



Review

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The effects of shift work on body weight change – a systematic review of longitudinal studies

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The effects of shift work on body weight change – a systematic review of longitudinal studies

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Objective This systematic review aims to summarize the available evidence to elucidate the effects of shift work, which includes night work, on body weight change.

Methods A systematic search strategy using longitudinal studies was performed. Articles were included based on strict inclusion criteria; methodological quality was assessed by a standardized quality checklist. The results were summarized using a levels of evidence synthesis.

Results The search strategy resulted in eight articles that met the inclusion criteria. Five of them were considered to be high- and three of them low-quality studies. Seven studies presented crude results for an association between shift work exposure and change in body weight: five high- and two low-quality studies. There was strong evidence for a crude relationship between shift work and body weight increase. Five studies presented weight-related outcomes adjusted for potentially relevant confounders (age, gender, bodyweight at baseline, and physical activity). Two studies found a significant difference between groups in the same direction. Consequently, the evidence for a confounders-adjusted relationship between shift work exposure and body weight was considered to be insufficient.

Conclusions Strong evidence for a crude association between shift work exposure and body weight increase was found. In order to further clarify the underlying mechanisms, more and better high quality studies about this subject are necessary.

Key terms body weight changes; cohort studies; irregular working hours.

Due to the 24/7 economy, the number of jobs including shift work and irregular working hours has increased substantially during the last decades. Up to an estimated 20% of European workers are thought to be exposed to shift work schedules that include time spent working at night (1). A recent report of the European Working Conditions Survey (2) indicates that this proportion has stabilized during the last ten years. In the Netherlands, more than 20% of the working population report that they work in shifts, while approximately 50% report occasional work during the evening or night (3). An overview article by Costa (4) stated that only 24% of the workforce still has a regular daytime, Monday–Friday working week.

A large amount of research has been published concerning the health effects of shift work. This research shows that, although the pathways are unclear, shift schedules including nightly hours are probably related to gastrointestinal and cardiovascular diseases (1, 5–9). Further, this kind of work is thought to be associated with an increased risk for several types of cancer (10–13).

Shift work including night work has also been found to be associated with diabetes and metabolic disturbances, but the evidence is not conclusive (6, 14, 15). However, recent longitudinal studies showed significantly increased risks for the metabolic syndrome among shift and night healthcare workers (16, 17). Still, the underlying mechanisms for the onset of metabolic health problems as a

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result of shift work are not yet clear. Possible mediators are reduced sleep and physical activity, changed eating habits and patterns, and an altered circadian rhythm (18–20). Weight gain, being overweight, or obesity might be the mediating factor between shift work and metabolic disturbances, which can eventually result in diabetes or cardiovascular diseases (1, 5).

Overweight and obesity are major healthcare problems for today's society. As an indirect result of the population getting heavier, healthcare costs are thought to be increasing. Estimates vary from 1–7% of the total healthcare cost in the developed world, and the amount of indirect costs due to loss of productivity and disability pensions might be even higher (21). It has been shown that overweight and obesity lead to an elevated risk of some forms of cancer, cardiovascular and digestive diseases, diabetes mellitus, sleep apnoea, and osteoarthritis (22, 23). In a large cohort study for example, Colditz et al (24) showed that body mass index (BMI) is a main predictor for the onset of diabetes. In a recent review, it was found that due to obesity, the all-cause mortality is increased by approximately 20% (25).

In recent years, several studies have investigated the association between shift work and weight gain, overweight, or obesity (26–31). Several of them have demonstrated a significant relation between working in shifts and body weight or obesity (26–29), while some others did not (30, 31). Most of these studies, however, had a cross-sectional design and thereby failed to determine a clear causal relationship between shift work and body weight change. Longitudinal research would be able to give more insight into the working mechanisms of this relationship and results could be used in efficient worksite prevention. This could eventually lead to a reduced risk for various kinds of diseases and a smaller burden on healthcare costs.

To date, no systematic review has been published about the effects of shift work on body weight. This review aims to summarize the available evidence and thereby elucidate the relationship between exposure to shift work, which includes night work, and body weight change. A systematic literature search, selection and quality assessment has been performed. In order to be able to find indications for causality, only longitudinal studies are included.

Methods

Search strategy

The literature search aimed to identify relevant peer-reviewed studies providing information about change in body weight as a consequence of shift work. The review was based on publications retrieved via a computerized

search of the following databases: Medline, Embase, the Cochrane library, and PsycINFO. The databases were searched for published articles up to 18 June 2010. The search terms included were: work schedule tolerance (Mesh), shift work, night work, irregular working hours, body weights and measures (Mesh), body weight changes (Mesh), BMI and body mass. After inclusion of the articles based on the selection criteria below, references were checked for additional articles. The full Medline search strategy can be seen in the Appendix, the search strategies for the other databases were based on this strategy.

Selection criteria

The retrieved abstracts were checked to ensure they met the following criteria: (i) the study was a fulltext, peer-reviewed article in written English, Dutch, German, French, Spanish, or Italian; (ii) the study compared a group of shift workers with a control group of day workers. Working at night (24.00–06.00 was part of the shift work exposure; (iii) the study had a longitudinal design: either prospective or retrospective; (iv) the outcome included: body weight, BMI, waist-to-hip ratio or waist circumference. At least two measurements of the outcome were provided or the difference between outcome measurements was presented; and (v) the study presented the association between shift and day work and an outcome related to body weight, or this association could be calculated by the authors.

