Night-Shift Nursing and Prediabetes: Circadian Disruption, Metabolic Risk, Screening, and Prevention

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Abstract

Abstract

Background: Prediabetes is an intermediate state of dysglycemia associated with increased risks of type 2 diabetes, cardiovascular disease, and microvascular complications. Nurses assigned to night or rotating shifts may be particularly vulnerable because occupational schedules conflict with endogenous circadian rhythms and are frequently accompanied by sleep restriction, irregular eating, psychological stress, and reduced opportunities for physical activity. This narrative review examines the association between night-shift nursing and prediabetes, emphasizing biological mechanisms, occupational contributors, screening, and prevention. Experimental studies demonstrate that circadian misalignment reduces glucose tolerance and insulin sensitivity, independently of sleep loss. Exposure to light at night, altered melatonin secretion, hypothalamic-pituitary-adrenal activation, sympathetic predominance, inflammation, and disruption of peripheral metabolic clocks may further impair glucose homeostasis. Observational studies, including large cohorts of female nurses, consistently associate prolonged rotating night-shift work with a higher incidence of type 2 diabetes. However, the frequency of laboratory-confirmed prediabetes among nurses varies substantially across studies because of differences in populations, shift definitions, and diagnostic methods. Risk assessment should incorporate shift duration and intensity alongside age, adiposity, family history, previous gestational diabetes, hypertension, dyslipidemia, sleep quality, and medication exposure. Screening should use glycated hemoglobin, fasting plasma glucose, or a 2-hour oral glucose tolerance test, with repeat testing determined by the initial result and overall risk. Prevention requires more than individual counseling. Effective programs should integrate structured lifestyle intervention, weight management, appropriate meal timing, protected sleep, physical activity, fatigue-aware scheduling, and institutional occupational-health support. Metformin may be considered for selected high-risk individuals, but night-shift exposure alone is not an indication for pharmacotherapy. Well-designed prospective studies using standardized definitions and repeated glycemic measurements are needed to determine the true burden of prediabetes among night-shift nurses and establish effective workplace interventions..

Keywords: *Prediabetes; Night-shift work; Nurses; Circadian rhythm; Insulin resistance; Occupational health*

Introduction

Night work is indispensable to hospital care. Nurses provide continuous observation, medication administration, emergency intervention, and coordination of care throughout the night. This service model, however, requires biological activity during the circadian phase normally allocated to sleep and fasting. Repeated conflict between occupational timing and internal physiology may contribute to metabolic dysfunction long before overt diabetes becomes clinically apparent.

Prediabetes represents glycemic values above the normal range but below the diagnostic thresholds for diabetes. It includes impaired fasting glucose, impaired glucose tolerance, and elevated glycated hemoglobin. Although often asymptomatic, prediabetes is not metabolically benign. It identifies individuals at increased risk of progression to type 2 diabetes and frequently coexists with central

obesity, hypertension, dyslipidemia, metabolic dysfunction-associated steatotic liver disease, and other manifestations of insulin resistance.[1,2]

Shift work is associated with obesity, metabolic syndrome, cardiovascular disease, and type 2 diabetes. Large prospective investigations involving nurses have been especially influential because they provide long follow-up and detailed information about rotating night duties.[3,4] Nevertheless, evidence addressing prediabetes specifically is less consistent. Many studies use self-reported diabetes, single glycemic measurements, or nonstandard definitions of shift exposure. Findings regarding established diabetes should therefore not be interpreted as direct estimates of prediabetes frequency.

This review discusses the clinical significance of prediabetes among night-shift nurses, the mechanisms linking circadian disruption to dysglycemia, approaches to risk assessment and screening, and preventive strategies applicable at both individual and institutional levels.

