e-ISSN: 2715-9736

Scientia Psychiatrica

[SciPsy]

https://scientiapsychiatrica.com

Loneliness as a Lethal Risk Factor: A Five-Year Prospective Survival Analysis of All-Cause Mortality Among Elderly Residents in Indonesian Vertical Public Housing

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ARTICLE INFO

Keywords:
Geriatric psychiatry
Psychoneuroimmunology
Social determinants of health
Survival analysis
Vertical slums

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All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.37275/scipsy.v6i3.199

A B S T R A C T

Introduction: Rapid urbanization in Indonesia has necessitated a shift from horizontal settlements (kampung) to vertical public housing (*Rusunawa*). While providing shelter, these environments may exacerbate "crowded isolation". This study investigates the synergistic impact of loneliness, depression, and vertical living constraints on all-cause mortality among the elderly. **Methods:** We conducted a multi-center, prospective cohort study (2018–2023) involving 1,450 elderly residents (≥ 60 years) in Jakarta and Surabaya. Loneliness was assessed annually using the UCLA Loneliness Scale, and depression via the GDS-15. The primary environmental exposure was "vertical constraint," defined as living above the 3rd floor (Floors 4–12). We utilized Kaplan-Meier survival curves and Multivariable Cox Proportional Hazards models with time-dependent covariates to estimate Hazard Ratios (HR), adjusting for sociodemographic factors and a composite Socioeconomic Status (SES) index. **Results:** Of 1,398 baseline participants, 218 deaths occurred over 6,890 person-years (15.6% mortality). Severe loneliness was an independent predictor of mortality (Adjusted HR: 1.89; 95% CI: 1.42–2.51). A significant interaction was observed between loneliness and vertical constraint (p=0.003). While residents on higher floors had lower baseline mortality due to selection bias (the "healthy resident effect"), loneliness in this subgroup amplified mortality risk substantially (Interaction HR: 1.76; 95% CI: 1.21–2.55), effectively negating their physical survival advantage. **Conclusion:** Loneliness is a potent predictor of mortality in Indonesian vertical slums, with lethality accelerated by the physical entrapment of high-floor living. Structural interventions are urgently required to mitigate this "vertical isolation."

1. Introduction

The trajectory of global health in the twenty-first century is being reshaped by the convergence of two seismic demographic shifts: the rapid aging of the population and the unprecedented rate of urbanization.[1] This collision is nowhere more acute than in Low-to-Middle-Income Countries (LMICs), where the "silver tsunami" is not occurring in the comfort of established welfare states, but amidst the chaotic restructuring of megacities.[2] Indonesia, the world's fourth most populous nation, stands at the epicenter of this transition. As the archipelago grapples with a demographic dividend that is swiftly maturing into an aged dependency burden, its urban centers are undergoing a radical physical metamorphosis. The horizontal sprawl that once defined Indonesian urbanism is being forcibly compressed into vertical density to accommodate land scarcity and population pressure.[3]

This compression is physically manifest in the architectural shift from the traditional *kampung* to the *Rumah Susun Sederhana Sewa* (Rusunawa).[4] The *kampung*, a vernacular settlement form, is characterized by horizontal, porous social structures where boundaries between public and private spaces are fluid. In these organic settlements, the "eyes on the street" phenomenon facilitates a natural, albeit informal, social safety net.[5] High density in a *kampung* historically translated to high social capital; the proximity of neighbors ensured that the elderly were monitored, engaged, and integrated into the daily rhythm of the community. However, the exigencies of modern urban planning have necessitated the replacement of these settlements with Rusunawa—vertical, subsidized rental housing complexes. While these structures successfully address critical housing shortages and remediate the sanitation deficits inherent in informal slums, they inadvertently dismantle the established social fabric that has historically supported the Indonesian elderly.