Two reviewers read all the abstracts independently. If no abstract was available or if it was not clear whether the article should be included based on the title or abstract, the fulltext article was read. Articles were included if they met all five inclusion criteria. If consensus between the two reviewers could not be reached, a third reviewer made a final decision.

Quality assessment

Differences in methodological quality across studies indicate that the results of some studies are more likely to be affected by bias than others, making it important to take the quality of a study into account. Two reviewers independently assessed the quality of each included study. A standardized checklist of predefined criteria was used, which was a modified version of the checklists of Hayden et al (32) and Van der Windt et al (33) (table 1). Each item was scored as positive (+) or negative (- = potential bias). If the paper provided insufficient information on the specific item, the item was scored with a question mark (? = don't know). If an item was not applicable, it was scored as such (NA). Disagreements between the reviewers on individual items were identified and solved during a consensus meeting.

Subsequently, the first author of each included article with a quality item that had scored a question mark was contacted in order to provide the author an opportunity to clarify that quality item of their article.

Eventually, for each study, a total quality score was calculated by counting the number of items that were rated positively. This number was divided by the total number of applicable items of the study. Based on this total score, a study was classified as being either a high- or low-quality study. A study was classified as high quality if it scored positively on at least 51% of the applicable items in the quality assessment list; otherwise, a study was classified as being of low quality. High-quality studies were considered to have an overall low risk of bias, while the low-quality studies have a high risk of bias. This is in accordance with previously published systematic reviews (21, 33–35).

Data extraction

Details about the following elements were extracted and tabulated from the publications: study population, sample size, response rate, study design, follow-up duration, exposure, controlled confounders, outcome measurement, results without adjustment for confounders, results with adjustment for confounders, and overall conclusion. The associations between exposure to shift work and body weight outcome were presented as the mean differences in outcome between baseline and follow-up. If possible, the 95% confidence intervals (95% CI) were calculated and presented as well.

The first author of the included article was contacted to provide additional information if calculation of the adjusted mean difference or P-value was not possible.

Analysis

Results of the studies were analyzed and, where possible, a statistical meta-analysis was performed. To gain insight into factors interfering with the relationship between shift work and body weight change, crude and adjusted results were analyzed separately.

To summarize the results, and thereby draw conclusions about the relationship, a levels of evidence synthesis was used. This synthesis took into account the methodological quality and the outcomes of the selected studies. It was applied to both the crude and adjusted weight-related outcomes of the studies. The three levels used were based on Hoogendoorn et al (34) and Sackett et al (36): (i) strong evidence: consistent findings in multiple high quality cohort studies; (ii) moderate evidence: consistent findings in one high-quality cohort study and in one or more low-quality cohort studies; (iii) insufficient evidence: only one study available or inconsistent findings in multiple cohort studies. Findings

Table 1. Checklist of methodological quality [based on Hayden et al (32) and Van der Windt et al (33)].

Study objective	
1	Positive if a specific, clearly stated objective is described.
Study population	
2	Positive if the main features of the study population are clearly described (sampling frame and distribution of the study population by age and gender).
3	Positive if the inclusion and exclusion criteria are clearly described.
4	Positive if the participation rate is $\geq 80\%$, or if it is lower, the non-response is not selective (data presented).
5	Positive if the response rate (proportion completing the study and providing outcome data) is $\geq 80\%$ or if the non-response is not selective (data presented).
6	Positive if information (potential confounders and outcomes) is presented about the population lost to follow-up.
Exposure assessment	
7	Positive if the characteristics of shift work are clearly described (type of work and shift schedules).
8	Positive if data are collected and presented about occupational exposure in the past and during the follow-up period.
Confounder assessment	
9	Positive if the most important confounders (age, gender, body weight at baseline, physical activity) are measured and used in the analysis for body weight outcome.
10	Positive if confounders are measured the same for all participants using standardized methods of acceptable quality.
Outcome assessment	
11	Positive if body weight is measured the same for all participants using a standardized method of physical examination.
12	Positive if data were collected for ≥ 1 year.
Analysis and data presentation	
13	Positive if the appropriate statistical model is used to evaluate the data.
14	Positive if mean differences in body weight outcome are presented or can be calculated (including 95% confidence interval).

were considered consistent if $\geq 75\%$ of the selected cohort studies showed significant ($P < 0.05$) results in the same direction.

Results

Study selection

The results of the selection procedure are presented in figure 1. The search strategy resulted in 1047 citations (571 PubMed, 291 Embase, 160 Cochrane, and 25 PsychINFO). After excluding the duplications, 839 titles and abstracts were examined. Out of these, 65 fulltexts were selected for further investigation. Seven articles met all inclusion criteria. The references of these articles were checked and this resulted in one additional article. The percentage agreement between the two reviewers was 95%. Initial disagreement about 3 of the 65 studies (resulting in a Cohen's κ of 0.86)

