pre-shift work data were not included). Exclusion of pre-shift work results was necessary to avoid overestimation of behavioural changes,

Table 1
Inclusion and exclusion criteria for the review.

	Inclusion Criteria	Exclusion criteria
Population	Shift workers; any age, gender, occupation	Not a shift working population[a]
Exposure	Shift work; including night shift, early morning, afternoon, evening, rotating shift work and/or on-call	Workers who transitioned to or from shift work (e.g., baseline was a different work schedule to follow-up)
Comparison	Not relevant	
Outcome	**Sleep:** self-reported sleep quality, sleep duration, sleep disturbance and/or objectively measured sleep (actigraphy, PSG, EEG) **Physical activity:** exercise, recreational physical activity, objectively measured physical activity and occupational physical activity **Dietary intake:** overall calorie intake, nutrient intake	**Sleep:** diagnosed sleep disorder **Nutritional intake:** meal timing or eating behaviour only
Setting	Any country Observational study	Conducted in laboratory Involves intervention
Study design	Longitudinal study with ≥30 days between time points	Two time points specifically assessed different work period (e.g., day-work vs shift work)
Publication type	Peer-reviewed journal publication	Conference Abstract Thesis
Language	English	
Other	Any publication date	Full text not available

Note. PSG = Polysomnography, EEG = Electroencephalogram.
[a] Studies that compare day work or general population to shift work will be excluded, except in the case that the shift workers data is able to be analysed independent of day workers (e.g., Time 1 and Time 2 results of shift workers are presented separately).

given that our review aims to examine health behaviours while working shift work only. Furthermore, studies that involved an intervention were excluded. As the primary aim of this review is to describe changes in health behaviours over time in shift workers, the inclusion of intervention studies would confound the findings. Specifically, it would not be possible to distinguish if health behaviours undergo longitudinal changes or changes due to the intervention. Studies of eating timing and reasons for eating (e.g., emotional eating) were excluded as the purpose of this review was to examine health behaviours with known associations with chronic disease risk. We acknowledge there is much work being done on meal timing and behaviours [39,40]. However we focused on known intake-related associations with chronic disease (e.g., fats, sodium, sugar) based on established relationships in the literature.

Information sources

For this review, studies published in peer-review journals were retrieved from four databases (Embase, MEDLINE, PsycInfo, Web of Science) in accordance with optimal search guidelines [41]. Searches of Google Scholar were conducted using key words to ensure all possible eligible articles were retrieved. Final database searches were conducted on 24/03/2021. Following full text selection, the reference lists of all included articles were also searched for relevant publications. As this was a scoping review, no authors of original publications were contacted for further information as a scoping review aims to present the available evidence, including any pitfalls in reporting [35].

Search strategy

Searches were conducted using key words: 'shift work' OR 'night shift' OR 'shiftwork' AND nutrition OR eat OR food OR diet OR 'physical activity' OR exercise OR 'health behavior' OR 'health behaviour' OR sleep AND longitudinal OR prospective OR cohort. No publication date limits or other restrictions were used in searches. All database search strategies and the number of results are available in supplementary material (Supplementary Table 2). All results from searches were exported to EndNote software [42] for management.

Study selection

One reviewer (MEC) screened for duplications and conducted title and abstract screening. Two reviewers (MEC & SAF) independently screened full text articles and any disagreements were resolved by discussion. There was an initial 92% agreement between the reviewers for full text screening. Publications (8%) for which reviewers disagreed were discussed between both reviewers and consensus was reached without the need for the third reviewer.

Data charting and synthesis

A pre-defined data chart was developed by the authors prior to the extraction of data (Supplementary Table 3). The pre-defined data chart included: author, publication title, year of publication, country of study, name of study (if applicable), study design, length of follow ups, sample size, sample characteristics (gender, age), occupation, type of shift work, experience in shift work, outcome measurements and key results (means, standard deviation, percentages, type of statistical testing and relevant statistical testing results). For studies that did not present relevant key results in text (e.g., mean total sleep time) but did present within figures, Plot-digitizer software [43] was used to extract this data. Data-charting was completed independently by the first author (MEC) and reviewed by both co-authors (SAF and ACR).

Following data charting narrative synthesis with summary table and result voting was undertaken, in accordance with Cochrane guidelines [44]. In line with our review objectives, studies were grouped by outcome of interest (i.e., sleep, physical activity, nutritional intake or a combination of these). Key study characteristics (e.g., country of study, data collection time points, outcome measure, shift work experience) and key results (e.g., means and standard deviation, p-values where available) were vote counted.

Critical appraisal of individual sources of evidence

Critical appraisal of included studies was undertaken using CASP Cohort checklist [45]. A CASP Cohort checklist was conducted independently by two authors (MEC and ACR) for every study, and any discrepancies were resolved by discussion with third author (SAF).

Results

Selection of sources of evidence

Following article screening, a total of 15 studies were eligible for inclusion (see Fig. 1). Of these studies, 11 investigated sleep outcomes, three measured physical activity and two assessed nutritional intake. No studies investigated all three outcomes of interest concurrently, however one study examined dietary intake and physical activity concurrently [46].

Characteristics of sources of evidence

Table 2 provides a summary of key features in each of the 15 included studies. Studies utilised sample sizes ranging from 25 to 29,019 participants. Studies were conducted in Sweden (n = 3) [47–49], Netherlands (n = 2) [46,50], Norway (n = 2) [51,52], Australia (n = 1) [53], Brazil (n = 1) [54], Canada (n = 1) [55], Croatia (n = 1) [56], Finland (n = 1) [57], Italy (n = 1) [58], Korea (n = 1) [59] and Taiwan (n = 1) [60].

Key study features

As shown in Fig. 2, the majority of included studies (67%, n = 10) utilised only two data collection points. A further 20% (n = 3) utilised three data collection points, one (7%) conducted four data collection points, and one (7%) reported a total of six data collection points. The length of time from baseline to the final reported follow up ranged from six months to 17 years (Fig. 2). Of all the included studies, 33% (n = 5) were six months in length [52–55,60], 40% (n = 6) were between one to four years [46,47,49,50,56,59] and 27% (n = 4) were more than four years in length [48,51,57,58]. Of the five studies that conducted more than one follow up, Kecklund et al. [49] conducted a five and 12 month follow up, Han et al. [59] conducted six monthly follow ups for two years (i.e., baseline and four follow-ups), Lammers-van der Holst et al. [50] conducted nine and 16 month follow up, Radoševic-Vidaček et al. [56] conducted a two and four year follow up, and Finnish Public Sector study conducted approximately four yearly follow ups for 16 years [57]. An overview of study outcomes of interest, data collection points, study length and measures utilised, is presented in Fig. 2.

Outcome measures

Studies with sleep outcomes utilised varied approaches to measurement. These included the Standard Shiftwork Index [61] (n = 3) [53,55,58], the Karolinska Sleep Questionnaire [62] (n = 1) [48], General Sleep Disturbance Scale [Korean version] [63] (n = 1) [59], Pittsburgh Sleep Quality Index [64] (n = 1) [10] and the Vidacek 1987 shift worker sleep quality scale [65] (n = 1) [59]. Three studies utilised objective sleep measure such as EEG [47] and actigraphy [50,52] in combination with self-report data. One study utilised non-validated, but previously used, questionnaires for sleep outcomes [49]. For physical activity outcomes, two studies