Prediabetes: Definition and Clinical Importance

According to the American Diabetes Association, prediabetes in nonpregnant adults may be identified by glycated hemoglobin of 5.7% to 6.4%, fasting plasma glucose of 100 to 125 mg/dL, or a 2-hour plasma glucose concentration of 140 to 199 mg/dL during a 75-g oral glucose tolerance test. Diabetes is diagnosed at glycated hemoglobin of at least 6.5%, fasting plasma glucose of at least 126 mg/dL, or a 2-hour value of at least 200 mg/dL. In the absence of unequivocal hyperglycemia, an abnormal diagnostic result should generally be confirmed.[1]

The World Health Organization uses a higher lower boundary of 110 mg/dL for impaired fasting glucose, while retaining the 2-hour impaired glucose tolerance range of 140 to 199 mg/dL.[5] Consequently, prevalence estimates depend partly on the criteria applied. Studies using the American Diabetes Association fasting threshold will identify more individuals with prediabetes than studies using the World Health Organization definition.

The available tests reflect different physiological disturbances. Fasting plasma glucose primarily identifies abnormalities in hepatic insulin sensitivity and basal glucose regulation. The oral glucose tolerance test is more sensitive to postprandial dysglycemia and impaired peripheral glucose disposal. Glycated hemoglobin estimates longer-term glycemic exposure but can be affected by anemia, altered erythrocyte turnover, hemoglobin variants, chronic kidney disease, pregnancy, and recent blood loss or transfusion.[1] These limitations are relevant to nurses because iron deficiency and other conditions affecting glycated hemoglobin interpretation may occur in otherwise young, apparently healthy workers.

Prediabetes is heterogeneous. Some individuals remain stable or return to normoglycemia, whereas others progress rapidly to diabetes. Progression is more likely with higher baseline glycemia, increasing body mass index, central adiposity, younger age combined with severe obesity, a strong family history, previous gestational diabetes, and deteriorating metabolic health.[2] Prediabetes also marks higher cardiovascular risk, although part of this association reflects accompanying hypertension, obesity, and dyslipidemia rather than glycemia alone.[6]

Burden Among Nurses and Night-Shift Workers

The prevalence of prediabetes among nurses differs widely across countries and healthcare settings. Variation is expected because nursing workforces differ in age, sex distribution, ethnicity, adiposity, socioeconomic conditions, shift patterns, and access to preventive care. Comparisons are further complicated when studies use random glucose, fasting glucose, glycated hemoglobin, or oral glucose tolerance testing interchangeably.

Night work itself is also defined inconsistently. A nurse working occasional overnight duties differs substantially from one undertaking permanent nights or rapidly rotating day-evening-night schedules. Cumulative years of night duty, number of nights per month, direction and speed of rotation, consecutive night shifts, recovery intervals, chronotype, and length of each shift may all modify metabolic effects. Classification based only on “night worker” versus “day worker” conceals much of this complexity.

The Nurses’ Health Studies provided important longitudinal evidence. Pan et al. examined two large cohorts of women and reported that longer exposure to rotating night-shift work was associated with a progressively higher risk of type 2 diabetes. Adjustment for body mass index attenuated the association,

suggesting that weight gain mediates part, but not all, of the risk.[3] A later analysis found that rotating night work and an unhealthy lifestyle were independently associated with type 2 diabetes and that their combination produced the greatest risk.[4]

Chronotype may alter susceptibility. In Nurses' Health Study II, mismatch between an individual's preferred sleep timing and assigned work schedule was associated with diabetes risk.[7] UK Biobank data similarly demonstrated that more frequent night-shift work was associated with a greater likelihood of type 2 diabetes after adjustment for demographic, behavioral, and genetic factors.[8] These findings support an exposure-response relationship but do not establish that night work inevitably causes diabetes in every worker.

Systematic reviews generally conclude that shift workers have a moderately increased risk of type 2 diabetes. A meta-analysis by Gan et al. found an overall association between shift work and diabetes, with variation by schedule and sex.[9] More recent syntheses have reached broadly similar conclusions, although effect estimates differ according to eligibility criteria and adjustment for adiposity and socioeconomic factors.[10]

Nurses may have additional occupational exposures not shared by all shift workers. These include high psychological demand, inadequate staffing, missed breaks, prolonged standing alternating with sedentary documentation, limited access to healthy food overnight, emotional strain, and unpredictable emergency activity. Conversely, nurses may possess greater health knowledge and access to screening. The metabolic consequences of nursing work therefore cannot be inferred solely from studies involving industrial or transportation workers.