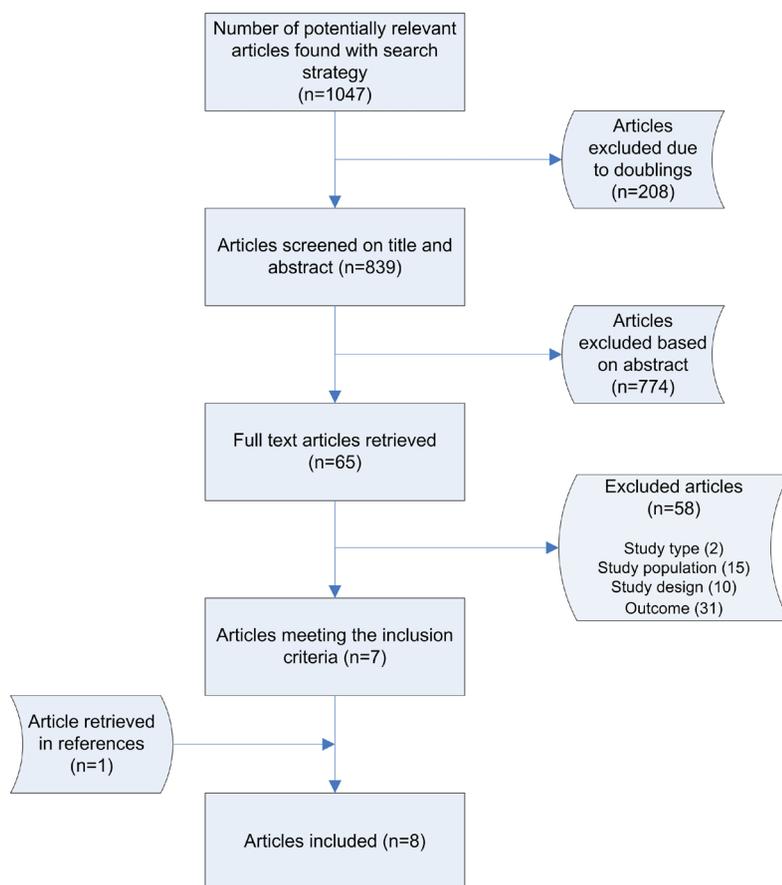


Figure 1. Result of the selection procedure.

was resolved in a consensus meeting. The most frequent reason for exclusion was the fact that the studies did not measure a change in body weight or another appropriate outcome. Many studies did measure body weight or BMI multiple times, but only used the baseline measurement as a confounder or covariate for their specific outcome. Therefore, change in weight outcome was not presented or could not be calculated.

Methodological quality assessment

The outcome of the quality assessment is presented in table 2. The scoring of the quality items by the two reviewers resulted in an initial agreement of 75% (Cohen's κ of 0.56). All disagreements between the two reviewers were resolved in a consensus meeting. Two out of six authors replied to our invitation to clarify the methodological quality of their article. As a result, two unclear items (?) were changed into positive (+). Eventually, five out of eight articles were considered to be high-quality studies.

Study characteristics

Large differences existed between the studies. Especially the kind of shift work exposure, population, sample size,

and duration of follow-up differed substantially. For this reason, no overall meta-analysis was performed on the outcome data. The characteristics of the eight studies included in this review are presented in table 3.

Study design. Six studies had a prospective design (37–42), and two retrospective studies were included (43, 44). The follow-up periods of the prospective studies ranged from 12 months (40) to 14 years (37). In the retrospective studies, data were obtained from the start of the participants' employment in the job (43, 44).

Population. Four studies reported findings from a population of nurses (39–41, 43). In addition to nurses, Geliebter et al (43) included security personnel, while Van Amelsvoort et al (40) included a mixture of nurses and factory personnel. Three studies reported about male factory personnel only (37, 38, 44). Hannerz et al (42) used a random nationwide sample. In their study, a male sample from the Central Population Register of Denmark was studied and participants with poor self-rated health at baseline were excluded.

The number of participants in the selected studies ranged from 55 (41) to 7.254 (37). The latter, Suwazono et al (37), did not report a drop-out rate for the 14 years of follow-up, while Copertaro et al (41) did not report any

Table 2. Results of the methodological quality assessment. [+ = positive; - = negative; ? = unclear or insufficient information; NA = not applicable.]

Study	Methodological items														Total score	Total %	Quality
	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Suwazono et al (37)	+	+	+	+	+ ^a	-	+	-	+	?	+	+	+	+ ^a	11/14	79	High
Morikawa et al (38)	+	?	-	?	+	-	+	+	+	+	-	+	+	+	9/14	64	High
Niedhammer et al (39)	+	+	-	-	-	+	+	+	+	+	+	+	+	?	9/14	64	High
Geliebter et al (43)	+	+	+	+	NA	NA	+	-	-	?	-	-	+	+	7/12	58	High
van Amelsvoort et al (40)	+	+	+	-	-	-	+	-	-	+	+	+	+	-	8/14	57	High
Copertaro et al (41)	+	+	+	?	?	?	+	+	-	?	?	+	+	-	7/14	50	Low
Hannerz et al (42)	-	+	-	+	-	-	-	-	+	+	-	+	+	+	7/14	50	Low
Romon et al (44)	+	+	-	-	NA	NA	+	-	-	?	-	?	+	-	4/12	33	Low

^a Item changed into “+” due to supplied information by the author.

loss to follow-up during 18 months. Van Amelsvoort et al (40) retained 70% of their initial sample after 12 months. Morikawa et al (38) lost 16% during 10 years. Hannerz et al (42) lost 18% to follow-up in five years, while Niedhammer et al (39) lost 5% in 1985 and 16% in 1990.