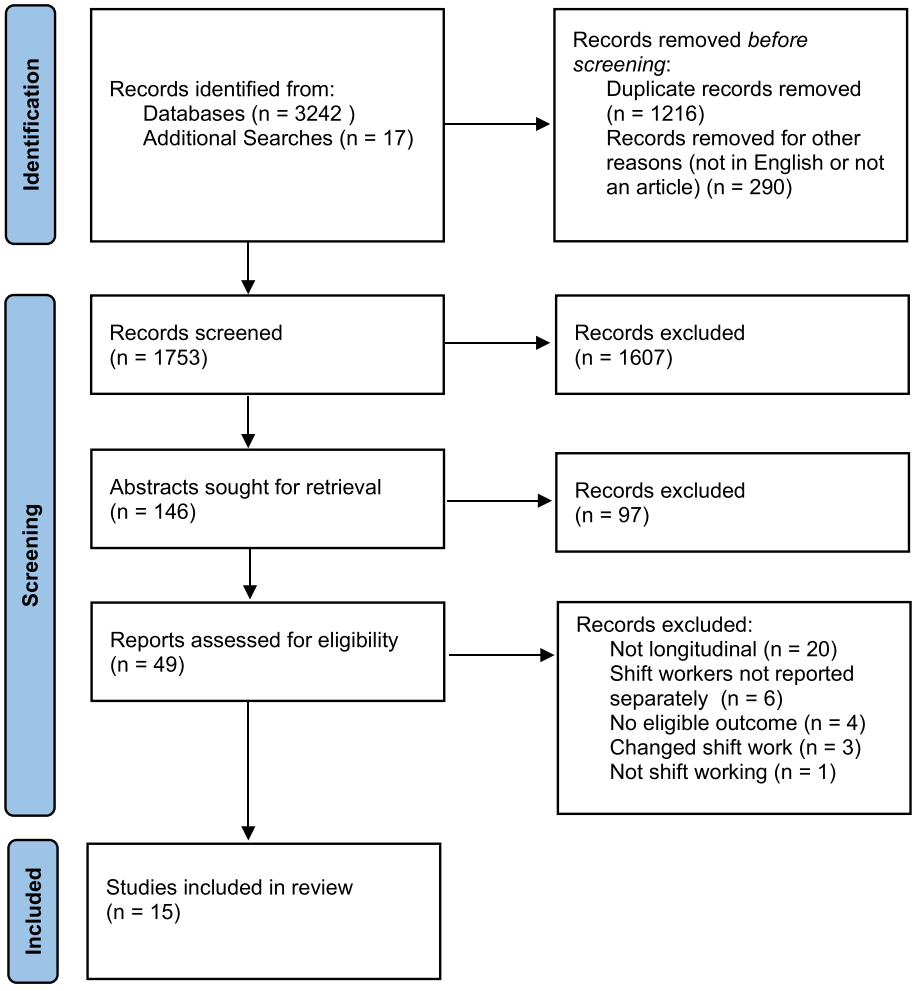

Fig. 1. PRISMA flowchart of screening of records.

Table 2
Summary of data charting for studies included in review.

Study/Author (publication year)	Country of study	Sample size	Sex (M:F)	Age mean ± SD or n [range]	Occupation	Type of shift work	Average shift work experience at Baseline mean ± sd [range]	Outcome measure	Outcome variable	Results Mean ± SD, where available	Significant change
Named Studies											
Finnish Public Sector Study (2020) [57]	Finland	29,019	4720:24,299	≤39 n = 12,309 40-49 n = 9253 ≥50 n = 7457	35% nurses, 8% primary and preschool teachers, 6% secondary school teachers.[a]	Rotating shift work, Shift work without nights, Permanent night work	NR	**Physical activity:** "How many hours of physical activity do you have per week on average during leisure time or commuting within the past year?" (<30mins per week was inactive)	Risk of physical inactivity (crude risk with baseline as comparator)[b]	T2 1.11 T3 1.37 T4 1.90 T5 1.84 T6 1.63	— ↑ ↑ ↑ ↑
SUSSH: The Survey of Shiftwork, Sleep and Health (2019) [51]	Norway	523	62:459 NR: 2	31.5 ± 7.6	Nurses	Permanent night workers, Rotating shift work	3.0y [0.0–7.0]	**Physical activity:** Questionnaire; "How many hours of sweaty exercise per week?"	% of participants engaged in >1 h sweaty exercise per week	T1 67% of shift workers T2 64% of shift workers	—
WOLF (2010) [48]	Sweden	913	829:84	Young n = 505 Old n = 408	Blue collar and white collar workers. No further occupational information reported.	Two-shift work, Rotating three shift, permanent night work or irregular shift work.	NR	**Sleep:** Karolinska Sleep Questionnaire [62]	Compared to T1 at T2 (% of workers reporting problem)		
									Difficulty falling asleep:	35% increased problems, 13% improved, 52% stayed the same	—
									Repeated awakenings:	40% had more problems, 15% improved	—
									Not well rested:	45% stayed the same 34% were less well rested	
										18% had improvements	—
										49% stayed the same	
Unnamed Studies											
Akerstedt & Kecklund (1991) [47]	Sweden	25	25:0	38.6 [25–55]	Papermill workers	Continuous three-shift system	>2 y	**Sleep:** EEG Self-report questionnaire	Nighttime TST:	T1 450 ± 15 T2 463 ± 18	—
									Daytime TST:	T1 313 ± 17 T2 348 ± 19	—
									Day subjective sleep quality:	T1 2.63 ± 0.09 T2 2.47 ± 0.09	—
									Night subjective sleep quality:	T1 3.07 ± 0.09 T2 2.97 ± 0.09	—
Costa et al. (2001) [58]	Italy	108	108:0	36.7 ± 8.9	Bus drivers	Rotating shift work	13.3y [1–34]	**Sleep:** Standard Shiftwork Index [61]	Average sleep duration by shift (hours)[b]	Early 5.35 ± 0.53 Morning 7.01 ± 0.59 Afternoon 8.48 ± 1.06 Late 8.53 ± 1.11 Off 8.47 ± 1.18	—
									Average sleep troubles by shift:	Early 16.4 ± 4.4 Morning 14.6 ± 3.9 Afternoon 12.6 ± 3.1 Late 11.9 ± 3.1	—

(*continued on next page*)

Table 2 (*continued*)

Study/Author (publication year)	Country of study	Sample size	Sex (M:F)	Age mean ± SD or n [range]	Occupation	Type of shift work	Average shift work experience at Baseline mean ± sd [range]	Outcome measure	Outcome variable	Results Mean ± SD, where available	Significant change
										Off 10.1 ± 3.1	
Flaa et al. (2021) [52]	Norway	50	49:1	43	Air ambulance pilots and crew	Rotating shift work	9.4y(±7.9)	**Sleep:** Actigraphy Self-report sleep diaries	Objective actigraphy TST (hours)	T1 6.01 ± 1.24 T2 5.57 ± 1.27	—
										T1 7.17 ± 1.26 T2 7.03 ± 1.30	—
									Subjective TST (hours): Objective sleep efficiency: Subjective sleep efficiency:	T1 84.4% T2 85.4% T1 92.5% T2 91.9%	— —
Han et al. (2020) [59]	Korea	355	18:337	24 [22–32]	Nurses	Rotating shift work	6wk	**Sleep:** General Sleep Disturbance Scale [63] Self-report questionnaire	General sleep disturbance score	T1 56.6 T2 54.7 T3 54.2 T4 55.2 T5 56.1	— — —
									Subjective sleep duration:	T1 5.6hrs. T2 6.4hrs. T3 6.7hrs. T4 6.6hrs. T5 6.6hrs	— — —
									Subjective sleep latency:	T1 24.3min T2 29.3min T3 30.2min T4 32.1min T5 35.6min	— ↑ ↑ ↑ —
									Subjective sleep quality (% reporting poor sleep):	T1 79.6% T2 69.3% T3 66.4% T4 64.6% T5 64.1%	— — —
Kecklund et al. (2001) [49]	Sweden	48	48:0	41 [22–62]	Construction workers	Rotating; afternoon, morning and double shifts	4mo	**Sleep:** Self-report questionnaire Self-report sleep diaries	Subjective insufficient sleep (lower = more insufficient sleep)	T1 3.8 ± 0.2 T2 3.8 ± 0.1 T3 3.3 ± 0.2	— ↑
									Subjective insomnia index (lower = more insomnia)	T1 4.3 ± 0.1 T2 4.3 ± 0.1 T3 3.9 ± 0.2	— —
Lammers-van der Holst et al. (2016) [50]	Netherlands	42	30:12	27 ± 7.5	Police officers	Rotating shift work	Not reported	**Sleep:** Actigraphy Self-report sleep diaries	Objective total sleep time (minutes)	T1 365 T2 346 T3 343	↓ ↓
									Subjective sleep quality (higher = better sleep)	T1 3.5 T2 3.5 T3 3.3	— —
Lin et al. (2012) [60]	Taiwan	407	0:407	*Of total sample (including non-shift workers)* = 29.9yrs.	Nurses	Rotating shift work	NR	**Sleep:** Pittsburgh Sleep Quality Index [64]	Average PSQI score	9.04±3.55[3]	—