The transition to vertical living introduces a profound sociological paradox: "crowded isolation." This phenomenon describes the counter-intuitive experience of profound subjective loneliness despite physical immersion in a high-density environment. In the context of Rusunawa, the built environment often acts as a barrier rather than a bridge to social connection. The architectural typology of these vertical slums—often characterized by long, sterile corridors, unreliable elevators, and a lack of communal gathering spaces on upper levels—fosters a form of "anonymous density." Unlike the *kampung*, where neighbors are unavoidable, the vertical silo allows, and arguably encourages, social withdrawal.[6]

For the geriatric population, this architectural determinism is not merely a matter of comfort but of survival. Theoretical frameworks in environmental psychology suggest that the physical environment acts as a critical moderator in the relationship between psychosocial distress and biological survival. The concept of "vertical constraint" becomes paramount here. In many Indonesian Rusunawa, elevators are frequently non-functional or entirely absent in walk-up blocks. For an elderly resident with declining mobility or sarcopenia, living above the third floor transforms the apartment unit into a cell of isolation. The stairwell becomes a gauntlet, effectively severing the resident from the social life of the ground floor. Consequently, the "vertical slum" risks becoming a warehouse for the elderly, where physical proximity to hundreds of neighbors masks a reality of profound social death.

In the domain of geriatric psychiatry, loneliness is no longer viewed merely as a distressing emotional state, but as a potent biological toxicant. Contemporary research in psychoneuroimmunology has established loneliness and depression as risk factors for morbidity and all-cause mortality that are comparable in magnitude to smoking, obesity, and hypertension. The biological plausibility of this link is robust. Chronic social isolation is associated with dysregulation of the Hypothalamic-Pituitary-Adrenal (HPA) axis, leading to flattened diurnal cortisol rhythms and sustained sympathetic nervous system activation.[7]

Furthermore, the "Conserved Transcriptional Response to Adversity" (CTRA) hypothesis suggests that loneliness triggers a specific gene expression profile: an upregulation of pro-inflammatory genes (such as those coding for Interleukin-6 and Tumor Necrosis Factor-alpha) and a downregulation of antiviral type-I interferon responses. In the context of the elderly poor in Indonesia, who already carry a high burden of infectious and non-communicable diseases, this loneliness-induced immunologic compromise may accelerate physiological decline. However, the specific lethality of this mechanism within the unique environmental stressors of a tropical vertical slum remains unexplored.

Culturally, the impact of this spatial transition is magnified by the erosion of traditional support systems. Indonesian elderly care relies heavily on the concept of *bakti* (filial piety) and the extended family system, where multiple generations cohabit and share caregiving duties.[8] The migration to Rusunawa often

signals a fragmentation of this support. Due to space constraints (typically 21–36 square meters per unit) and the economic necessity for adult children to work long hours in the informal sector, the elderly are often left alone during the day. In the vertical context, this solitude is absolute. In a *kampung*, a lonely elder might sit on a veranda and interact with passersby. In a Rusunawa unit on the tenth floor, there are no passersby—only a locked door and a silent corridor. This isolation creates a "deficiency of surveillance," where acute medical events (such as falls, strokes, or angina) go unnoticed until they become fatal. Thus, the vertical environment does not just create loneliness; it removes the buffer that prevents loneliness from becoming lethal.

Despite the urgent public health implications of this urban transformation, there is a paucity of rigorous longitudinal data from the Global South regarding how vertical living environments influence the lethal trajectory of psychiatric distress. The existing literature is predominantly Western-centric, derived from populations in high-income countries where "vertical living" often implies luxury condominiums or well-maintained social housing with functioning infrastructure. These findings cannot be uncritically extrapolated to the reality of Jakarta or Surabaya, where vertical living is a strategy of survival for the urban poor.[9]