Exposure. The authors of the selected studies used different definitions for shift, night, and day work. A summary of the exposure characteristics is presented in table 4. The working hours of the experimental groups in some studies consisted of three different shifts (morning, evening, and night) with a continuous (covering the whole week) rotating system (37, 41). However, other studies included participants with both two- and three-shift systems (38), participants exposed to both continuous and non-continuous (covering only week days) systems (44), and counterclockwise shift systems (38, 40). Furthermore, some studies included nurses with permanent night (39, 43) or evening (43) work. The exposure in these two latter studies shows the profound differences between studies because another study excluded all participants with fixed, permanent night work (37).

Differences in day work definitions were present as well. The control group of three studies worked between approximately 07.00–17.30 (42–44). Other studies did not give any specifications of the daytime working hours (37, 38, 40), while participants in the control group of some other studies worked on morning or evening shifts themselves (table 4) (39, 41).

Outcome measurement. Different outcome measures for body weight change were used. Several studies measured body weight and calculated it in kilograms of body weight change (39, 43, 44). Others obtained body weight and body height and converted this into BMI and BMI change (37, 38, 42). Copertaro et al (41) reported a change in mean waist circumference. Van Amelsvoort et al (40) were the only authors that, in addition to change in body weight and BMI, presented waist-to-hip ratio as well.

Secondly, there was a difference in the way the outcome was measured. In six of eight studies, qualified people (eg, physicians) measured the body weight related outcomes (37–41, 44). Two studies based their outcomes on self-reported body weight changes provided by the participants (42, 43).

Confounding. The different studies measured a wide variety of potential confounders. These confounders however, were not always used in the analyses to adjust the body weight-related outcomes (table 3).

Outcomes

The unadjusted and adjusted results on body-weight-related outcome of the eight included articles are presented in table 5. Two articles provided sufficient information about the outcome (42, 44), while mean values could be calculated in two other studies (38, 43). Four first authors were contacted by email and asked to provide additional data for adjusted mean difference or P-value calculation. One author did not respond (41), another did, but could not reproduce the data (39). Van Amelsvoort (40) provided data about the adjusted difference in several outcomes between groups. Suwazono (37) provided data about the mean percentual BMI change for both groups. However, the author reported that due to job schedule type changes, this mean change was only available for a one-year period from baseline (while the follow-up period of the study was 14 years).

Associations between shift work and body weight change, crude results. Seven out of the eight studies presented crude, non-adjusted outcomes of type of work and body weight change: five high- and two low-quality studies. The five high-quality studies (37–40, 43) found a significant difference between the groups. Morikawa et al (37) and Suwazono et al (38) found more body weight-related change for shift workers in a male Japanese population, while Niedhammer et al (39) and Geliebter et al

Table 3. Study characteristics. [BMI=body mass index; NA=not available]

Study	Quality score	Study population	Sample size	Response rate	Study design	Follow-up time	Exposure	Controlled confounders	Outcome measurement
Suwazono et al (37)	79%	Japanese male workers at a steel company	N=7254: 2926 alternating shift; 4328 day shift	NA	Prospective study on the effect of shift work on weight gain	14 years	Day shifts: no hours reported. Alternating: shifts starting at either 07.00, 15.00 or 23.00	Age, BMI measured during the study, drinking, smoking, and regular exercise	BMI obtained by annual health examination was calculated into the percentage BMI increase relative to BMI at job entry
Morikawa et al (38)	64%	Japanese male blue-collar workers at a sash and zipper factory	N=1144: 712 day-workers; 434 shiftworkers	84%	Prospective study on the effects of shift work on changes in metabolic disturbance parameters	10 years (two measurements)	Day work: no specifications presented. Shift work: various systems	Age, BMI, smoking, alcohol consumption, and leisure time physical activity at baseline	Change in BMI, calculated after obtaining weight and height at the beginning and end of the study
Niedhammer et al (39)	64%	French female nurses	1985: N=363: 215 day workers; 148 night workers 1990: N=305: 216 day workers; 9 night workers	1985: 89% 1990: 78%	Prospective study on the relationship between night work, overweight and weight gain	5 years (two measurements) 5 years (two measurements)	Day work: permanent or alternating day and evening work. Night work: permanent night work or alternating morning, evening, and night work	Age, BMI at baseline, births during the 5-year period, smoking and sports activities	Weight gain measured by a physician every 5 years. (plus a correlation coefficient between exposure to night work and weight gain)
Geliebter et al (43)	58%	US male and female nurses, nurses' aids and security personel	N=85: 49 late shifts 36 day shifts	NA	Retrospective measurement of weight gain during day and night work	None	Day shift: 08.00–16.00. Late shift: 16.00–24.00 or 24.00–08.00	Age, years on the shift, and smoking status	Self-reported weight change since the start of their current job type
van Amelsvoort et al (40)	57%	Mix of nurses, workers at a incinerator plant and other employees	N=264: 105 day workers; 159 shift workers	65%	Prospective study on the impact of 1-year shift work on cardiovascular disease risk factors	1 year	Day work: no specifications presented. Shift work: working in an alternating work schedule, including nights	Age, gender, BMI at baseline, physical sporting activity and physical activity during leisure time. Data obtained after contacting the first author	Measured change in BMI and waist circumference
Copertaro et al (41)	50%	Italian female and male nurses	N=58: 30 rotating shifts; 28 daytime shifts	NA	Prospective measurement of predictors for cardiovascular disease	18 months (four measurements)	Day shifts: 08.00–16.00 or 14.00–22.00. Rotating shifts: starting at 06.00, 14.00 or 22.00	NA	Waist circumference (cm) measured by medics
Hannerz et al (42)	50%	Random male sample from the Central Population Register of Denmark	N=1980: 379 irregular working; 1601 regular working	76%	Prospective study on work factors related with changes in BMI	5 years (two measurements)	NA	Age, cohabiting, smoking, baseline BMI, work hours/week, cold/hot work environment, physical activity at work, decision authority, psychological demands, possibilities to communicate with colleagues, conflicts at work, and job insecurity.	Self-reported height and weight was calculated into Δ BMI
Romon et al (44)	33%	French male factory workers	N=84: 27 3-rotating shift; 47 5-rotating shift; 20 day shift	NA	Retrospective dietary survey of annual weight gain	None	Day shifts: permanent day work between 07.30–17.30. Rotation shifts: shift work starting at 05.00, 13.00, or 21.00	None. Groups were matched on age, socio-professional level and seniority	Annual weight gain in kg/year since the start of the shift type. Obtained by occupation health service records