McLaughlin et al. (2008) [55]	Canada	88	68:20	38.9 ± 9.2	Trade workers, Airport operations, Equipment operators,	Rotating shift work	3.98y	**Sleep:** Sleep quality and disturbance scale from Standard Shiftwork Index [61].	Subjective sleep disturbance (higher = increased disturbance)	T1 48.56 ± 9.26 T2 55.51 ± 12.7	↑
Pasqua et al. (2004) [54]	Brazil	28	28:0	32.8 ± 5.3	Repair workers	Fixed morning, afternoon or night work	NR	**Nutritional intake:** 3-day dietary record [68]	Daily calories by shift (kcal/24hrs)	Morning shift T1 2010 T2 2440 Afternoon shift T1 2285 T2 2790 Night shift T1 2053 T2 2395	Overall calorie intake (not by shift): ↑
Radoševic-Vidaček et al. (1995) [56]	Croatia	101	101:0	21.7 ± 1.1	Oil refinery workers	Rotating shift work	17mo	**Sleep:** Vidacek 1987 sleep quality scale [65] Self-report questionnaire	Subjective sleep duration over shift cycle (hours): Subjective sleep quality:	T1 7.87 T2 7.76 T3 7.61 T1 17.4 T2 17.1 T3 17.5	↓ ↓ — —
van Amelsvoort et al. (2004) [46]	Netherlands	159	88:71	26.8 [26.0–27.7]	Various	Rotating shift work	1 week - 2mo	**Physical activity:** Baecke (1982) habitual physical activity short questionnaire [66] **Nutritional intake:** Food frequency questionnaire [67]	PA during sport score: Leisure time PA score: Energy intake: Energy intake from fat (% of total energy intake): Cholesterol intake (mg/day):	T1 2.61 T2 2.52 T1 2.68 T2 2.62 T1 12,200(KJ/day) T2 11,719(KJ/day) T1 40.3 T2 39.8 T1 306.0 T2 292.2	— — — — —
West et al. (2007) [53]	Australia	37	9:28	[20–59] (59% between 20 and 24) *yrs.*	Nurses	Rotating shift work	6mo	**Sleep:** Sleep disturbance scale from Standard Shiftwork Index [61]	Sleep Disturbance scale by shift:	Morning T1 16.7 ± 3.1 T2 17.3 ± 3.7 Afternoon T1 14.6 ± 3.0 T2 15.1 ± 3.1 Night T1 20.6 ± 5.7 T2 20.9 ± 4.2 Off T1 12.2 ± 3.4 T2 12.5 ± 2.9	—

T1 = Time point 1 (baseline). T2 = Follow up 1, T3 = Follow up 2, T4 = Follow up 3, T5 = Follow up 4, T6 = Follow up 5.
↑ indicates significant increase, ↓ indicates significant decrease, — no significant change Results are reported in mean(standard deviation) where available. For studies that did not report mean, the most relevant outcome has been reported. Significant results denoted with an arrow indicate the direction of change (i.e., increase, decrease), not whether the change is positive for health. TST; total sleep time, PA; Physical activity.

[a] Contains details of other workers, where shift workers have been reported with non-eligible participants.

[b] Analysis included only participants who change between time points.

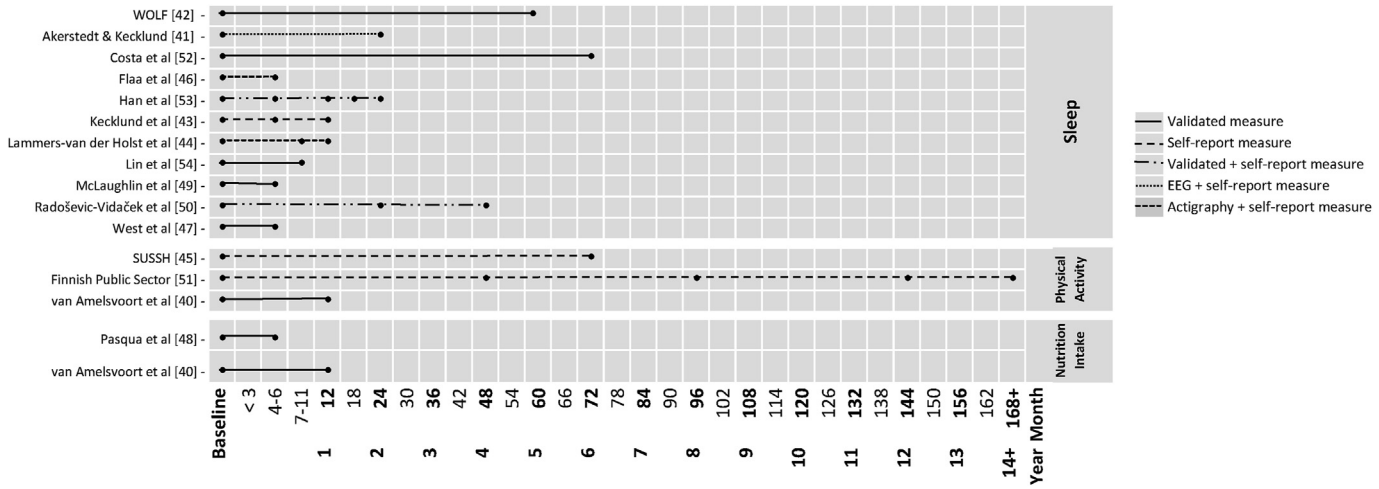

Fig. 2. Dot plot graph depicting an overview of frequency of data collection and individual study follow up times in longitudinal studies. This graph is grouped by outcome study type (sleep, physical activity and nutrition intake), first author/study name [citation] on the y-axis, and follow-up data collections from baseline through to final follow-up reported on the x-axis. Each dot denotes a data collection period. Type of data collection is represented by different density of line, with the figure key provided on the right hand side. Self-report measure includes self-report sleep diaries/logs. Studies appear multiple times if they report >1 of the health behaviours of interest, with data collection periods reported for specific health behaviour of interest (sleep, physical activity or nutritional intake).

Table 3
Summary of critical appraisal of included studies using CASP Cohort Checklist indicated by colour representation of relevant CASP item.

	Finnish Public Sector [51]	SUSSH [45]	WOLF [42]	Akerstedt & Kecklund [41]	Costa et al [52]	Flaa et al [46]	Han et al [53]	Kecklund et al [43]	Lammers-van der Holst et al [44]	Lin et al [54]	McLaughlin et al [49]	Pasqua et al [48]	Radoševic-Vidaček et al [50]	van Amelsvoort et al [40]	West et al [47]
Did the study address a clearly focused issue?	Y	Y	G	G	Y	G	G	G	G	G	G	G	G	G	G
Was the cohort recruited in an acceptable way?	Y	G	Y	G	Y	G	Y	Y	Y	G	Y	G	Y	R	Y
Was exposure accurately measured to minimise bias?	G	G	G	G	G	G	G	G	G	G	Y	G	Y	G	G
Was outcome accurately measured to minimise bias?	Y	R	R	G	Y	G	G	R	G	G	G	G	R	G	Y
Have the authors identified all important confounding factors?	G	G	G	R	R	R	R	R	G	G	R	R	R	G	R
Have they taken account of the confounding factors in the design and/or analysis?	G	G	Y	R	R	R	R	R	G	R	G	R	R	R	R
Was the follow up of subjects complete enough?	Y	G	Y	G	Y	G	G	R	G	Y	Y	R	R	G	R
Was the follow up of subjects long enough?	Y	Y	Y	Y	Y	Y	G	G	Y	Y	Y	Y	G	Y	Y
Do you believe the results?	G	G	Y	Y	Y	G	G	G	G	G	Y	G	G	Y	Y
Can the results be applied to the local population?	Y	R	Y	R	R	R	R	R	R	R	R	R	R	Y	Y
Do the results of the study fit with other available evidence?	G	Y	G	Y	Y	Y	G	G	G	G	G	G	G	Y	Y

CASP: Critical Appraisal Skills Program, Green: Yes, Yellow: Can't Tell, Red: N

used a single item response to gauge activity (n = 2), and one study utilised a validated measure, Baecke (1982) habitual physical activity short questionnaire [66] (n = 1) [46]. Both eligible nutritional intake studies utilised validated measures, specifically the Food Frequency Questionnaire [67] (n = 1) [46] and the 3-day dietary record [68] (n = 1) [54].