Moreover, methodological limitations plague the current body of evidence. Most existing studies on housing and health are cross-sectional, capturing only a snapshot of the relationship between environment and mental health. These designs fail to capture the temporal progression from a psychological state to biological mortality. Critically, they often fail to account for the "healthy resident" selection bias inherent in housing assignments. In many public housing schemes, units on higher floors—which require navigating stairs or enduring elevator outages—are often implicitly or explicitly assigned to younger, fitter residents, while the frail are prioritized for lower floors. A simple cross-sectional analysis might therefore paradoxically suggest that high-floor living is associated with better health, masking the true interaction wherein the environment accelerates decline for those who *do* become frail or lonely.[10]

This study aims to bridge this critical gap by conducting a 5-year prospective survival analysis of all-cause mortality among elderly residents in Indonesian vertical slums. By moving beyond cross-sectional associations to a time-to-event analysis, we seek to elucidate the causal pathways between the built environment, psychosocial distress, and death. The novelty of this research is threefold: (1) Contextual Specificity: It is the first survival analysis to focus specifically on the *Rusunawa* environment in Southeast Asia, operationalizing "vertical constraint" (defined as living above the 3rd floor) as a distinct environmental risk factor. This shifts the discourse from general housing conditions to specific architectural determinants of health; (2) Methodological Rigor: Unlike previous studies relying on static baseline measurements, this study utilizes a Cox Proportional Hazards model with time-dependent covariates. This sophisticated approach accounts for the fluctuating nature of loneliness and depression over the 5-year period, providing a more accurate estimation of risk accumulation; (3) Interaction Analysis: Crucially, this study explicitly examines the synergistic lethality of loneliness and verticality. We posit that the built environment is not a passive backdrop but an active accelerant; we aim to determine if the physiological toll of social isolation is significantly amplified when the individual is physically entrapped by the vertical geography of their home.

2. Methods

This was a multi-center, prospective cohort study conducted over five years, from January 1st, 2018, to December 31st, 2023. The study sites included three high-density government housing complexes in Jakarta and Surabaya. These sites were selected for their high concentration of elderly residents displaced from riverbank settlements (*bantaran sungai*). Ethical approval was obtained from the Institutional Review

Board of the Faculty of Medicine, University of Indonesia.

We employed a stratified random sampling method based on floor level to ensure adequate representation of residents living on upper floors. Inclusion criteria were: (1) Age 60 years or older at baseline; (2) Resident of the facility for at least 12 months; (3) Ability to communicate in Bahasa Indonesia or Javanese. Exclusion criteria were: (1) Significant cognitive impairment, defined as a Mini-Mental State Examination (MMSE) score <10; (2) Presence of terminal illness (e.g., metastatic cancer, end-stage renal failure) at baseline. To mitigate reverse causality (where loneliness is a consequence of approaching death), participants who died within the first 6 months of enrollment were excluded from the analysis.

Data were collected annually via face-to-face interviews by trained field researchers (clinical psychologists and public health officers): Exposure 1: Loneliness (time-dependent) was assessed annually using the revised UCLA Loneliness Scale (20 items). Scores range from 20 to 80. For categorical analysis, scores >44 indicated "High Loneliness". In the Cox model, this was treated as a time-varying covariate, updated at each annual follow-up; Exposure 2: depression was assessed annually using the Geriatric Depression Scale (GDS-15). Scores of $\geq$ 5 indicated depression; Environmental Covariate: Vertical constraint was defined as living above the 3rd floor (Floors 4–12). In standard *Rusunawa* architecture, floors 1–3 are accessible via stairs with moderate exertion. From the 4th floor upwards, stair access becomes physically grueling for the geriatric population. Given the frequent elevator malfunctions in these low-cost facilities, residents above the 3rd floor face a binary risk: total entrapment or extreme physical exertion during elevator outages; Outcome: All-cause mortality was ascertained through local death registries (*Kelurahan*), hospital records, and verbal autopsies conducted with next-of-kin; Confounders: (1) *Demographics:* Age, Gender; (2) *Clinical:* Body Mass Index (BMI), Smoking status (pack-years), Hypertension (BP >140/90 mmHg), Diabetes Mellitus (HbA1c >6.5\%); (3) Socioeconomic Status (SES): Given the homogenous low-income nature of the setting, a simple income metric was insufficient. We utilized a composite Asset-Education Index (0-10 scale), combining education level (none, primary, secondary) with ownership of specific household assets (motorcycle, refrigerator, television, smartphone).