Table 4. Exposure characteristics. [NS=not significant]

Study	Quality score	Shift work exposure				Day work exposure		
		Shift system	Schedule	Continuity	Rotation	Shifts	Working time	
Suwazono et al (37)	79%	4 team/3-shift system	5 days on, 2 off; 5 evenings on, 1 off; 5 nights on, 2 off	Continuous	Clockwise	NS	NS	
Morikawa et al (38)	64%	2-shift or 3-shift system	5 on, 2 off and 3 or 4 on, 1 off (3-shift system)	Continuous and non-continuous	Counter-clockwise (3 shift)	NS	NS	
Niedhammer et al (39)	64%	3-shift system or permanent night work	Several kinds	No information presented	Clockwise	Permanent day or morning and evening shifts	09.00–17.00 or 06.00–14.00 and 13.00–21.00	
Geliebter et al (43)	58%	Permanent night work or evening shift	Fixed	No information presented	None	None	08.00–16.00	
van Amelsvoort et al (40)	57%	Various exposures: 32% fast clockwise schedule (at most 3 consecutive night shifts) 17% fast counterclockwise schedule (at most 3 consecutive night shifts) 35% medium counterclockwise schedule (at most 5 consecutive night shifts) 15% irregular schedule				NS	NS	
Copertaro et al (41)	50%	3-shift system	1 morning, 1 evening, 1 night on, 2 off	Continuous	Clockwise	Morning and afternoon	08.00–14.00 and 14.00–22.00	
Hannerz et al (42)	50%	Various irregular working hours					Permanent day duty	NS
Romon et al (44)	33%	3-shift system	5 on, 2 off (slow) or 3 on, 1 off (fast)	Continuous and non-continuous	No information presented	None	8 hours between 07.30–17.30	

(43) reported similar results for male and female nurses in France and the US, respectively. Van Amelsvoort et al (40) however, found significant results in the other direction. The two low-quality studies (41, 44) did not find any significant difference in body weight-related outcome between groups.

Because multiple high-quality studies provided consistent (four out of five studies; 80%) findings, it is concluded that there is strong evidence for a crude relationship between shift work and body weight change.

Associations between shift work and body weight change, adjusted for potentially relevant confounders. Six of the eight articles presented body-weight-related outcomes adjusted for potential confounders, five high- and one low-quality study. The high-quality study of Geliebter et al (43) found a significant difference in body weight change between late shift and day shift nurses, while adjusting for age, years in shift work, and smoking status. The potentially relevant confounders (ie, gender, body weight at baseline, and physical activity) were not taken into account and, therefore, the study was not considered in the analysis. The other studies showed varying results. Hannerz et al (42) found no significant difference in their Danish male sample. Niedhammer et al (39) did not find a significant effect of night work on body weight change in a nurses' population. The two high-quality studies among male Japanese workers

found a significant effect. Morikawa et al (38) found a difference in BMI increase between shift workers and day workers after a follow-up of ten years. Suwazono et al (37) showed a significantly higher BMI increase after one year for shift workers compared to day workers. Again, the study of Van Amelsvoort et al (40) found results in the other direction. The shift workers showed a loss in weight outcome after adjustment, which was significantly different from the day workers.

Because two of four high-quality studies (50%) found a significant difference in the same direction, the results are considered to be inconsistent. Subsequently, if the low quality study of Hannerz et al (42) is included, only 40% (two out of five) of the studies show results in the same direction. Therefore moderate evidence was rejected as well, and it is concluded that there is insufficient evidence for an adjusted relationship between shift work and body weight change.

Discussion

This paper is the first systematic review of the scientific literature to investigate the association between exposure to shift work, including night work, and body weight change. The included studies show that there is strong evidence for a crude relationship between

Table 5. Study results. [BMI=body mass index; 95% CI=95% confidence interval; SE=standard error; NS=not significant; SD=standard deviation; NA=not available]

