

Chronodisruption: Bringing Time into Public Health

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Introduction:

The timing of everyday life has become an environmental exposure. As modern societies increasingly organize work, sleep, eating, and light exposure in ways that conflict with human circadian biology, chronodisruption persistent misalignment of the body's temporal organization with environmental and behavioural time cues is emerging as a potentially important determinant of population health.^[1,2]

Life evolved in a temporally predictable environment. Stable daily and seasonal cycles generated by the Earth's rotation and orbit shaped the evolution of endogenous circadian clocks. These central (suprachiasmatic nucleus in brain) and peripheral clocks (present in virtually every organ) coordinate physiological processes from gene expression to hormone secretion and remain synchronized with the external environment through recurring time cues such as the lightdark cycle, food intake, and physical activity.^[2] Within just a few generations, however, the temporal environment has been transformed beyond anything human physiology evolved to accommodate.^[2]

Disruption of this alignment forms the basis of chronodisruption. As originally conceptualized by Erren and Reiter, chronodisruption arises from misalignment between endogenous circadian rhythms and environmental or behavioural time cues, including light

exposure, sleepwake schedules, meal timing, and work patterns.^[1] Contemporary societies expose individuals to multiple and often coexisting sources of chronodisruption. Artificial light at night (ALAN) suppresses nocturnal melatonin secretion, shift work requires wakefulness and food intake during the biological night, social jetlag repeatedly shifts biological timing without changes in geography, and late or irregular eating may uncouple peripheral metabolic clocks from central circadian regulation.^[2,3] Together, these exposures produce cumulative temporal disorganization that has become a characteristic feature of modern living rather than an exceptional circumstance.^[2]

From a public health perspective, chronodisruption merits consideration alongside other recognized environmental exposures because its principal sources are identifiable, measurable, and potentially modifiable. Shift work, light pollution, social jetlag, irregular sleep, and mistimed eating can be assessed using actigraphy, light monitoring, chronotype instruments, and circadian biomarkers.^[2,3] Equally important, many of their upstream determinants including lighting design, workplace scheduling, school start times, and urban planning are amenable to population-level intervention.^[2] The critical question is not whether chronodisruption occurs, but what the accumulated evidence reveals about its contribution to human disease

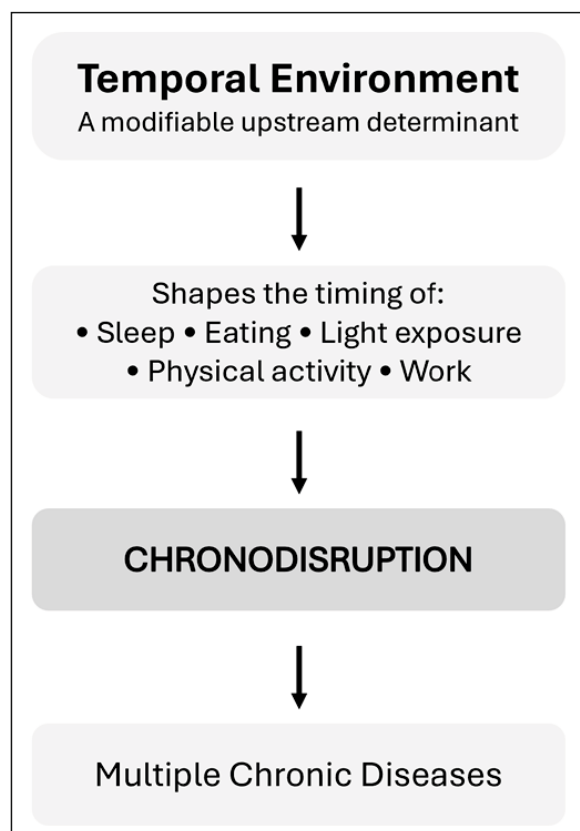
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Figure 1. Conceptual framework illustrating how the temporal environment, as a modifiable upstream determinant of health, shapes the timing of key behavioural and environmental exposures. Persistent disruption of this temporal organization (chronodisruption) contributes to the development of multiple chronic diseases.



and population health.

