



Embodied Uncertainty: Socioeconomic Stress and Sleep Patterns among Older Adults Affected by a Major Earthquake

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Abstract: Large-scale disasters generate prolonged socioeconomic uncertainty that may profoundly affect health in later life. While post-disaster sleep problems among older adults have been widely reported, far less is known about how ongoing socioeconomic stress becomes embodied in objectively measured sleep patterns. This exploratory study examines the relationship between socioeconomic uncertainty and sleep among older adults affected by a major earthquake. A mixed-methods design was employed. Ten disaster-affected older adults wore wrist-worn wearable devices continuously for approximately two weeks, providing objective data on sleep duration, sleep-stage distribution, and daily physical activity. Semi-structured interviews captured lived experiences of post-disaster living conditions, financial concerns, housing stability, and perceived uncertainty regarding future life prospects. The mean sleep duration was 5 hours and 11 minutes, with substantial inter-individual variability and frequent nocturnal awakenings. Interview data revealed persistent socioeconomic uncertainty related to housing stability, time-limited assistance, institutional ambiguity, and anticipated future instability. These findings suggest that sleep disturbance may function as an embodied indicator of chronic socioeconomic stress rather than a transient psychological response.

Keywords: Embodiment, Socioeconomic Uncertainty, Disaster, Older Adults, Sleep, Wearable Devices.

INTRODUCTION

Sleep is a fundamental biological process that plays a critical role in physical recovery, emotional regulation, and cognitive functioning across the life course. In later life, however, sleep becomes increasingly vulnerable due to age-related changes in sleep architecture, chronic health conditions, and reduced physiological resilience. Disturbed sleep among older adults is associated not only with diminished quality of life but also with heightened risks of functional decline, cognitive impairment, depressive symptoms, and reduced capacity to cope with stressors encountered in everyday life.

Large-scale disasters such as earthquakes impose abrupt and prolonged disruptions to everyday life, exposing survivors to multiple layers of stress. These include displacement from familiar environments, disruption of social networks, loss of material and symbolic resources, and uncertainty regarding future living conditions. A substantial body of disaster research has documented elevated rates of sleep disturbance, insomnia symptoms, and shortened sleep duration following major disasters. Older adults have consistently been identified as a particularly vulnerable group due to pre-existing health conditions, reduced mobility, and greater dependence on social and institutional support systems [1,2].

Importantly, sleep difficulties among disaster survivors often persist long after immediate threats have subsided. Longitudinal studies conducted in various post-disaster

contexts indicate that sleep problems may remain prevalent months or even years into the recovery phase. This persistence suggests that post-disaster sleep disturbance cannot be explained solely by acute psychological trauma or short-term environmental disruption. Instead, it points to the influence of ongoing stressors embedded in survivors' everyday lives during prolonged recovery processes [3].

For older adults, these longer-term stressors may be especially consequential. Ageing-related changes in physical health, cognitive function, and social roles intersect with disaster-related disruptions to create complex patterns of vulnerability. Recovery trajectories in later life may differ substantially from those of younger populations, as opportunities for economic recovery, residential mobility, and role reconfiguration are often constrained. Understanding sleep disturbance among older disaster survivors therefore requires attention to the broader social and structural conditions shaping daily life after the disaster.

Among the ongoing stressors influencing post-disaster health, socioeconomic uncertainty has emerged as a critical but underexplored determinant. Socioeconomic uncertainty refers not only to material deprivation or income loss, but also to sustained ambiguity regarding housing stability, financial security, access to institutional support, and future life trajectories. Following major disasters, older adults often face time-limited housing arrangements, unclear eligibility thresholds for assistance, fluctuating policy environments, and constrained opportunities to rebuild economic stability. These conditions generate uncertainty that may persist even when immediate material needs are temporarily met.

Conceptually, socioeconomic uncertainty differs from direct economic loss. While material loss may be acute and quantifiable, uncertainty is characterized by indeterminacy, temporal ambiguity, and lack of predictability. These features undermine individuals' ability to plan for the future and restore a sense of control over daily life. Emerging scholarship in social science and public health suggests that uncertainty itself constitutes a distinct form of stress with profound implications for mental and physical health [4].

Prolonged uncertainty has been linked to chronic cognitive and emotional arousal, including rumination and anticipatory worry [5]. Such processes are known to interfere with sleep initiation and maintenance by sustaining physiological hyperarousal during the night. From this perspective, sleep disturbance may represent a physiological imprint of unresolved social conditions, rather than a transient response to past traumatic events.