Current evidence supports an increased metabolic risk associated with prolonged or intensive night-shift exposure. It does not provide a single universally applicable estimate of prediabetes prevalence among night nurses. Local frequency should be established through representative sampling, standardized laboratory testing, and transparent characterization of shift exposure.

Circadian Regulation of Glucose Metabolism

Human physiology follows an approximately 24-hour rhythm coordinated by the suprachiasmatic nucleus of the hypothalamus. Light is the dominant signal synchronizing this central clock with the external day-night cycle. Peripheral clocks in the liver, skeletal muscle, adipose tissue, pancreas, and gastrointestinal tract are also influenced by feeding, activity, sleep, and hormonal signals.[11,12]

Glucose tolerance is normally better during the biological morning than during the biological evening. Insulin secretion, insulin sensitivity, hepatic glucose production, gastrointestinal function, and energy expenditure all display circadian variation. When food intake and activity occur at biologically inappropriate times, central and peripheral clocks may become desynchronized.

Controlled laboratory experiments provide evidence that circadian misalignment directly impairs metabolic function. Scheer et al. subjected healthy adults to behavioral cycles that were misaligned with endogenous circadian timing and observed increased glucose despite increased insulin, consistent with reduced insulin sensitivity. Leptin decreased, cortisol rhythms became inverted, and blood pressure increased.[13]

Morris et al. subsequently separated the effects of circadian phase from behavioral misalignment. Glucose tolerance was lower during the biological evening, while circadian misalignment produced an additional deterioration independent of circadian phase.[14] Similar findings were demonstrated in actual shift workers studied under controlled conditions.[15] These experiments strengthen causal interpretation because they reduce confounding by obesity, diet quality, income, and other characteristics that complicate observational research.

Mechanisms Linking Night-Shift Nursing to Prediabetes

Circadian misalignment and peripheral clock disruption

Night-shift nurses remain active, eat, and receive light exposure when endogenous physiology promotes sleep and fasting. Daytime sleep then occurs when the circadian system promotes wakefulness. Repeated transitions between daytime and nighttime schedules may prevent complete adaptation.

The liver regulates glycogen storage and glucose production, skeletal muscle is responsible for much

insulin-mediated glucose disposal, adipose tissue influences circulating fatty acids and adipokines, and pancreatic β cells coordinate insulin secretion. Misalignment among these tissues may impair their integrated response to meals.[11,12]

Sleep restriction and poor sleep quality

Night-shift nurses frequently obtain shorter and more fragmented sleep than day workers. Daytime sleep is vulnerable to environmental light, household responsibilities, noise, social obligations, and circadian wake signals. Rapid schedule changes may further reduce recovery.

Experimental sleep restriction decreases insulin sensitivity and alters neuroendocrine regulation of appetite.[16] A meta-analysis of prospective cohorts found that short sleep, long sleep, difficulty initiating sleep, and difficulty maintaining sleep were each associated with incident type 2 diabetes.[17] Obstructive sleep apnea provides an additional pathway, particularly among nurses with obesity, resistant hypertension, loud snoring, or excessive daytime sleepiness.

Meal timing and dietary behavior

Hospital night duty can produce irregular meal timing, prolonged fasting followed by large meals, frequent snacking, and reliance on refined carbohydrates or energy-dense convenience foods. Even when total caloric intake is unchanged, consuming meals during the biological night may provoke a larger glycemic response because insulin sensitivity and β-cell responsiveness are lower.

In a controlled study of healthcare workers, rotational night-shift conditions impaired postprandial glucose metabolism and altered pancreatic function.[18] Experimental simulated night work also showed that restricting meals to daytime prevented the rise in glucose seen when meals were consumed during both daytime and nighttime.[19] These findings suggest that meal timing is a modifiable component of night-shift metabolic risk, although long-term effectiveness and practicality in hospitals remain uncertain.

Melatonin and exposure to light at night

Melatonin signals biological night and contributes to the temporal organization of metabolism. Bright light during night duty suppresses melatonin and shifts circadian phase. Genetic variation in the melatonin receptor MTNR1B is also associated with fasting glucose and type 2 diabetes, illustrating a biological connection between melatonin signaling and glucose regulation.[20]

The clinical effect of manipulating light is complex. Bright light may improve alertness and reduce errors during night duty but can delay circadian timing and interfere with post-shift sleep if exposure occurs at an inappropriate phase. Light-based interventions should therefore consider timing, intensity, rotation pattern, commuting safety, and individual chronotype.