Quality of included studies

A summary of the quality of included studies is presented in Table 3. None of the included studies was considered "YES" for all CASP Cohort items. Common issues included a lack of identification of important confounders, a lack of accounting for confounding factors in design/analysis and application of results to population.

Further, many areas of study quality were scored "cannot tell" largely due to a lack of reporting in areas such as acceptability of recruitment of cohort, length of follow ups (specifically, what the target length of follow up should be for particular endpoints) and whether results could be believed. Overall, many studies were considered to address a clearly focused issue, and to measure exposure accurately to minimise bias.

Synthesis of results

Participant characteristics

The average age of participants within the studies ranged from 21.7 to 45.7yrs, noting that three studies reported age categorically and therefore could not be examined for average age [48,53,57]. Five studies had a majority male sample [46,48,50,52,55], while four studies had a majority female sample [51,53,57,59]. An additional five studies investigated a male only sample [47,49,54,56,58] and one study investigated females only [60]. Of the included studies 33% (n = 5) investigated healthcare workers, 33% (n = 5) investigated construction and/or trade workers. One study investigated transport workers, one study investigated public safety workers, two studies investigated various occupations and one study did not report this information. Of the included studies 53% (n = 8) were conducted in one workplace or worksite [47,49,52,54–56,58,59], 27% (n = 4) were conducted across different workplaces and occupations [46,48,51,57] and 20% (n = 3) were conducted with individuals in the same occupation, but across different workplaces [50,53,60]. None of the included studies examined health behaviours in shift workers utilising a population level study.

Shift work history

The average history in shift work employment at baseline ranged between one week to 13.3 years however a third of studies (n = 5) did not report shift work history [48,49,54,57,60]. Of the included studies 33% (n = 5) examined experienced shift workers with ≥2 years of shift work history (range 2–13.3yrs.) [47,51,52,55,58]. Another 33% (n = 5) examined inexperienced shift workers with <2 years of shift work history (range six weeks − 17 months) [46,50,53,56,59]. All of the studies of experienced workers (≥2 years shift work) only conducted one follow up: at six months [52,55], two years [47] or six years [51,58] post commencement of the study. Studies of inexperienced shift workers (<2 years shift work) conducted: one follow up at six months [53] or 12 months [46], two follow ups over one year [50] or four years [56] and four follow ups over five years [59]. Studies of experienced shift workers had a slightly older average age of between 31.5 and 49.1 years, while samples of inexperienced shift workers were somewhat younger with average age ranging between 29.9 and 41.2 years. As shown in Fig. 3, of the studies that report shift work experience, there is a tendency for samples of younger workers with less experience.

Sleep studies. Of the 11 studies with sleep outcomes, seven utilised a two data point design, with the single follow up taking place after six months [52,53,55,60], two years [47], five years [48] or six years [58] (Fig. 2). Three studies conducted two follow-ups at five and 12 months [49], nine and 16 months [50] and two and four years [56]. Finally, one study conducted four follow ups: at six months, 12 months, 18 months and 24 months [59].

Objective sleep duration

Of the studies that utilised objective measures, one study used 24 h EEG [47] and two studies utilised 24 h actigraphy for an average of 2.5 days [50] and three weeks [52]. All studies using objective measures recorded sleep over a 24-h period but did not report whether total sleep time was continuous or included napping. One study which utilised objective sleep measures in experienced papermill workers showed no significant change in sleep over two years [47]. However, sleep was below the recommended amount per 24 h for adults [19], with an average 5.2–5.8 h of sleep when working night shift rotation [47]. This was consistent with a study of experienced air ambulance pilots and crew which reported no significant change in objectively recorded sleep duration over six months [52]. However, average total sleep time was 5.8–6.0 h per night which is below recommended healthy durations for adults [19]. Finally, a study of early career police officers showed a significant decrease in objective sleep duration, as measured by actigraphy. These inexperienced police officers were sleeping on average 5.7 h per day at follow-up, compared to 6.1 h at baseline [50].

Subjective sleep duration

Studies of early career nurses (six weeks experience) showed that subjective sleep duration significantly increased between six weeks experience to six months experience and then remained stable [59]. It is important to note that this baseline assessment was conducted very soon after beginning shift work (~6 weeks) and thus, may have been influenced by an adjustment to shiftwork. Interestingly, the subjective sleep duration still remained below recommended daily levels [19] with average sleep duration being 6.4–6.7 h at follow ups, compared to 5.6 h at baseline. It is important to note that this baseline assessment was conducted very soon after beginning shift work (~6 weeks). Further, this study showed a significant increase in sleep latency which continued to increase over the first two years of shift work, with an average of >35 min to fall asleep at the two year follow-up [59]. Radoševic-Vidaček et al. found that male rotating shift workers with an average of 17 months shift work experience had a significant decrease in subjective sleep duration, from an average of 7.9 h at baseline to 7.6 h at four years [56]. One study of male bus drivers showed no significant change in sleep over a six year period, however average sleep when on early shifts remained insufficient (average 5.4 h). Finally, a study of male construction workers working double shifts showed a significant increase in reported self-report insufficient sleep over a one year period [49].

Subjective sleep quality and disturbance

A study of trade workers (77% male) with an average > 4 years shift work experience, showed a significant increase in sleep disturbance over six months [55]. In contrast, West et al.'s study of a less experienced worker group (~six months shift work experience) of Australian Nurses (76% female) found no significant change [53]. Lin et al. [60] found that subjective sleep quality of female nurses did not significantly change over 6 months. However, PSQI scores at both time points were above the cutoff for clinically poor sleep, suggesting sleep was already problematic at baseline [64]. In contrast, a study of inexperienced, majority female, nurses in Korea, found that the percentage of nurses reporting poor sleep at baseline (79.6%) decreased following a two year period (64.1%) [59].

A study of experienced male shift workers (n = 25) showed no significant differences in sleep quality over two years [47]. However, the measure used for sleep was not validated and thus interpretation of its relevance is difficult [47]. No significant changes in insomnia symptoms [49] over one year, and sleep quality over four years [56] were observed in male shift workers. Of note, the latter study was conducted in a sample of young workers (average age 22 years at baseline). This is consistent with the findings of a study of majority male, young (average age 27 years), police officers which found stable and relatively good sleep