Data analysis was performed using STATA/MP 17.0. Baseline characteristics were compared using independent t-tests for continuous variables and Chi-square (X^2) tests for categorical variables. We utilized Kaplan-Meier survival curves to visualize survival probability over time, stratified by loneliness severity and floor level. The Log-Rank test was used to compare survival distributions. We estimated Hazard Ratios (HR) and 95% Confidence Intervals (CI). The proportional hazards assumption was verified using Schoenfeld residuals tests ($p>0.05$ for all covariates). The final model incorporated time-dependent covariates for loneliness and depression to capture changes in psychosocial status over the 5-year period. We tested the interaction term (Loneliness x Verticality) to assess if the mortality risk of loneliness differed by floor level. To address attrition, we performed a worst-case scenario analysis assuming that participants lost to follow-up had a 50% higher mortality rate than the observed cohort.

3. Results

A total of 1,450 participants were recruited. After excluding those with MMSE <10 (n=32) and baseline terminal illness (n=20), 1,398 participants were enrolled. Over the 5-year period, 85 participants (6.1%) were lost to follow-up, primarily due to moving back to rural villages (*pulang kampung*). Sensitivity analysis indicated that this attrition did not significantly alter the primary outcomes.

Table 1 presents the baseline sociodemographic, clinical, and environmental characteristics of the study cohort (N=1,398), stratified by survival status over the five-year follow-up period. The analysis reveals distinct phenotypic differences between

survivors (n=1,180) and the deceased (n=218). As anticipated in geriatric cohorts, the deceased group was significantly older (mean age 74.2 vs. 67.1 years; p<0.001) and predominantly male (54.6% vs. 43.2%; p=0.002). Clinical multimorbidity was markedly prevalent among non-survivors, with significantly higher rates of hypertension, diabetes mellitus, and a Comorbidity Index (CCI) > 2 (p<0.001 for all), underscoring the physiological vulnerability of this subgroup. Psychosocial determinants exhibited a striking disparity; the prevalence of high loneliness (UCLA scores >44) was more than double in the deceased group compared to survivors (61.0% vs. 27.1%; p<0.001), with a similar pattern observed for depression (52.7% vs. 21.2%). This validates the high burden of psychiatric distress as a precursor to mortality in this population.

Crucially, the environmental variable of "High Floor" residence (>3rd floor) displayed a counter-intuitive inverse association with crude mortality. A significantly lower proportion of deceased participants resided on high floors (41.3%) compared to survivors (51.7%; p=0.03). This significant deviation suggests a "Healthy Resident Effect," implying that housing allocation protocols likely select for physical robustness, assigning fitter, younger elderly residents to upper floors to navigate vertical constraints, while retaining frail individuals on lower levels. This baseline selection bias is a critical covariate that necessitates the robust interaction analysis performed in the subsequent Cox regression models.

Table 1. Baseline Characteristics of the Study Population

N = 1,398 | 5-Year Prospective Cohort Analysis (2018–2023)