Study	Quality score	Crude	Adjusted	Conclusion
Suwazono et al (37)	79%	Provided data by the first author, %BMI change after one year from baseline: shift Δ BMI 0.56% (95% CI 0.44–0.69%) day Δ BMI 0.31% (95% CI 0.21–0.42%) P=0.004	Provided data by the first author, %BMI change after one year from baseline: shift Δ BMI 0.63% (95% CI 0.44–0.82%); day Δ BMI 0.40% (95% CI 0.24–0.56%) P=0.002	Shift workers had a significant higher increase in BMI after one year from baseline compared to day workers. No differences in results between adjusted and non-adjusted analysis.
Morikawa et al (38)	64%	Mean BMI change for shift workers was 0.88 (SE 0.07) Mean BMI change for day workers was 0.63 (SE 0.06) P=0.002, calculated mean difference 0.25 (SE 0.08)	Mean BMI change for shift workers was 0.89 (SE 0.07); mean BMI change for day workers was 0.62 (SE 0.06) P=0.001, calculated mean difference 0.83 (SE 0.25)	There was a significant higher BMI change in shift workers after 10 years of follow-up compared to the day workers.
Niedhammer et al (39)	64%	1985. Mean weight change for current night workers was 0.3 kg, for current day workers 0.6 kg (NS).	1985. Correlation coefficient: -0.0 (NS).	1985. No significant difference in weight gain between groups after 5 years. Both crude and adjusted.
		1990. Mean weight change for night workers was 2.2 kg, for day workers 1.3 kg. Significant difference but no P-value reported.	1990. Correlation coefficient: 0.8 (0.08) (NS).	1990. A significant crude difference in weight gain between groups after 5 years.
Geliebter et al (43)	58%	Late shift weight gain since start of current job type=4.3 kg; day shift weight gain=0.9 kg; P=0.02, calculated mean difference is 3.4 (SE 1.43)	Late shift weight gain=4.4 kg; day shift weight gain=0.7 kg; P=0.008, calculated mean difference is 3.7 (SE 1.36)	Significant more reported weight change in late shift workers compared to day shift workers. Both crude and adjusted.
van Amelsvoort et al (40)	57%	Mean weight change shift work: -0.98 kg; mean weight change day work: 0.43 kg, P=0.003. Calculated mean difference 1.41 kg (SE 0.47)	Adjusted data below provided by the first author: mean weight change shift work: -1.02 kg; mean weight change day work: 0.28 kg, P=0.007. Mean difference 1.30 kg (SE 0.48)	Significant crude difference between groups in weight and BMI change. Shift workers lost weight and BMI compared to day workers who gained weight and BMI.
		Mean BMI change shift work: -0.31; mean BMI change day work: 0.13, P=0.004. Calculated mean difference 0.44 (SE 0.15)	Mean BMI change shift work: -0.33; mean BMI change day work: 0.07, P=0.011. Mean difference 0.40 (SE 0.16)	
		Mean waist-to-hip ratio change shift work: -0.0093; mean waist-to-hip change day work: -0.0052, P=0.3. Calculated mean difference 0.0041 (SE 0.0042)	Mean waist-to-hip ratio change shift work: -0.0102; mean waist-to-hip change day work: -0.0053, P=0.256. Mean difference 0.0049 (SE 0.0043)	
Copertaro et al (41)	50%	Rotating nurses' circumference changed from 95.8 cm (SD 9.1) to 95.7 cm (SD 9.2). Mean difference of -0.1 in 18 months; daytime nurses' circumference changed from 90.2 (SD 10.2) to 90.4 (SD 9.9), mean difference of +0.2 in 18 months. No P-value reported	NA	Although there was no P-value presented, no crude difference was found between groups.
Hannerz et al (42)	50%	NA	Irregular working hours lead to a Δ BMI of -0.05 (95% CI -0.024–0.15) compared to the group without irregular working hours. P=0.6382.	No adjusted difference found between groups
Romon et al (44)	33%	Annual weight gain in: 3-day rotating shifts: 0.73 kg (SD 0.30); 5-day rotating shifts: 0.89 kg (SD 0.28). Day shifts: 1.02 kg (SD 0.54). (NS)	NA	No significant crude difference in annual weight gain between groups.

longitudinal exposure to shift work and body weight outcomes. Additionally, it is concluded that there is insufficient evidence for a relation between shift work exposure and body weight change when confounders are taken into account.

The results of this review must be interpreted with caution because of the limited number of studies, the methodological quality of the studies, and the heterogeneity between the included studies. The small amount of eligible studies was rather surprising considering the large amount of shift work related literature that has been published. A majority of the articles had to be excluded because, as a result of different study objectives, the relevant outcome data was not presented. The available body weight data of their studies might have altered our results though. Eventually, only five of eight included studies could be used to investigate the adjusted relation between shift work exposure and body weight change. If the three remaining studies would have made adjustments for potentially relevant confounders, other conclusions might have been drawn for this relation.

One of those potential confounders is physical activity during leisure time. Physical fitness is an important factor influencing body weight gain, it might improve individual tolerance to shift work (19, 45, 46) and has a positive effect on sleep amount and quality, leading to a reduction in metabolic disturbances (19, 47). Shift work literature generally states that employees involved in shift work become physically less active, have less time to participate in organized, social sporting activities and find it difficult to stay physically fit (46). Consequently, if this is true, than physical activity would be an intermediate factor rather than a confounder. In this review, however, none of the included studies analyzed physical activity as an intermediate factor. Moreover, they did not analyze physical activity as an individual confounder, but adjusted their results together with the other confounders (37–40). Hence, another analysis of the role of physical activity may give more insight in the relation between shift work and body weight gain.

Of course, the lack of thorough analysis mentioned above holds true for other factors as well. Factors such as age and gender should be analyzed for possible effect modifying effects. Moreover, longitudinal studies are most suitable to examine if variables such as smoking, energy intake, and physical activity during work, which are routinely included in shift work studies, should be treated as intermediate factors.