Neuroendocrine stress responses

Night nursing combines circadian stress with emotionally and cognitively demanding work. Acute emergencies, alarms, critically ill patients, conflict, and inadequate staffing activate sympathetic and hypothalamic-pituitary-adrenal responses. Persistent sympathetic predominance and altered cortisol timing may increase hepatic glucose output, impair insulin action, disturb sleep, and promote visceral adiposity.

Psychological stress may also influence eating behavior. Fatigue and emotional strain can increase preference for palatable, energy-dense foods and reduce motivation for physical activity after work. These pathways are difficult to separate epidemiologically but are clinically relevant because they can amplify the metabolic effects of circadian misalignment.

Inflammation, adiposity, and altered energy balance

Chronic circadian disruption and insufficient sleep may promote low-grade inflammation, oxidative stress, endothelial dysfunction, and altered secretion of leptin and ghrelin.[21] Reduced leptin signaling, increased hunger, and lower energy expenditure can favor weight gain. Obesity then worsens hepatic and peripheral insulin resistance, creating a reinforcing cycle.

Body mass index partially mediates the association between rotating night work and diabetes in nurses.[3] Nevertheless, relying exclusively on body mass index may miss metabolically high-risk workers with central adiposity or reduced muscle mass. Waist circumference, blood pressure, lipid profile, and clinical

features of metabolic dysfunction should accompany weight assessment.

Additional Occupational and Individual Risk Factors

Night duty should be interpreted as one contributor within a broader risk profile. Age, overweight or obesity, central fat accumulation, first-degree family history of diabetes, previous gestational diabetes, polycystic ovary syndrome, hypertension, dyslipidemia, cardiovascular disease, and belonging to a high-risk ethnic population remain major determinants.[1,2]

Duration and intensity of exposure are important. A nurse working several night shifts monthly for many years may have a different risk from a newly employed nurse with occasional night duties. Rapid rotations and short recovery intervals may be more disruptive than predictable schedules, although permanent night work is not automatically safe because complete circadian adaptation is uncommon when workers return to daytime living on days off.

Chronotype can modify tolerance. Evening-oriented individuals may cope better with late work than morning-oriented individuals, while morning types may experience greater sleep loss and circadian misalignment.[7] Age, caregiving responsibilities, commuting time, shift autonomy, and the ability to obtain uninterrupted daytime sleep also influence vulnerability.

Certain medications increase dysglycemia risk, including long-term systemic glucocorticoids, some antipsychotic agents, selected antiretroviral therapies, and several immunosuppressive drugs.[1] Nurses with previous gestational diabetes require particular attention because their lifetime diabetes risk remains increased even when glucose normalizes after pregnancy.

Screening and Risk Assessment

Night-shift work should prompt risk awareness, but screening decisions should not be based on occupational schedule alone. The American Diabetes Association recommends testing all adults beginning at 35 years of age and earlier testing in adults with overweight or obesity who have one or more additional risk factors. Individuals with prediabetes should generally be reassessed at least annually.[1]

For occupational-health programs, a practical assessment should document:

1. Age, body mass index, waist circumference, and blood pressure.
2. Family history of diabetes and cardiovascular disease.
3. History of gestational diabetes or polycystic ovary syndrome.
4. Shift type, number of nights per month, shift length, consecutive nights, recovery intervals, and cumulative years of exposure.
5. Sleep duration, insomnia symptoms, daytime sleepiness, snoring, and possible obstructive sleep apnea.
6. Meal timing, dietary quality, physical activity, smoking, and alcohol intake.
7. Medications and medical conditions affecting glucose metabolism.
8. Fasting glucose, glycated hemoglobin, and, when indicated, lipid profile and liver enzymes.

Glycated hemoglobin is operationally convenient because fasting is unnecessary and day-to-day biological variation is relatively low. Fasting plasma glucose is inexpensive but requires a verified fasting interval, which may be difficult after night duty. The timing of testing deserves attention: a sample obtained immediately after a stressful night shift or severe sleep loss may not represent usual metabolic status. Whenever feasible, testing should follow a typical recovery period and the conditions should be documented.