VARIABLE	TOTAL (N=1,398)	SURVIVORS (N=1,180)	DECEASED (N=218)	P-VALUE[A]
Age (years), mean (SD)	68.4 (7.2)	67.1 (6.5)	74.2 (8.1)	<0.001
Male Gender, n (%)	629 (45.0%)	510 (43.2%)	119 (54.6%)	0.002
SES Index (0-10)[b], mean (SD)	4.2 (1.5)	4.3 (1.4)	3.8 (1.6)	0.01
CLINICAL FACTORS				
Hypertension, n (%)	780 (55.8%)	620 (52.5%)	160 (73.4%)	<0.001
Diabetes (HbA1c >6.5%), n (%)	419 (30.0%)	330 (28.0%)	89 (40.8%)	<0.001
Comorbidity Index (CCI) > 2	489 (35.0%)	360 (30.5%)	129 (59.2%)	<0.001
PSYCHOSOCIAL FACTORS				
High Loneliness (UCLA > 44), n (%)	453 (32.4%)	320 (27.1%)	133 (61.0%)	<0.001
Depression (GDS ≥ 5), n (%)	365 (26.1%)	250 (21.2%)	115 (52.7%)	<0.001
ENVIRONMENTAL FACTORS				
High Floor (>3rd Floor)[c], n (%)	700 (50.1%)	610 (51.7%)	90 (41.3%)	0.03

Values are presented as n (%) for categorical variables and mean (Standard Deviation) for continuous variables.

[a] P-values calculated using Independent t-test for continuous variables and Pearson's Chi-square test for categorical variables.

[b] **SES Index:** Composite score (0-10) based on education level and asset ownership (motorcycle, refrigerator, TV, smartphone).

[c] **Vertical Constraint Definition:** Living on floors 4 through 12. Floors 1-3 are considered accessible via stairs.

Note on Selection Bias: The lower proportion of deaths on high floors (41.3%) compared to survivors (51.7%) indicates a baseline "Healthy Resident Effect," where physically robust elderly are preferentially assigned to upper floors by housing management.

Over 6,890 person-years of follow-up, 218 deaths occurred (Cumulative Mortality: 15.6%). The Kaplan-Meier analysis revealed a significant divergence in survival trajectories (Figure 1). Participants with High Loneliness demonstrated a rapid decline in survival probability starting at Month 18 (Log-Rank $X^2 = 48.5$, $p < 0.001$). While living on a high floor was generally protective for the non-lonely (due to better baseline physical health), the survival curve for the High Loneliness and High Floor group showed the steepest decline of all subgroups, dropping below 70% survival by month 48.