Furthermore, to summarize the results of the studies included, a levels of evidence synthesis, which is often used for reviews concerning studies with a longitudinal design, was applied. Due to this synthesis, the low-quality studies were disregarded when multiple high-quality studies were available. Because of this, the

quality assessment and the chosen distinction between high- and low-quality studies are very influential. In the present study, similar weight was given to all quality items. This resulted in the situation that a study could be considered as high quality although shift work exposure was vaguely assessed, no confounders had been used, or weight change was retrospectively self-reported. It is arguable whether this kind of weight allocation is correct.

Another important issue in this review is the fact that when comparing the scores on the quality criteria of the different studies (table 2), profound reasons for possible selection bias can be observed. Only four of eight articles had a clear description of their inclusion and exclusion criteria and yet three studies had a non-selective, non-response or a participation rate of at least 80%. Additionally, during follow-up, in some studies the response rate did not reach 80% or there was no response rate presented at all. Selection into shift work may be associated with better adaptability and fewer adverse health effects. This leaves the most suitable, healthy people in the job (healthy worker effect), thereby underestimating the real effect of shift work exposure (5, 45).

This review studied the effect of shift work including night work because working during nights alters the circadian rhythm, which could lead to adverse health effects via several pathways (1, 5–9). However, two studies were included that partly used participants who were not exposed to the working hours defined as being night work (24.00–06.00 hours). Geliebter et al (43) used fixed evening workers (27 out of the 49 late shift participants) and 27.5% of the participants in the study of Morikawa et al (38) were on a two-shift system, which normally does not involve night shifts. It is arguable if these numbers have over- or underestimated the association found in these studies, but they at least blurred the association for which this review was looking.

Lack of a complete description of exposure might have underestimated the results as well. Only three studies presented information about shift work exposure before the beginning of the study (38, 39, 41). Furthermore, during the follow-up period, the exact exposure was not entirely clear either. Although it was adequately described in the retrospective (43, 44) and the short-term follow-up studies (37, 40, 41), the other studies only assessed the shift work exposure at baseline and at the end of the follow-up, which implies that it cannot be ruled out that the workers might have changed the type of (shift) work several times during this period (38, 39, 42). Moreover, large differences between studies in follow-up duration were observed. Only two studies reported sufficient follow-up periods, 10 (38) and 14 years (37) respectively, to expect real

effects of the shift work exposure. Although Suwazono et al (37) and Van Amelsvoort et al (40) found significant differences in body weight gain between groups after one year, larger effects and effects in a similar direction might have been found if all studies had used longer periods of follow-up.

Findings compared to other reviews

Earlier reviews that have addressed the problem of shift work and body weight change did not come to the same conclusion. In a narrative review published in 2003, Knutsson (6) stated that the evidence for the impact of shift work on body weight is inconsistent, and the evidence for a relation with metabolic factors of diabetes is inconclusive. In a recent review, Antunes et al (48) merely stated that shift work plays a role in increasing BMI.

In these reviews, both longitudinal and cross-sectional data were used to explain the findings, no differentiation was made between crude and adjusted associations, and the methods used were non-systematic. Moreover, they did not perform a methodological quality assessment and did not use a levels of evidence synthesis.

Explanation of the findings

Our findings are in accordance with shift work literature, which claims that shift work exposure can lead to unhealthy behavior and subsequent disturbances in gastrointestinal and psychophysiological functioning causing body weight gain and obesity (9, 26, 38).

The review presented here found insufficient evidence for an adjusted relation between shift work exposure and body weight gain. However, two Japanese studies adjusted for health behavior still found a relation between shift work and body weight gain (37, 38). Although they did not measure food intake, the studies explain their results by claiming that the timing and amount of food intake is involved. However, two recent reviews state that total energy intake seems not to be affected by shift work, although meal frequency is irregular and reduced, and that high-energy snacking seems to be increased (19, 49). Therefore, it seems that food intake itself cannot fully explain possible body weight gain as a result of shift work. It has become clear though, that irregular meal pattern and time of day intake could contribute to negative consequences in metabolism (20) because of the relation between circadian rhythm and food intake (19).

During daytime, when individuals normally eat, the human body promotes glucose metabolism and fat storage, while during the night, glucose sparing and fat metabolism is promoted. As a result, shift workers

show a lowered glucose and lipid tolerance following the change from day to night working (50). Other studies reported about increased leptin and blood lipid concentrations, higher low-density lipoprotein levels and a decreased glucose tolerance and insulin sensitivity as a result of nocturnal eating (48, 51–55). These factors are all considered as risk factors for body weight gain and the onset of the metabolic syndrome, type 2 diabetes, and cardiovascular diseases (19, 53, 56). Interestingly, Sopowoski et al (57) found that men have higher and longer elevated triacylglycerol levels compared to women in response to eating at night. These findings could mean that women have lower risk to gain weight as a result of night work compared to men. This might be a part of the explanation for the results shown in this review; two all-male, high-quality studies found an adjusted association between weight gain and shift work exposure while this was not found in studies of female nurses.