Chronodisruption and Health: Current State of the Evidence

Evidence linking chronodisruption to chronic disease has expanded rapidly over the past two decades. Evidence from experimental circadian misalignment studies, prospective cohorts, systematic reviews, and umbrella reviews indicates that chronodisruption affects multiple physiological systems, although the strength of evidence varies across health outcomes.^[2,5]

The strongest evidence concerns cardiometabolic disease. Experimental studies consistently demonstrate impaired glucose metabolism, insulin sensitivity, blood pressure regulation, autonomic function, and inflammatory signalling during circadian misalignment. Importantly, although sleep restriction and shift work frequently coexist in real-world settings, experimental studies controlling for total sleep time demonstrate that

circadian misalignment independently impairs metabolic and autonomic function.^[4] Complementing these mechanistic findings, prospective cohorts and systematic reviews report increased risks of obesity, type 2 diabetes, myocardial infarction, and cardiovascular disease among long-term shift workers.^[2,4,5]

Moderately consistent evidence from systematic reviews and meta-analyses links chronodisruption to depression, anxiety, cognitive dysfunction, sleep disorders, adverse pregnancy outcomes, immune-related disorders, and gastrointestinal disorders, although the certainty of evidence varies across outcomes.^[2]

Emerging evidence also suggests possible associations with accelerated biological ageing, neurodegenerative disorders, and musculoskeletal disease, supported by growing mechanistic and observational evidence but comparatively fewer prospective epidemiological studies.^[2]

Cancer represents a more nuanced area of evidence. The most convincing human evidence concerns prolonged night-shift work, which the International Agency for Research on Cancer (IARC) has classified as probably carcinogenic to humans (Group 2A).^[6] Associations with breast cancer are the most consistently reported, whereas evidence for colorectal, prostate, endometrial, and other cancers continues to evolve.^[6]

Collectively, these findings suggest that chronodisruption functions as a systems-level exposure rather than an organ-specific risk factor. By disrupting multiple interconnected physiological processes, it may contribute to the development of a broad spectrum of chronic diseases.^[2] Important methodological limitations nevertheless remain, including heterogeneous exposure assessment, residual confounding, healthy-worker effects, and the absence of standardized metrics for chronodisruption.^[7]

Despite these limitations, the evidence has progressed well beyond hypothesis generation. The more pressing question is no longer whether chronodisruption warrants scientific investigation, but how its growing evidence base should inform public health policy and prevention.

Chronodisruption in Public Health Practice

The growing evidence linking chronodisruption with chronic disease may invite an apparently straightforward conclusion: people should sleep more regularly, reduce evening light exposure, and avoid late-night eating. Such behaviours undoubtedly matter. Yet this interpretation overlooks a fundamental principle of public health that health behaviours are rarely determined by individual choice alone. They are shaped by the environments in which people live, work, study, and interact.^[8]

Here, we use the term *temporal environment* to describe the social, occupational, technological, and physical conditions that collectively determine when people sleep, work, eat, and are exposed to light. Just as food environments influence dietary behaviour, built environments and neighbourhood design shape physical

activity, temporal environments shape the timing of health behaviours. Modern societies increasingly determine not only what people do, but also when they do it often in ways that conflict with human circadian biology.^[2]

Many of the determinants of chronodisruption lie beyond individual control. Employers determine work schedules, schools determine start times, cities influence light pollution, digital technologies extend wakefulness, and labour policies shape working hours. Consequently, chronodisruption should not be viewed solely as a matter of sleep hygiene or personal responsibility. Like other environmental health exposures, it arises largely from conditions created by institutions and policies, making it a legitimate target for population-level intervention.^[2,8]

The workplace provides perhaps the clearest example. Shift workers, healthcare professionals, emergency responders, transport personnel, and many industrial employees rarely choose when they sleep or eat. Rotating schedules, overnight duties, and unpredictable working hours impose circadian misalignment as an occupational condition rather than a personal failing.^[9]

Beyond the workplace, early school start times illustrate how institutional schedules can conflict with human biology. Adolescence is accompanied by a physiological delay in circadian timing, causing teenagers to fall asleep and wake later than younger children.^[10] Early school schedules therefore require many students to wake before their biological clock is optimally aligned for wakefulness, resulting in chronic sleep restriction and circadian misalignment.^[10] Evidence that delaying school start times improves sleep duration, daytime alertness, mental well-being, and, in some settings, academic performance and road safety has prompted organizations such as the American Academy of Paediatrics to recommend later school start times for adolescents.^[10,11] This provides a compelling example of circadian biology already informing public policy.