From the standpoint of the social determinants of health, sleep can be understood not merely as an individual behavior or clinical outcome, but as a socially patterned and embodied phenomenon shaped by structural conditions. Social and economic environments become internalized through physiological processes, influencing health outcomes over time. Sleep is particularly sensitive to these processes, as it reflects the interaction between social stressors, psychological states, and biological rhythms.

Recent advances in wearable technology provide new opportunities to examine sleep under real-world conditions. Wrist-worn devices enable continuous, non-invasive measurement of sleep duration, sleep-stage distribution, and daily activity patterns in naturalistic settings. When combined with qualitative inquiry, wearable data allow researchers to move beyond retrospective self-report and examine how structural stressors

are translated into embodied experiences. Mixed-methods approaches are therefore especially well-suited to exploring the social dimensions of sleep in disaster contexts.

Older adults represent a particularly important population for such investigation. Ageing-related changes in sleep architecture may amplify the physiological impact of prolonged uncertainty, while fixed incomes, health-related expenditures, and reliance on institutional support may intensify perceptions of insecurity. Moreover, disasters often exacerbate pre-existing social inequalities, rendering older adults structurally vulnerable during recovery processes.

The present study adopts an exploratory mixed-methods approach to examine how socioeconomic uncertainty following a major earthquake is reflected in sleep patterns among older adults. By integrating wearable-derived sleep data with semi-structured interviews, this study seeks to illuminate the mechanisms through which uncertainty related to housing stability, financial security, and institutional arrangements becomes embodied in disrupted sleep. Rather than evaluating specific support programs, the focus is on identifying broader social and structural processes shaping health during post-disaster recovery.

By situating sleep at the intersection of disaster recovery, ageing, and socioeconomic conditions, this study contributes to international discussions on the social determinants of health. Understanding how uncertainty becomes embodied in sleep patterns may inform more comprehensive approaches to post-disaster recovery that address not only psychological distress and material loss, but also the structural sources of prolonged vulnerability among ageing populations.

METHODS

Study Design

This study employed an exploratory mixed-methods design integrating objective sleep data derived from wearable devices with qualitative data obtained through semi-structured interviews. This design was selected to capture both physiological indicators of sleep and the lived experiences through which socioeconomic uncertainty is perceived, interpreted, and managed in everyday life. By combining quantitative and qualitative approaches, the study aimed to examine sleep not merely as a clinical outcome, but as an embodied response to social and economic conditions in a post-disaster context.

Participants and Setting

Participants were disaster-affected adults aged 65 years and older who had experienced displacement following a major earthquake. Recruitment was conducted through a community-based support setting that provided social interaction and assistance for displaced individuals. Inclusion criteria were: (1) age 65 years or older, (2) experience of displacement due to the earthquake, and (3) ability to provide informed consent. Individuals with apparent severe cognitive impairment were excluded to ensure reliable participation in interviews.

Wearable-Based Sleep and Activity Measurement

Objective sleep and physical activity data were collected using wrist-worn wearable devices [6] worn continuously for approximately two weeks. Participants were instructed to wear the device at all times, including during sleep, and to remove it only briefly for charging when necessary. The wearable devices automatically recorded total sleep duration, sleep-stage distribution (light sleep, deep sleep, and rapid eye movement sleep), nocturnal awakenings, and daily step counts under free-living conditions. These indicators were selected to capture sleep quantity, sleep structure, sleep continuity, and daily activity patterns. While wearable-based sleep estimation does not replace clinical polysomnography, it is widely used to identify longitudinal sleep patterns and inter-individual variability in real-world settings [7].

Qualitative Interviews

Semi-structured interviews were conducted face-to-face in a quiet and private space within the community setting. An interview guide was used to explore participants' post-disaster living conditions, housing stability, financial concerns, access to institutional support, health status, and subjective sleep experiences. Particular attention was paid to perceptions of uncertainty regarding future living arrangements and financial security.

Interviews were conducted during the wearable monitoring period or shortly thereafter to facilitate reflection on recent sleep experiences. With participants' consent, interviews were documented through detailed notes. Identifying information was removed during data organization to ensure anonymity.

Data Analysis

Quantitative data derived from wearable devices were summarized descriptively to examine average sleep duration, sleep-stage proportions, nocturnal awakenings, daily step counts, and inter-individual variability. Given the exploratory nature of the study and the small sample size, inferential statistical testing was not conducted.

Qualitative interview data were analyzed thematically. Responses related to socioeconomic uncertainty were coded inductively, with recurring themes identified across participants. Integration of quantitative and qualitative findings occurred at the interpretive stage, allowing sleep data to be contextualized within participants' narratives of uncertainty and everyday life.