Implications for further research

This review found strong evidence for a crude relationship between shift work, which includes night work, and body weight gain. Although recent literature suggests that shift work itself, due to nocturnal eating and alterations in circadian rhythm, could lead to body weight gain, insufficient evidence was found in the results of the included studies of this review. In order to clarify this further, more and better research should be conducted. With the resulting data, stronger conclusions about the risk factors of shift work for body weight gain can be drawn. Furthermore, this can shed more light on the involvement of shift work exposure in the onset of metabolic disturbances, type 2 diabetes, and cardiovascular diseases. Shift work researchers should consider publishing more data about body weight outcomes in the future, even if it is not their primary outcome.

Furthermore, to be able to compare the different aspects of shift work systems and their health consequences better, exposure must be assessed more properly (12, 58). The shift exposure assessment should encompass at least the following modalities: the type of shift work, the schedule, the number of different shifts (morning, evening, night) per month or year, and the cumulative numbers of years in shift work. Ideally, the information about the type and schedule of shift work should include the amount of night work, the rest periods, the rotating type, and direction of rotation. The information should make clear whether the schedule is continuous (includes weekends) or discontinuous as well. Eventually, all this information should be summarized into an “integrated exposure” variable by, for instance, summing the products of the

shifts worked and the number of years worked on this particular schedule (58).

The chosen control group is important as well. In general, the control group should be day workers, composed of people who are quite similar to shift workers (58). Often, the chosen control group works during the day and evening. This can be seen in the studies by Niedhammer et al (39) and Copertaro et al (41) as well, and might have altered the results found. Further, when the control group consists of a group of day workers, they often tend to differ from shift workers socially, economically, and in personality factors. This should be measured and used in the analysis.

Different aspects of shift work systems can cause circadian disruption. This disruption might lead to detrimental health effects, as for example, body weight gain. Tolerance to shift work might be an important factor with regards to the development of detrimental health effects. Shift work tolerance is a complex phenomenon with large inter-individual differences in the speed of (re)adapting to circadian disruption (12, 45, 59). Costa (45) claims that short-term adjustment (circadian adjustment and sleeping) and long-term adjustment (personal factors, working circumstances, social circumstances) to shift work are related to different factors. Therefore, in future studies, the relation between exposure and body weight change should be conducted with large cohorts of newly employed shift workers and these cohorts should be followed for an extensive period of time.

Importantly, potentially relevant confounders, intermediate factors, and effect modifiers should be appropriately and objectively measured, and adequately used in the analysis. For instance, health habits, such as physical activity, should be considered as a possible intermediate factor, and should be analyzed like that as well. Further, these factors should be measured objectively because imprecise measures of health habits have shown to increase the likelihood of false null findings (26).

Concluding remarks

This review shows that there seems to be an association between exposure to shift work, which includes night work, and body weight increase. If the results of the studies are adjusted for potentially relevant confounders (eg, gender, age, body weight at baseline and physical activity), insufficient evidence remains. In order to further clarify the underlying mechanisms, shift work studies should present more body weight-related outcomes. More importantly, better high-quality studies about this subject are necessary.

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Appendix

Search strategy for Medline: Search #1 AND #2 AND #3 NOT #4

#1 Shift work	"Work Schedule Tolerance"(Mesh) OR "Personnel Staffing and Scheduling"(Mesh) OR shiftwork(tiab) OR "shift-work"(tiab) OR nightwork(tiab) OR "irregular working"(tiab) OR "rotate shift"(tiab) OR "rotate shifts"(tiab) OR "Workload"(Mesh) OR workload(tiab) OR ((night(tiab) OR shift(tiab)) AND work(tiab)) OR ("Circadian Rhythm"(Mesh) OR "Sleep Disorders, Circadian Rhythm"(Mesh) OR "Biological Clocks"(Mesh) OR "Sleep-Wake Schedule"(tw) OR "sleep-wake cycle"(tiab) OR "circadian rhythm"(tiab) OR Nyctohemeral(tiab) OR diurnal(tiab)) AND (Work(mh) OR work(tiab) OR labour(tiab) OR labor(tiab) OR "Workplace"(Mesh) OR "Occupations"(Mesh) OR occupation*(tiab) OR vocation*(tiab)) OR "Workplace/psychology"(Mesh)
#2 Overweight/ weight gain	"Overnutrition"(Mesh) OR "Body Weights and Measures"(Mesh) OR "obese"(tiab) OR "obesit*" (tiab) OR "overweight"(tiab) OR "Body Mass"(tiab) OR BMI(tiab) OR "Body Weight Changes"(Mesh)
#3 Study type	"Cohort Studies"(Mesh) OR cohort(tiab) OR research design(mh:noexp) OR comparative study(pt) OR evaluation studies(pt) OR control(tw) OR controll*(tw) OR prospectiv*(tw) OR volunteer*(tw) OR longitudinal(tiab) OR retrospective(tiab) OR "Case-Control Studies"(Mesh)
#4 Publication types filter	NOT ("addresses"(Publication Type) OR "biography"(Publication Type) OR "comment"(Publication Type) OR "directory"(Publication Type) OR "editorial"(Publication Type) OR "festschrift"(Publication Type) OR "interview"(Publication Type) OR "lectures"(Publication Type) OR "legal cases"(Publication Type) OR "legislation"(Publication Type) OR "letter"(Publication Type) OR "news"(Publication Type) OR "newspaper article"(Publication Type) OR "patient education handout"(Publication Type) OR "popular works"(Publication Type) OR "congresses"(Publication Type) OR "consensus development conference"(Publication Type) OR "consensus development conference, nih"(Publication Type) OR "practice guideline"(Publication Type))