The oral glucose tolerance test can detect impaired glucose tolerance when fasting glucose and glycated hemoglobin are nondiagnostic. It is particularly useful when clinical suspicion remains high or results are discordant. However, it is less convenient for large workforce programs and has greater within-person variability.

Abnormal results should be interpreted clinically rather than through automated labeling alone. Discordance between glycated hemoglobin and plasma glucose should prompt consideration of iron deficiency, hemoglobinopathy, kidney disease, altered erythrocyte turnover, laboratory interference, or an evolving glycemic disorder.[1] Workers meeting diabetes thresholds should receive confirmatory testing and appropriate medical assessment rather than being managed solely within an occupational

screening program.

Risk assessment must also protect confidentiality. Glycemic screening should support treatment and prevention, not punitive scheduling, discrimination, or threats to employment. Individual results should remain confidential, while aggregated anonymous data may guide institutional prevention policies.

Prevention and Management

Structured lifestyle intervention

Lifestyle modification is the foundation of diabetes prevention. In the Diabetes Prevention Program, an intensive intervention targeting at least 7% weight loss and 150 minutes of moderate physical activity weekly reduced diabetes incidence by 58% compared with placebo. Metformin reduced incidence by 31%.[22] Benefits of both strategies persisted during long-term follow-up, although the relative differences diminished over time.[23]

For nurses, recommendations must be adapted to shift schedules. Advice designed only for conventional daytime workers is unlikely to be sustained. Plans should specify when to sleep, eat, exercise, and use caffeine across night-duty and recovery days.

Nutrition and meal timing

Dietary quality remains central. Meals should emphasize vegetables, legumes, whole grains, minimally processed carbohydrate sources, lean protein, nuts, and unsaturated fats while limiting sugar-sweetened beverages, refined starches, and highly processed foods. Total energy intake should support gradual weight reduction when excess adiposity is present.

Meal timing may offer additional benefit. Nurses should preferably consume their main meals during daylight or the earlier part of their waking period. If food is required overnight, smaller meals or snacks rich in protein and fiber may be metabolically preferable to large carbohydrate-heavy meals. Evidence from simulated night work supports daytime-restricted eating,[19] but rigid overnight fasting may be impractical or unsafe during prolonged duty. Recommendations should be individualized, particularly for pregnant workers and those using glucose-lowering medication.

Hospitals influence food choice. Healthy meals, refrigeration, clean meal areas, protected breaks, and access to water should remain available overnight. Education alone is unlikely to overcome an environment in which vending machines and fried or sugar-rich foods are the only accessible options.

Physical activity and weight management

Adults should undertake at least 150 minutes of moderate-intensity aerobic activity weekly, distributed across several days, with resistance exercise on 2 or more days when medically appropriate.[2] Light activity and brief walking breaks during duty can reduce uninterrupted sedentary time but do not replace structured exercise.

Exercise timing should fit the individual's fatigue and sleep pattern. Vigorous activity immediately before intended daytime sleep may impair sleep in some workers, whereas activity after waking may improve alertness and insulin sensitivity. Sustainable scheduling is more important than prescribing a single universal exercise time.

Weight reduction of 5% to 10% can produce meaningful metabolic improvement in individuals with overweight or obesity. Waist circumference and cardiometabolic markers should be monitored alongside weight because improvements can occur without large changes on the scale.

Sleep and circadian protection

A protected sleep opportunity of approximately 7 to 9 hours should be encouraged. The sleep environment should be dark, quiet, and cool. Eye masks, blackout curtains, silenced notifications, and family cooperation can improve daytime sleep. Caffeine may enhance alertness early in a night shift but should be limited several hours before planned sleep. Alcohol and sedative misuse should not be used as sleep strategies.

Short planned naps may improve alertness, although post-nap sleep inertia should be anticipated in safety-critical settings. Suspected sleep apnea or clinically significant insomnia requires formal evaluation.