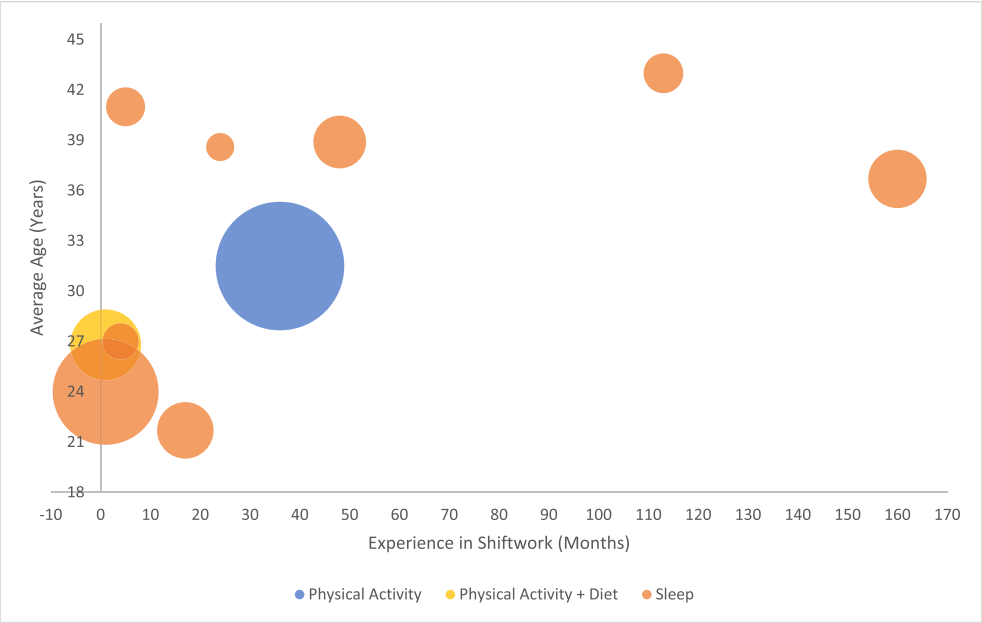

Fig. 3. Bubble graph representing the spread and size of studies which report average shift work experience and average shift worker age. Axes comprise average worker age (y-axis), and average shift work experience (x-axis). The bubbles represent sample size (range n = 25–355) and type of outcome (colour: sleep, orange; physical activity, blue; physical activity and diet, yellow).

quality over 16 months [50]. Finally a five year study with a relatively large sample (n = 913) of majority male (91%) Swedish workers showed that compared to baseline, 35% of shift workers report increased sleep difficulties and 40% report increased repeated awakenings at follow-up, however these changes were not significant [48].

Physical activity studies. Of the three eligible studies with physical activity endpoints, two studies utilised questionnaires which assessed hours of exercise [51] and physical activity [57] per week and the other study utilised a validated measure of physical activity level [46]. Two studies conducted one follow up: at one year [46] or six years [51]. One study, the Finnish Public Sector Study, reported five follow ups across 17 years [57] (Fig. 2).

The Finnish Public Sector Study showed that at baseline, between 14% and 19% of shift workers were classified as inactive. Longitudinal modelling showed that shift workers were increasingly physically inactive over time [57]. This was the only study to show statistically significant changes in physical activity. In contrast, no significant changes in physical activity (operationalised as >1 h "sweaty" exercise per week), were found in a study of nurses or early-career shift workers (operationalised as leisure time physical activity score) [46].

Nutritional intake studies. The two studies with nutritional intake outcomes utilised different but validated outcome measures. One study conducted a single follow up point at six months [54] and the other study conducted one follow up at 12 months [46] (Fig. 2). A study of shift workers early in their career in various occupations showed no significant differences in caloric intake, despite a slight decrease in average calories (- 115cal/day), fat (- 0.4%/*total energy intake*) and cholesterol (−13.8 mg/*day*) [46]. Finally, the study utilising a 3-day dietary record in male repair workers in Brazil, found that caloric intake significantly increased by 440 kcal/*day*, 505 kcal/*day*, 342 kcal/*day* for morning, afternoon and night shift respectively, over a six month period [54].

Summary of results. Of the included studies that examined sleep with objective methods (n = 3), all reported that shift workers achieved sleep durations which are shorter than minimum recommended sleep need, both at baseline and follow up [47,50,52]. However, one of these studies qualified that workers were meeting the minimum recommended sleep need during nocturnal sleep (i.e., when not working night shift) [47]. This is contrasted to worker-reported, subjective sleep measures. For example, one study found that despite a significant increase in sleep duration between baseline and six month follow up, shift workers did not meet the minimum sleep need [59]. Insufficient sleep was also reported in these workers at 12 and 24 month follow ups [59]. The discrepancies in objective and self-report measures of sleep are further demonstrated in one study in which workers self-reported meeting sleep needs (at both baseline and follow up) but according to objective measures, the same individuals were experiencing insufficient sleep [52]. However, one study did find a small, but significant, decrease in subjective sleep over four years (two follow up periods), but this was within recommended sleep durations at each time point (7:87 h, 7:76 h, 7:61hrs.) [56]. Finally, 25% (n = 1) of studies did not find a change in subjective sleep duration longitudinally, but on average sleep duration on early (5.35 ± 0:53hrs.) shifts was below recommendations [58]. On all other shifts (morning, afternoon, late and off) workers met minimum sleep recommendations [58]. Overall, most studies (n = 8) reported no significant longitudinal change in subjective sleep quality [47,48,50,53,56,58–60], and one study found a significant increase in poor sleep quality [55]. The absence of a significant change in sleep quality may in part be explained by more than half of the studies reporting overall poor sleep quality [48,53,55,59,60].

The majority (n = 2) of studies investigating physical activity did not find a longitudinal change [46,51]. However, one study found a significant increased risk of inactivity [57]. Differences in measures used for physical activity in most studies meant it was not possible to consider whether shift workers were meeting the physical activity guidelines. However, one study did report that 64% of shift

workers sampled were engaged in more than 1 h of 'sweaty' physical activity per week [51], which is similar to current physical activity guidelines [69].

Of the studies that examined nutritional intake in shift workers, one study found a significant increase in longitudinal overall calorie intake [54]. The other study found no significant longitudinal difference in calorie consumption, fat intake or cholesterol intake [46]. Despite no significant longitudinal change, the study found that shift workers were consuming more (39–40% of total intake) than the recommended amount of saturated fats (7–10% of total intake) [46].

Discussion

The present scoping review is the first known review to synthesise longitudinal investigations of sleep, physical activity and nutritional intake in shift workers following systematic search methods and using rigorous eligibility criteria in line with PRISMA Scoping Review requirements. The pertinent findings from this review suggest that shift workers are not obtaining adequate sleep, many are suffering poor sleep quality, some shift workers are physically inactive and emerging evidence suggests shift workers may consume too much saturated fat. When considered together, these findings indicate that shift workers may be at risk of poorer health behaviours throughout their career and providing some level of support for the possible casual pathway between shift work and poorer health behaviours.

Study findings and measures used by existing studies

Studies of sleep generally used validated measures, with a small number utilising objective measures and the remainder relying on participant self-report. Findings related to sleep duration, both objective and subjective, suggest that while sleep may remain stable for experienced shift workers, the duration of sleep per day is insufficient at all time points according to our existing knowledge of sleep need for adults [19]. When examining sleep duration in inexperienced shift workers (<2 years shift work), studies suggest a decrease in objective [50] and subjective sleep duration at follow-up [56]. When considering sleep quality, many studies reported no significant changes. However, studies often found generally poor sleep quality or frequent sleep disturbance from baseline, meaning that any changes were relative to already poor quality sleep. An exception appeared in studies of young male samples where sleep quality was reported to be within normal range. Importantly, only three studies of male samples met inclusion criteria and all utilised small sample sizes (between n = 25–108) in specific worker groups - papermill workers [47], police officers [50] and oil refinery workers [56]. Nonetheless, these findings are consistent with previous research that suggests young age and male sex may contribute to shift work tolerance [70].

In contrast to studies with sleep measures, the studies of physical activity included in this review had large sample sizes [51,57] and were conducted across various occupations and/or workplaces [46,51,57]. However, as only three studies met criteria for inclusion, with varied outcome measures utilised, the findings that shift workers in various occupations may become less physically active over time should be interpreted with caution. Further, two studies examining physical activity outcomes used dichotomised variables of minutes/hours exercise per week, which did not align with specified physical activity guidelines [51,57]. Together, these findings provide limited insight into physical activity behaviours of shift workers longitudinally. There is a need for future studies which utilise validated methods with clear interpretation guidelines to allow for understanding of physical activity in shift workers over time, both in inexperienced and experienced worker cohorts.