Urban light pollution and pervasive digital technologies similarly shape temporal environments beyond workplaces and schools, extending chronodisruptive exposures across everyday life.^[2,12]

These temporal pressures are not distributed equally across society. Individuals with the least control over their working conditions often experience the greatest chronodisruptive burden, making circadian health an issue of health equity as much as biology.^[8,9]

This perspective has important implications for public health practice. Rather than establishing entirely new programmes, circadian health can be integrated into existing health promotion, occupational health, school health, and non-communicable disease (NCD) prevention strategies. Examples include evidence-informed shift scheduling and healthier workplace lighting for night-shift workers,^[9] later school start times for adolescents,^[10,11] reducing unnecessary artificial light at night,^[12] and health promotion messages that encourage regular sleepwake schedules, morning daylight exposure, consistent meal timing, and dimmer indoor lighting during the evening.^[2] Public health

responses span the entire prevention continuum from primordial strategies that create healthier temporal environments to tertiary approaches that support circadian health as part of chronic disease management (Table 1).

Implementation, however, should remain proportionate to the evidence. Current uncertainties including heterogeneous exposure assessment, limited implementation research, and the absence of standardized measures of chronodisruption preclude sweeping recommendations.^[7] At present, chronodisruption is best regarded as an emerging environmental determinant of health whose prevention can be progressively integrated into existing public health systems while the evidence base continues to mature.

Research Priorities: From Association to Action

Research on chronodisruption has evolved from experimental chronobiology to a substantial epidemiological literature linking temporal disruption with multiple chronic diseases.^[2,7] The next challenge is no longer simply demonstrating association, but

Table 1. Illustrative public health strategies for prevention of chronodisruption across the prevention continuum.

Level	Public Health Goal	Illustrative Public Health Strategies
Primordial	Create healthier temporal environments	Evidence-informed shift scheduling policies; later school start times; reduction of artificial light at night; circadian-friendly lighting policies in workplaces and public spaces; labour policies supporting healthier working hours.
Primary	Promote circadian alignment	Regular sleepwake schedules; morning daylight exposure; consistent meal timing; health promotion to reduce evening screen exposure; dimming indoor lighting during the evening.
Secondary	Identify chronodisruption and high-risk groups	Periodic health assessment for long-term shift workers; screening for sleep disorders; cardiometabolic risk monitoring; assessment of sleep and circadian health in high-risk groups.
Tertiary	Reduce complications and improve outcomes	Incorporation of circadian health into chronic disease management; addressing sleep and circadian disruption during long-term care.

Examples are illustrative and represent current and emerging opportunities for integrating circadian health into public health practice

generating the evidence needed to translate these findings into public health policy and practice.

The first priority is measurement. Despite growing recognition of chronodisruption, heterogeneous definitions and diverse measurement approaches continue to limit comparisons across studies. Developing standardized operational definitions, validated multidimensional exposure metrics, and practical surveillance tools should therefore be a research priority rather than a methodological detail.^[7]

The second priority is causal inference. Longitudinal cohort studies and intervention trials are needed to clarify dose response relationships, interactions with established risk factors, and whether improving circadian alignment translates into meaningful reductions in chronic disease.^[7]

The third priority is implementation. Biological plausibility alone is insufficient for public health action. Policymakers require evidence that circadian-health interventions are feasible, scalable, equitable, and cost-effective. Implementation science, pragmatic trials, and health economic evaluations will therefore be essential for translating chronobiological discoveries into routine public health practice.^[13]

Finally, the evidence base must become more globally representative. Most epidemiological evidence originates from high-income countries, despite rapid urbanization, expanding 24-hour economies, and epidemiological transition in many low- and middle-income countries.^[2,13] In these settings, chronodisruptive exposures may arise under distinct social and occupational conditions, including irregular and poorly regulated shift work in informal labour sectors, increasing night-time economic activity, and occupational heat requiring adaptations of work schedules, such as moving agricultural and outdoor work to cooler evening or night hours^[14] Future research must better characterize these context-specific exposures if circadian health is to inform global public health policy.

The principal barriers to progress are no longer conceptual. They are methodological, translational, and

political. Addressing these challenges will determine whether chronobiology remains primarily a laboratory science or becomes an integral component of population health.

Conclusion

Public health has repeatedly expanded its understanding of the environmental determinants of health from infectious agents and contaminated water to tobacco smoke, air pollution, unhealthy diets, and the built environment. The convergence of epidemiological, experimental, and mechanistic evidence now suggests that another dimension deserves consideration: the temporal organization of everyday life.

Recognizing chronodisruption as an environmental exposure broadens, rather than replaces, existing risk factor frameworks by acknowledging that the health effects of light, food, physical activity, work, and sleep depend on when they occur as well as their quantity and quality.

Important uncertainties remain, and they should guide future research rather than delay thoughtful public health action. Many opportunities to promote circadian health already exist within current public health systems, requiring integration rather than reinvention.

As the global burden of chronic disease continues to rise, recognizing the temporal environment as a modifiable determinant of health may represent one of the next important opportunities for disease prevention.

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