Exposure to bright light during the earlier part of night duty may improve alertness, while reducing

morning light exposure during the commute can facilitate sleep. Because incorrectly timed light can worsen misalignment, structured programs should involve professionals familiar with sleep and circadian medicine.

Shift scheduling and institutional measures

Workplace organization is an essential component of prevention. Potentially beneficial measures include predictable rosters, forward rotation from day to evening to night, adequate recovery time, limits on excessive consecutive night shifts, avoidance of frequent rapid transitions, protected breaks, and opportunities for worker input.[24]

No single roster suits every hospital or worker. Longer blocks of night duty may reduce repeated transitions but increase cumulative sleep loss, while rapid rotation limits adaptation but may reduce prolonged night exposure. Scheduling policies should consider fatigue, patient safety, staffing requirements, commuting risk, age, chronotype, pregnancy, and cardiometabolic health.

Occupational programs should provide periodic metabolic screening, confidential counseling, weight-management services, sleep assessment, and referral pathways. Outcomes should include staff well-being, absenteeism, retention, medication errors, and patient safety as well as laboratory indicators.

Pharmacological prevention

Metformin may be considered in adults with prediabetes who have particularly high progression risk, especially younger adults with marked obesity, higher fasting glucose or glycated hemoglobin, or a history of gestational diabetes.[2] Night-shift exposure by itself is not an accepted indication for metformin.

Before treatment, clinicians should evaluate kidney function, gastrointestinal tolerance, contraindications, and the possibility of vitamin B_{12} deficiency during long-term therapy. Pharmacological prevention should complement rather than replace sleep, nutrition, physical activity, weight management, and workplace modification.

Management of blood pressure, dyslipidemia, smoking, and overall cardiovascular risk is equally important. Prediabetes should initiate comprehensive cardiometabolic prevention rather than an isolated effort to lower glucose.

Research Gaps and Future Directions

The evidence base has several limitations. First, many investigations combine permanent nights, rotating nights, evening shifts, and irregular schedules. Standardized exposure definitions should include start and end times, monthly night frequency, consecutive shifts, rotation direction, shift length, recovery time, and cumulative exposure.

Second, cross-sectional studies cannot establish whether night duty preceded dysglycemia. Healthy-worker selection may also distort associations because workers who develop illness may transfer to daytime schedules, making current night workers appear healthier. Prospective cohorts beginning before or near the start of night-duty exposure are needed.

Third, prediabetes should be measured using standardized laboratory criteria rather than self-report or isolated random glucose. Repeated glycated hemoglobin and fasting glucose measurements, with oral glucose tolerance testing in selected participants, would reduce misclassification.

Fourth, future analyses should distinguish confounding from mediation. Adiposity, diet, sleep duration, socioeconomic conditions, stress, and physical activity may partly explain why night work affects glycemia, but adjusting indiscriminately for all these factors may obscure the biological pathway being studied.

Finally, intervention trials in real hospitals are limited. Cluster-randomized or pragmatic studies should compare roster designs, protected sleep programs, healthy overnight food provision, timed light exposure, meal-timing strategies, and integrated metabolic prevention. Evaluation should extend beyond short-term fasting glucose to insulin sensitivity, glycated hemoglobin, weight, sleep, staff performance, and long-term progression to diabetes.

Conclusion

Night-shift nurses are exposed to a combination of circadian misalignment, restricted and fragmented

sleep, biologically inappropriate meal timing, occupational stress, and adverse changes in activity and weight. Experimental findings demonstrate that circadian misalignment can impair glucose tolerance and insulin sensitivity, while prospective cohorts consistently associate prolonged rotating night work with increased type 2 diabetes risk. Nevertheless, the exact frequency of prediabetes among night-shift nurses remains uncertain because of heterogeneous populations, exposure definitions, and diagnostic methods.

Prediabetes screening should combine validated laboratory testing with assessment of traditional cardiometabolic risks and detailed night-work exposure. Prevention should integrate weight management, healthy nutrition, appropriately timed meals, regular exercise, protected sleep, and treatment of associated cardiovascular risk factors. Hospitals must also address scheduling practices, recovery time, food access, staffing, and confidential occupational-health support. Individual behavior is important, but sustainable prevention requires a work environment that makes metabolically healthy choices possible.

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