Our scoping review indicates limited and conflicting evidence in relatively small samples related to nutritional intake in both inexperienced (<2 years shift work) and experienced shift workers longitudinally. One study found that shift workers consumed considerably more saturated fat than dietary recommendations [46]. The available studies utilised very different measures of nutritional intake with one study [54] using a 3-day dietary record which asks individuals to report all they ate and drank for the past three days [68]. The other study [46] utilised a food frequency questionnaire, which assesses consumption of 104 food items over the past month [67]. Therefore, differences may arise from the measures used, as well as differences in the worker groups surveyed, as well as in the follow-up period.

Impact of prior experience with shift work

The present scoping review found that ~30% of the included studies (n = 5) investigated workers early in their career [46,50,53,56,59] and a further ~30% of studies (n = 5) investigated more experienced shift workers (≥2 years history of shift work) [47,51,52,55,58]. The remaining studies did not report shift work experience [48,49,54,57,60]. All studies of experienced shift workers only conducted one follow up. Therefore, the stability in these health behaviours may partly be explained by self-selection into shift work and selective attrition out of shift work [70,71], known as "healthy worker effect" [72]. It is also possible that studies of experienced shift workers were confounded by lapses of time between follow ups and thus, data was not collected frequently enough to see changes in health behaviours during the interval time period. If so, it would not be appropriate to conclude that there were no changes in health behaviours in shift workers more broadly – but rather, that those who remain in shift work and are responsive to data collection have more stable health behaviours over time. This is an important distinction when considering the health impacts of shift work, and requires considerable investment in future longitudinal studies, including accounting for shift work experience in study design and analysis. It will be important for future studies to clarify how baseline and follow-up samples differ in sociodemographic, occupational and other characteristics to better understand the changes in sample longitudinally.

Studies of inexperienced shift workers used more intensive data collection, conducting between one to four follow-ups. While studies of inexperienced shift workers are also vulnerable to selective occupational attribution, more frequent data collection allows more regular tracking of changes. The indication that early-career shift workers may be experiencing declines in sleep duration and poor sleep quality highlights a need for further investigation to inform interventions aimed at improving early adaptation to shift work. This is particularly important given younger workers are most represented in the 'inexperienced' workers (Fig. 3), and supporting their health and wellbeing during their working life needs to be a priority. It is also important to reiterate that ~30% of studies did not report shift work history, and there is a clear need to better understand how the early years of shift work can impact health behaviours [73].

When comparing studies with experienced vs inexperienced shift workers, there were differences in both study design and findings. This highlights a need for studies which aim to understand the relationship between exposure time to shift work and changes in health behaviours consistently in terms of measurement tools, and frequency of follow up.

Methodological limitations in longitudinal studies: few, and inconsistently spaced, follow ups

Overall this scoping review indicates that many studies of sleep only investigate baseline and one follow up either in the short term (~six months [52,53,55]) or with a longer lapse of time such as two years [47], five years [48] or six years [58]. Some sleep studies utilised more intensive data collection (i.e., more than one follow-up) [49,50,59], however this was within a total study length period of between one to two and half years. The longitudinal designs were also similar in physical activity studies, with two studies completing only one follow-up each, at one year [46] and six years [51]. One unique study of physical activity collected data at five time points for sixteen years [57]. Finally, studies of nutritional intake were also impacted by few follow ups, with both available studies collecting data at only two time points, one at six months post baseline [54] and the other at 12 months.

Currently, 'longitudinal' studies have examined health behaviours predominantly at two time points, either very close together or with a large lapse of time to follow up. The protocols are likely constrained by cost, as well as specific resources and staffing needs. Further, longitudinal studies are vulnerable to attrition which can impact planned data collection and sample sizes [71]. Further, it is also possible that only healthier shift workers, and those with better health behaviours, remain in the study and thus, the effects of shift work on health behaviours are underestimated [71]. Therefore, studies which utilise only two data points with large lapses of time may be impacted by this form of selective attrition, influencing our understanding of the true impact of shift work on health behaviours.

When considering lapses of time between measurements, it is not clear whether the follow up times in the current literature are based on any theoretical grounds, as is suggested for design of longitudinal studies [71]. It will be important for future studies to ensure that the length of time between data collection waves is sufficient to capture anticipated changes in health behaviours impacted by shiftwork, but not so long as to be impacted by selective attrition (either to the study or the occupation itself). It is also important to note that many of the studies, particularly those investigating sleep and nutritional intake, utilised convenience samples of specific occupations and/or workplaces. Sleep related issues are more prominent in certain occupations [74] and thus, this also impacts interpretability and generalisability of the current findings.

It is important to note that many of the studies included in this review did not appear to identify, or account for, important confounders in design or analysis. Future longitudinal studies should identify and account for these confounders, including those identified in this review (i.e., age, gender, shift work experience or occupation type). Critical appraisal also indicated that many studies failed to provide sufficient detail of recruitment strategy, and whether the length of follow ups was appropriate. It is necessary for future studies to be transparent in recruitment strategies, and, to provide a clear rationale for the time frame of follow up data collections.

Summary

The present review suggests that overall shift workers have stable but insufficient sleep at most time points. Further, many shift workers, particularly inexperienced shift workers, are experiencing poor sleep quality. Shift workers may be experiencing physical inactive and some poorer nutritional intake (i.e., high levels of saturated fat intake), however, these findings are based on very few available studies.

Sleep studies were the most well represented outcome in existing longitudinal studies of shift work and health behaviours. The literature on physical activity and nutritional intake is extremely limited. A limited number of studies investigated behavioural outcomes at more than one time point, and no study to date has examined all three behaviours concurrently. Further, many studies either assessed health behaviours over a relatively short time period, or had substantial time lapse between data collection points.

Studies in shift workers suggest sleep either stabilises over time, or extremely impacted workers select out of this work schedule – but higher quality, and larger, longitudinal studies are needed for confirmation and detailed analysis. Irrespective of attrition, it was clear that sleep remains insufficient and perceived to be of poor quality for many workers, even when experienced. Physical activity behaviours may decline with exposure to shift work, however it is possible that this could be influenced by normal aging effects. Finally, nutritional intake evidence is extremely limited in availability, meaning little is known about possible changes in nutritional intake over time for shift workers. Given that this is a potentially modifiable behaviour to support health, longitudinal examination of food intake warrants greater attention in future studies.

Limitations

The present scoping review must be considered in light of some limitations. Our review identified 15 studies which were eligible for inclusion. However, through the screening process multiple studies were examined which evaluated one or more of the outcomes of interest but did not meet the criteria necessary for inclusion, commonly due to reporting (e.g., shift workers were not reported separately to day workers). Thus, there are more longitudinal investigations in the field than were included in the review, but it is not possible to distinguish changes specific to shift workers independent of their day working counterparts. Although not eligible for the present review, these publications make important contributions to the field and as such a summary of the publications identified through full text screening but not eligible for inclusion is provided in Supplementary Table 4, with reasons for exclusion.

Many of the studies included in the present review did not provide the necessary detail to understand the potential impacts of shift work experience, or the average age of shift workers. Therefore, the findings regarding shift work experience, while important, are not representative of all studies included in the review. It is recommended that future longitudinal studies of shift workers consistently document experience (years) in shift work, and worker age, to more clearly establish where vulnerabilities to poor health behaviours emerge. This may also inform experience-specific intervention timepoints, or approaches, for use in this worker population.

A crucial limitation of existing studies, which is present in all naturalistic studies, is that authors cannot control for the healthy worker effect. Workers who are more likely to enter and remain in shift work may be engaged in better health behaviours. In addition, workers who do not cope with shifts and subsequently have poorer health behaviours may leave shift work. Therefore, it is important to acknowledge the potential for strength of the relationships between shift work and health behaviours to be underestimated.

Two authors independently screened full text articles, and two authors independently completed quality appraisal checks, while a single author conducted title and abstract screening. In future, including two authors in title and abstract screening may be beneficial. A final important limitation is that most of existing studies within this area were largely conducted in European

countries. Therefore, our understanding of any differences in health behaviours globally remains insufficient. Further studies across different countries will provide an understanding of any possible differences between countries.