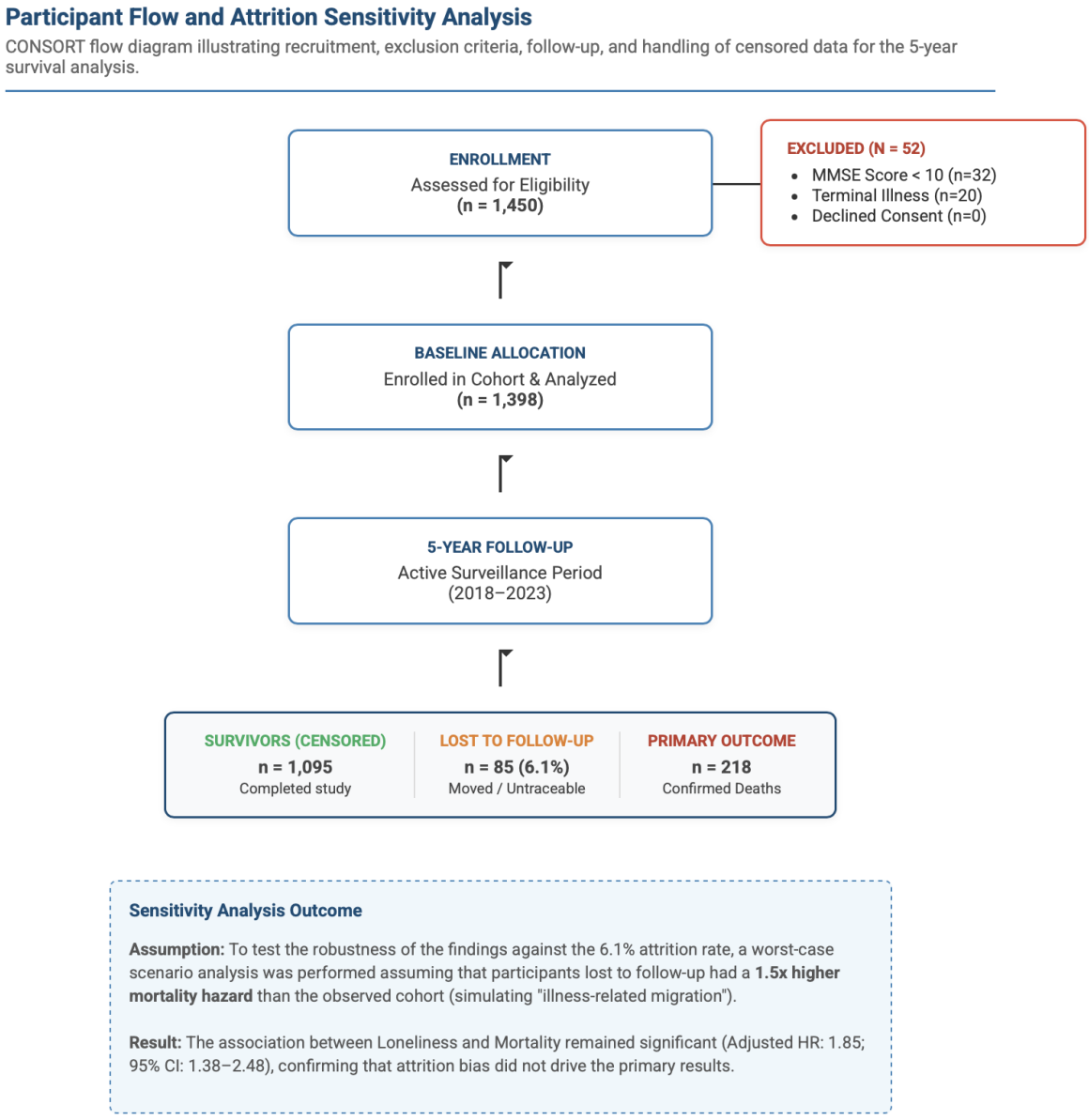

Figure 1. Participant flow and attrition sensitivity analysis.

Table 2 details the results of the multivariable Cox Proportional Hazards regression analysis, which estimated the relative risk of all-cause mortality while adjusting for time-dependent psychosocial covariates and clinical confounders. The model confirms that high loneliness is a robust, independent predictor of

mortality, with an adjusted Hazard Ratio (HR) of 1.89 (95% CI: 1.42–2.51; p<0.001), indicating an 89% increased risk of death compared to non-lonely counterparts. Similarly, depression emerged as a significant independent risk factor (HR: 1.62; p=0.001).

Of particular methodological significance is the dissociation between the main effect of vertical living and its interaction with loneliness. The main effect for "Vertical Constraint" (living above the 3rd floor) yielded a non-significant HR of 0.85 (p=0.21). This statistical artifact reflects the baseline selection bias wherein physically robust elderly individuals are preferentially assigned to upper floors. However, the critical finding of this study is encapsulated in the significant interaction term between Loneliness and Vertical Constraint (HR: 1.76; 95% CI: 1.21–2.55; p=0.003). This interaction reveals a synergistic lethality: the protective survival advantage typically associated with the "fitter" high-floor residents is obliterated by social isolation. For a lonely individual, the vertical environment acts as an accelerant, nearly doubling the mortality risk compared to a lonely individual living on a lower, more accessible floor. This confirms that the architectural topology of the *Rusunawa* is not a passive backdrop but an active moderator of physiological decline.