Ethical Considerations

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki. Ethical approval was obtained from the institutional review board of Tokyo Online University. Prior to participation, all subjects received both oral and written explanations of the study's purpose, procedures, potential risks, and benefits. Participants were informed of their right to withdraw from the study at any time without penalty. Written informed consent was obtained from all participants before data collection. To ensure confidentiality, all collected data were anonymized, securely stored, and used solely for research purposes.

RESULTS

Participant Characteristics

Ten disaster-affected older adults participated in the study. Participants ranged in age from their mid-60s to late 70s and included both men and women. Household composition varied, with several participants living alone and others residing with family members. All participants had experienced substantial disruption to their housing and daily routines following the earthquake and were living in temporary or alternative accommodation at the time of data collection.

Although all participants completed the interview component of the study, the duration of usable wearable data varied slightly due to early discontinuation or device-related constraints. These variations were considered in the descriptive interpretation of sleep patterns.

Sleep Duration and Inter-Individual Variability

Wearable-derived sleep data revealed generally short sleep duration across participants, accompanied by pronounced inter-individual variability. The mean sleep duration during the monitoring period was 5 hours and 11 minutes per night, which is below commonly recommended sleep durations for older adults.

Several participants consistently slept fewer than four hours per night, exhibiting compressed sleep periods and frequent nocturnal awakenings. In contrast, a smaller number of participants achieved longer sleep durations approaching seven hours. However, even among those with relatively longer sleep duration, sleep was often fragmented and irregular. Within-individual variability was also observed. Some participants experienced marked night-to-night fluctuations in sleep duration, suggesting that sleep disruption was not a stable trait but rather responsive to daily circumstances and perceived stressors.

Sleep Architecture and Fragmentation

Analysis of sleep-stage distribution indicated that light sleep accounted for the largest proportion of total sleep time across participants. Deep sleep and rapid eye movement (REM) sleep constituted relatively smaller proportions, with several participants displaying notably low levels of deep or REM sleep across multiple nights.

Fragmented sleep characterized by frequent nocturnal awakenings and early morning arousal was a common pattern. These awakenings were observed repeatedly rather than as isolated events, indicating persistent disruption of sleep continuity. Such patterns are consistent with heightened cognitive or emotional arousal during the night.

Daily Physical Activity Patterns

Daily physical activity, assessed through average step counts, varied widely among participants. Some maintained moderate levels of daily activity, while others recorded consistently low activity levels, reflecting reduced mobility or limited opportunities for physical movement in post-disaster living environments. At a descriptive level, no consistent

linear association between activity levels and sleep duration was observed. Participants with higher activity levels did not necessarily experience longer or less fragmented sleep, suggesting that factors beyond physical activity contributed to sleep disruption.

Socioeconomic Uncertainty in Lived Experience

Qualitative interviews revealed persistent socioeconomic uncertainty as a dominant feature of participants' post-disaster lives. Rather than describing acute deprivation alone, participants emphasized ongoing ambiguity and lack of predictability. This uncertainty was organized around several interrelated domains.

Housing Stability and Temporal Uncertainty

Uncertainty regarding housing stability emerged as one of the most salient concerns. Although participants were temporarily housed, many described their living arrangements as provisional and time limited. References to contract expiration, potential rent obligations, and unclear prospects for permanent housing were common.

Even when current housing conditions were described as acceptable, the anticipated end of housing support generated significant anxiety. This sense of "temporary stability" was frequently framed in temporal terms, with participants expressing concern about how their lives would unfold in the coming years.

Financial Insecurity and Institutional Ambiguity

Participants also reported financial insecurity related to repair costs, replacement of household goods, and increased living expenses following displacement. Beyond material concerns, institutional ambiguity emerged as a distinct source of stress.

Several participants expressed frustration with eligibility thresholds for support and uncertainty regarding future assistance. Perceived inconsistency or unfairness in institutional decision-making contributed to feelings of insecurity and diminished trust, undermining participants' ability to plan for the future.

Anticipated Future Instability

Across interviews, participants frequently articulated concerns about the sustainability of daily life in later years. Anticipated instability related to ageing, fixed incomes, health expenses, and potential changes in support arrangements featured prominently. This forward-looking uncertainty was often described as emotionally difficult to set aside, particularly at night. Participants emphasized that such worries persisted even during periods of relative calm, suggesting that uncertainty itself constituted an ongoing stressor.

Linking Socioeconomic Uncertainty and Sleep Experiences

Participants frequently drew explicit connections between socioeconomic uncertainty and sleep disruption. Several described difficulties maintaining sleep due to persistent worry,

particularly nocturnal awakenings and early morning arousal. Others reported shortened sleep duration associated with rumination about housing, finances, or future plans.