Conclusion

Sleep duration is largely insufficient for shift workers, and workers experience long term poor sleep quality. Beyond this, the early career period appears a vulnerable timeframe for declines in sleep duration and increases in perceived poor sleep quality. Limited literature suggests shift workers are likely engaging in persistently insufficient physical activity and consuming considerably more than the recommended saturated fat intake.

The current review highlights a need for further investigation of health behaviours to identify pathways between shift work and increased chronic disease risk. In particular, a focus on physical activity and nutritional intake in shift workers over time is warranted.

Given the associations between sleep, physical activity and nutritional intake, and chronic disease, it is imperative that we understand how these behaviours change in shift workers, including quantification of their role in health outcomes. Addressing the gaps highlighted by this review will underpin the development of strategies to minimise the impact of shift work on health behaviours. These insights may assist workers to better cope with and sustain shift work with benefits for worker health and employment as well as for employers in retention and productivity. The findings from the present scoping review indicate a particular need for sleep strategies that support good sleep health in shift workers. A shared responsibility, with individual and occupational level strategies, should be the focus of investment [75,76].

Importantly, the present scoping review indicates a crucial need for studies of shift workers with multiple health behaviour outcomes, across a period longer than 6 months with more frequent data collection points. Future studies of physical activity and nutritional intake should aim to utilise validated and comparable measures of behaviour to ensure useful interpretation of findings, and comparisons with existing literature. Undertaking longitudinal studies is costly, time and resource intensive, and requires clear engagement strategies to ensure continued participation of study participants which make these studies challenging to initiate and sustain. However, the information generated from such longitudinal studies is key to address the gaps highlighted in this review, and provide significant understanding of the pathway between shift work and increased health risk.

Practice points

1) Longitudinal studies suggest that sleep duration is consistently insufficient for shift workers
2) Early career shift work in particular is associated with decreases in sleep duration and increased poor sleep quality
3) There is some limited evidence that shift workers may be physical inactive and have some poor nutritional intakes (i.e., excessive saturated fat consumption) in shift workers over time
4) These findings indicate that health behavioural strategies and interventions, at individual or organisational levels, may be warranted for shift workers

Research agenda

1) There is a need for longitudinal studies which examine multiple health behaviours, particularly physical activity and nutritional intake, in shift workers
2) Future studies should conduct regular follow-ups, ideally from early career, over a long period of time
3) Future longitudinal studies should utilise consistent measures of sleep, physical activity and nutritional intake in shift workers to facilitate comparisons over time, and between different worker groups in different countries and occupations.

Conflicts of interest

The authors do not have any conflicts of interest to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2022.101612.

References

[1] Eurofound. Sixth European working conditions survey – overview report. 2017.
[2] McMenamin T. Time to work: recent trends in shift work and flexible schedules. Mon Labor Rev 2007;130:3–15.
[3] Australian Bureau of Statistics (ABS). Working time arrangements. November 2009. Australia.
*[4] Kecklund G, Axelsson J. Health consequences of shift work and insufficient sleep. BMJ 2016;355:i5210.
[5] Costa G. The 24-hour society between myth and reality. J Hum Ergol 2002;30:15–20.
[6] Torquati L, Mielke GI, Brown WJ, Kolbe-Alexander T. Shift work and the risk of cardiovascular disease. A systematic review and meta-analysis including dose-response relationship. Scand J Work Environ Health 2018;44(3):229–38.
[7] Vyas MV, Garg AX, Iansavichus AV, Costella J, Donner A, Laugsand LE, et al. Shift work and vascular events: systematic review and meta-analysis. BMJ 2012;345:e4800.
[8] Wang F, Zhang L, Zhang Y, Zhang B, He Y, Xie S, et al. Meta-analysis on night shift work and risk of metabolic syndrome. Obes Rev 2014;15(9):709–20.
[9] Mancio J, Leal C, Ferreira M, Norton P, Lunet N. Does the association of prostate cancer with night-shift work differ according to rotating vs. fixed schedule? A systematic review and meta-analysis. Prostate Cancer Prostatic Dis 2018;21(3):337–44.
[10] Lin X, Chen W, Wei F, Ying M, Wei W, Xie X. Night-shift work increases morbidity of breast cancer and all-cause mortality: a meta-analysis of 16 prospective cohort studies. Sleep Med 2015;16(11):1381–7.
[11] Dorrian J, Skinner N. Alcohol consumption patterns of shiftworkers compared with dayworkers. Chronobiol Int 2012;29(5):610–8.
*[12] Knauth P, Hornberger S. Preventive and compensatory measures for shift workers. Occup Med (Lond) 2003;53(2):109–16.
*[13] Short SE, Mollborn S. Social determinants and health behaviors: conceptual frames and empirical advances. Curr Opin Psychol 2015;5:78–84.
[14] Danaei G, Ding EL, Mozaffarian D, Taylor B, Rehm J, Murray CJL, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. PLoS Med 2009;6:e1000058.
[15] Gallicchio L, Kalesan B. Sleep duration and mortality: a systematic review and meta-analysis. J Sleep Res 2009;18:148–58.

* The most important references are denoted by an asterisk.