These qualitative accounts closely aligned with wearable-derived sleep patterns indicating fragmented and shortened sleep. Although causal relationships cannot be established, the convergence of objective sleep indicators and subjective narratives suggests that ongoing socioeconomic uncertainty may be reflected in disrupted sleep patterns. Notably, participants often distinguished these worries from memories of the earthquake itself, emphasizing concerns about future stability.

DISCUSSION

Socioeconomic Uncertainty as an Embodied Stressor

This exploratory mixed-methods study examined sleep patterns among older adults affected by a major earthquake, focusing on how ongoing socioeconomic uncertainty may become embodied in physiological rhythms. By integrating wearable-derived sleep data with qualitative accounts, the findings suggest that sleep disturbance among disaster-affected older adults cannot be understood solely as a short-term psychological reaction or residual trauma. Instead, disrupted sleep appears to function as an embodied manifestation of prolonged socioeconomic stress.

Participants' narratives consistently emphasized uncertainty surrounding housing stability, financial sufficiency, institutional eligibility, and future living arrangements. These concerns persisted even when immediate material needs were temporarily met, underscoring the importance of predictability rather than deprivation alone. Such uncertainty is likely to promote sustained cognitive and emotional arousal, including rumination and anticipatory worry, which interfere with sleep initiation and continuity.

Sleep as an Indicator of Structural Vulnerability in Later Life

From a social determinant of health perspective, sleep disturbance in this context reflects structural vulnerability rather than individual pathology [8]. Older adults occupy a uniquely vulnerable position in post-disaster recovery processes due to ageing-related changes in sleep architecture, reduced physiological resilience, fixed incomes, and reliance on institutional support systems.

The pronounced inter-individual variability observed in sleep patterns highlights that vulnerability is not uniform. Sleep may therefore serve as a sensitive indicator of how structural stressors are experienced and embodied differently across individuals.

Temporal Uncertainty and Sleep Fragmentation

A key contribution of this study lies in its attention to the temporal dimension of uncertainty. Participants' concerns were frequently framed in terms of time-limited housing arrangements and uncertain future support. This temporal ambiguity was closely linked to nocturnal awakenings and early morning arousal.

Sleep fragmentation, rather than total sleep deprivation alone, emerged as a salient pattern. Fragmented sleep may represent a physiological imprint of unresolved social conditions that persist precisely because underlying uncertainties remain unaddressed.

Methodological Contributions of Mixed-Methods Approaches

Methodologically, this study demonstrates the value of integrating wearable-derived sleep data with qualitative inquiry to examine embodied social stress. Wearable devices captured day-to-day variability and real-world patterns that would likely be missed by retrospective self-report alone. Qualitative interviews provided essential context for interpreting these patterns.

This approach illustrates how physiological measures can be meaningfully incorporated into social science research when embedded within analyses of lived experience.

Implications for Disaster Recovery and Social Policy

The findings suggest that disaster recovery frameworks characterized by time-limited assistance and ambiguous eligibility criteria may inadvertently reproduce stress among older adults. Addressing sleep problems in post-disaster contexts may therefore require policy measures that enhance predictability, transparency, and continuity in housing and financial support. Recognizing sleep disturbance as a socially patterned outcome highlights the need for recovery strategies that address structural sources of uncertainty rather than focusing exclusively on individual-level interventions.

Conceptual Contributions

Conceptually, this study contributes by framing sleep as an embodied indicator of socioeconomic uncertainty. By emphasizing temporality, predictability, and embodiment, the findings extend existing disaster and ageing research and highlight new pathways through which social conditions shape health.

Limitations and Future Directions

Several limitations should be acknowledged. The small sample size and context-specific nature of the study limit generalizability, and causal relationships cannot be inferred. Wearable-based sleep measures provide indicative patterns rather than clinical diagnoses.

Future research should adopt longitudinal designs to examine how changes in socioeconomic uncertainty correspond to shifts in sleep patterns over time, particularly at key transition points such as the expiration of housing support.

CONCLUSION

This exploratory mixed-methods study demonstrates that sleep patterns among disaster-affected older adults reflect embodied socioeconomic uncertainty. Sleep disturbance

appears closely linked to persistent concerns about future stability rather than solely to past trauma.

Addressing sleep problems in disaster recovery requires attention not only to individual health behaviors but also to the structural conditions that shape predictability and security in later life. Recognizing sleep as an embodied outcome of social conditions may support more socially informed and sustainable approaches to post-disaster recovery for ageing populations.

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