[16] Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies. Sleep 2010;33:585–92.
[17] Oftedal S, Vandelanotte C, Duncan MJ. Patterns of diet, physical activity, sitting and sleep are associated with socio-demographic, behavioural, and health-risk indicators in adults. Int J Environ 2019;16:2375.
[18] Siegel JM. Clues to the functions of mammalian sleep. Nature 2005;437:1264–71.
*[19] Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. Sleep Health 2015;1(1):40–3.
[20] Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Publ Health Rep 1985;100:126–31.
[21] Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, et al. Defining and setting national goals for cardiovascular health promotion and disease Reduction. Circulation 2010;121:586–613.
[22] Carlson SA, Adams EK, Yang Z, Fulton JE. Percentage of deaths associated with inadequate physical activity in the United States. Prev Chronic Dis 2018;15:E38.
[23] Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012;380:219–29.
[24] National Health and Medical Research Council. Nutrient reference values for Australia and New Zealand : including recommended dietary intakes. Canberra, Australia. Avaliable form, https://www.nhmrc.gov.au/about-us/publications/nutrient-reference-values-australia-and-new-zealand-including-recommended-dietary-intakes; 2006.
[25] Howard BV, Wylie-Rosett J. Sugar and cardiovascular disease. Circulation 2002;106:523–7.
[26] Hill JO, Wyatt HR, Peters JC. Energy balance and obesity. Circulation 2012;126:126–32.
[27] Casas-Agustench P, Arnett DK, Smith CE, Lai C-Q, Parnell LD, Borecki IB, et al. Saturated fat intake modulates the association between an obesity genetic risk score and Body Mass Index in two US populations. J Acad Nutr Diet 2014;114:1954–66.
[28] Mokdad AH, Remington PL. Measuring health behaviors in populations. Prev Chronic Dis 2010;7(4). A75-A.a Ding D, Rogers K, Van Der Ploeg H, Stamatakis E, Bauman AE. Traditional and emerging lifestyle risk behaviors and all-cause mortality in middle-aged and older adults: evidence from a large population-based Australian cohort. PLoS Med 2015;12:e1001917.
[29] Mellow ML, Crozier AJ, Dumuid D, Wade AT, Goldsworthy MR, Dorrian J, et al. How are combinations of physical activity, sedentary behaviour and sleep related to cognitive function in older adults? A systematic review. Exp Gerontol 2022;159:111698.
[30] Al Khatib HK, Harding SV, Darzi J, Pot GK. The effects of partial sleep deprivation on energy balance: a systematic review and meta-analysis. Eur J Clin Nutr 2017;71:614–24.
[31] Kredlow MA, Capozzoli MC, Hearon BA, Calkins AW, Otto MW. The effects of physical activity on sleep: a meta-analytic review. J Behav Med 2015;38:427–49.
[32] Oftedal S, Rayward AT, Fenton S, Duncan MJ. Sleep, diet, activity, and incident poor self-rated health: a population-based cohort study. Health Psychol 2021;40:252–62.
[33] Dulloo AG, Miles-Chan JL, Montani JP. Nutrition, movement and sleep behaviours: their interactions in pathways to obesity and cardiometabolic diseases. Obes Rev 2017;18(Suppl 1):3–6.
[34] Mokdad AH, Remington PL. Measuring health behaviors in populations. Prev Chronic Dis 2010;7:A75-A.
[35] Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol 2005;8(1):19–32.
[36] Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol 2018;18:1–7.
[37] Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci 2010;5(1):69.
*[38] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med 2018;169(7):467–73.
[39] Bonham MP, Leung GKW, Davis R, Sletten TL, Murgia C, Young MJ, et al. Does modifying the timing of meal intake improve cardiovascular risk factors? Protocol of an Australian pilot intervention in night shift workers with abdominal obesity. BMJ Open 2018;8:e020396.
[40] Mohd Azmi NAS, Juliana N, Mohd Fahmi Teng NI, Azmani S, Das S, Effendy N. Consequences of circadian disruption in shift workers on chrononutrition and their psychosocial well-being. Int J Environ 2020;17:2043.
[41] Bramer WM, Rethlefsen ML, Kleijnen J, Franco OH. Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study. Syst Rev 2017;6:1–12.
[42] EndNote X9. Philadelphia, PA: Clarivate; 2013.
[43] Huwaldt JA, Steinhorst S. PlotDigitizer. 2015. 2.6.8.
[44] McKenzie JEBS, Ryan RE, Thomson HJ, Johnston RV. Chapter 9: summarizing study characteristics and preparing for synthesis. In: Higgins JPTTJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, editors. Cochrane Handbook for systematic Reviews of interventions. 62nd edititon 2021.
[45] Critical apprasial skills programme (cohort study) checklist [online], https://casp-uk.net/wp-content/uploads/2018/01/CASP-Cohort-Study-Checklist_2018.pdf; 2018.
[46] Van Amelsvoort LGPM, Schouten EG, Kok FJ. Impact of one year of shift work on cardiovascular disease risk factors. J Occup Environ Med 2004;46(7):699–706.
[47] Akerstedt T, Kecklund G. Stability of day and night sleep-a two-year follow-up of EEG parameters in three-shift workers. Sleep 1991;14(6):507–10.
[48] Akerstedt T, Nordin M, Alfredsson L, Westerholm P, Kecklund G. Sleep and sleepiness: impact of entering or leaving shiftwork–a prospective study. Chronobiol Int 2010;27(5):987–96.
[49] Kecklund G, Ekstedt M, Akerstedt T, Dahlgren A, Samuelson B. The effects of double-shifts (15.5 hours) on sleep, fatigue and health. J Hum Ergol 2001;30:53–8.
[50] Lammers-van der Holst HM, Van Dongen HPA, Drosopoulos S, Kerkhof GA. Inter-individual differences in sleep response to shift work in novice police officers–A prospective study. Chronobiol Int 2016;33(6):671–7.
[51] Buchvold HV, Pallesen S, Waage S, Moen BE, Bjorvatn B. Shift work and lifestyle factors: a 6-year follow-up study among nurses. Front Public Health 2019;7:281.
[52] Flaa TA, Bjorvatn B, Pallesen S, Røislien J, Zakariassen E, Harris A, et al. Subjective and objective sleep among air ambulance personnel. Chronobiol Int 2021;38(1):129–39.
[53] West SH, Ahern M, Byrnes M, Kwanten L. New graduate nurses adaptation to shift work: can we help? Collegian 2007;14(1):23–30.
[54] Pasqua IC, Moreno CRC. The nutritional status and eating habits of shift workers: a chronobiological approach. Chronobiol Int 2004;21(6):949–60.
[55] McLaughlin C, Bowman ML, Bradley CL, Mistlberger RE. A prospective study of seasonal variation in shirt-work tolerance. Chronobiol Int 2008;25(2):455–70.
[56] Radošević-Vidaček B, Vidaček S, Kaliterna L, Prizmić Z. Sleep and napping in young shiftworkers: a 5-year follow-up. Work Stress 1995;9(2–3):272–80.
[57] Cheng WJ, Härmä M, Ropponen A, Karhula K, Koskinen A, Oksanen T. Shift work and physical inactivity: findings from the Finnish Public Sector Study with objective working hour data. Scand J Work Environ Health 2020;46(3):293–301.
[58] Costa G, Sartori S, Facco P, Apostoli P. Health conditions of bus drivers in a 6 year follow up study. J Hum Ergol 2001;30(1–2):405–10.
[59] Han K, Kim Y-H, Lee HY, Cho H, Jung YS. Changes in health behaviours and health status of novice nurses during the first 2 years of work. J Adv Nurs 2019;75(8):1648–56.
[60] Lin PC, Chen CH, Pan SM, Pan CH, Chen CJ, Chen YM, et al. Atypical work schedules are associated with poor sleep quality and mental health in Taiwan female nurses. Int Arch Occup 2012;85(8):877–84.
[61] Barton J, Spelten E, Totterdell P, Smith L, Folkard S, Costa G. The Standard Shiftwork Index: a battery of questionnaires for assessing shiftwork-related problems. Work Stress 1995;9(1):4–30.
[62] Nordin M, Åkerstedt T, Nordin S. Psychometric evaluation and normative data for the Karolinska sleep questionnaire. Sleep Biol Rhythm 2013;11(4):216–26.
[63] Choi H, Kim S, Kim B, Kim I. Korean versions of self-reported sleep questionnaires for research and practice on sleep disturbance. Kor J Rehabil Nurs 2012;15(1):1–10.
[64] Buysse DJ, Reynolds 3rd CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatr Res 1989;28(2):193–213.
[65] Vidaeek S, Radosevi-Vidaeek B, Katliterna LJ. Predictive validity of individual difference measures for sleep problems in shift workers: preliminary result. In: Orginski A, Pokorsk J, Rutenfraz J, editors. Contemporary advances in shiftwork research. Medical Acamedy Krakow; 1987. p. 277–85.
[66] Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. Am J Clin Nutr 1982;36(5):936–42.
[67] Feunekes IJ, Van Staveren WA, Graveland F, De Vos J, Burema J. Reproducibility of a semiquantitative food frequency questionnaire to assess the intake of fats and cholesterol in The Netherlands. Int J Food Sci Nutr 1995;46(2):117–23.
[68] Witschi JC. Short-term dietary recall and recording methods. In: Willett W, editor. Nutritional epidemiology. 2nd ed. New York: Oxford University Press; 1998. p. 53–68. 1998.
[69] Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The physical activity guidelines for Americans. JAMA 2018;320:2020–8.
[70] Saksvik IB, Bjorvatn B, Hetland H, Sandal GM, Pallesen S. Individual differences in tolerance to shift work – a systematic review. Sleep Med Rev 2011;15(4):221–35.

*[71] Taris TW, Kompier M. Challenges in longitudinal designs in occupational health psychology. Scand J Work Environ Health 2003;1:1–4.
*[72] Härmä M, Gustavsson P, Kolstad HA. Shift work and cardiovascular disease – do the new studies add to our knowledge? Scand J Work Environ Health 2018;44(3):225–8.
[73] Reynolds AC, Crowther ME, Ferguson SA, Paterson JL, Howie C, Adams RJ. Protecting the health and safety of the paramedic workforce in Australia: the role of cohort studies with new recruits. Emerg Med Australasia (EMA) 2021;33:935–7.
[74] Reynolds AC, Ferguson SA, Appleton SL, Crowther ME, Melaku YA, Gill TK, et al. Prevalence of probable shift work disorder in non-standard work schedules and associations with sleep, health and safety outcomes: a cross-sectional analysis. Nat Sci Sleep 2021;13:683–93.
[75] Gander P, Hartley L, Powell D, Cabon P, Hitchcock E, Mills A, et al. Fatigue risk management: organizational factors at the regulatory and industry/company level. Accid Anal Prev 2011;43:573–90.
[76] Lerman SE, Eskin E, Flower DJC, George EC, Gerson B, Hartenbaum NP, et al. Fatigue risk management in the workplace. J Occup Environ 2012;54:231–58.