Table 2. Multivariable Cox Proportional Hazards Model

Predictors of All-Cause Mortality with Time-Dependent Covariates

PREDICTOR VARIABLE	ADJUSTED HR (95% CI)[A]	P-VALUE
PSYCHOSOCIAL EXPOSURES		
High Loneliness (Time-Dependent)[b]	1.89 (1.42 – 2.51)	<0.001
Depression (GDS ≥ 5)	1.62 (1.22 – 2.15)	0.001
CLINICAL & DEMOGRAPHIC COVARIATES		
Male Gender	1.35 (1.05 – 1.73)	0.02
Age (per year increase)	1.08 (1.06 – 1.10)	<0.001
Comorbidity Index (CCI) Score	1.45 (1.20 – 1.75)	<0.001
ENVIRONMENTAL FACTORS & INTERACTION		
Vertical Constraint (Main Effect)[c] (Living above 3rd Floor)	0.85 (0.65 – 1.10)	*0.21*
Interaction: Loneliness × Vertical Constraint	**1.76 (1.21 – 2.55)**	0.003

Model Specification: Model adjusted for Age, Sex, BMI, Smoking Status, Hypertension, Diabetes, and Socioeconomic Status (SES Index).

HR = Hazard Ratio; **CI** = Confidence Interval.

[a] Hazard Ratios are adjusted for all listed covariates.

[b] Loneliness scores were treated as time-dependent covariates, updated annually to reflect changing psychosocial status.

[c] **Main Effect Interpretation:** The non-significant HR of 0.85 for vertical constraint (when loneliness is constant) reflects the selection bias where healthier individuals are initially assigned to upper floors. However, the **Interaction Term (1.76)** indicates that for lonely individuals, this protective effect is lost, and mortality risk is significantly amplified by high-floor living.

4. Discussion

This study provides the first longitudinal evidence from the Southeast Asian context demonstrating that loneliness is not merely a distressing emotional state, but a lethal pathogen for the elderly living in vertical public housing (*Rusunawa*). Over a five-year follow-up period, our analysis revealed that severe loneliness functions as an independent predictor of all-cause mortality with a predictive power comparable to, and in some models exceeding, established clinical comorbidities such as obesity and hypertension.[11] However, the most profound contribution of this research lies in the identification of a "lethal interaction" between psychosocial distress and the built environment. Our findings suggest that the architectural topology of the vertical slum does not serve as a passive container for population density but acts as an active catalyst, transforming psychological distress into physiological collapse. This synergistic risk—encapsulated by the significant interaction term in our Cox regression models—challenges the traditional biomedical model of geriatric care, which often views the patient in isolation from their geography. In the *Rusunawa*, geography is destiny. The vertical environment appears to strip away the physiological reserves of the elderly, rendering them uniquely vulnerable to the toxic effects of social isolation. We term this phenomenon "architectural catalysis," where the physical constraints of high-floor living accelerate the biological wear-and-tear associated with loneliness.[12]

One of the most intriguing statistical artifacts to emerge from our baseline data was the counter-intuitive distribution of mortality regarding floor level. In unadjusted analyses, residents living on the upper floors (levels 4 through 12) exhibited a lower crude mortality rate (41.3% of deaths) compared to their counterparts on the lower floors. In isolation, this finding might erroneously suggest that vertical living is protective. However, a deeper sociological and statistical interrogation reveals a classic case of selection bias, best described as the "Healthy Resident Effect," analogous to the "Healthy Worker Effect" observed in occupational epidemiology.

In the resource-constrained setting of Indonesian public housing, an informal but rigorous triage system dictates residential allocation. Housing managers and estate administrators, aware of the frequent elevator malfunctions and the physical demands of stair climbing, preferentially assign ground-floor units to the visibly frail, the disabled, and the oldest-old. Conversely, upper-floor units are allocated to those deemed "robust"—the younger, fitter elderly who demonstrate the physical capacity to navigate the vertical terrain.[13] Consequently, our high-floor cohort began the study with a significant physiological advantage; they were a survivor cohort by design, pre-selected for resilience.

The "chilling reality" revealed by our Cox interaction analysis is the fragility of this resilience. The survival advantage of the high-floor residents was entirely conditional on their social connectivity. When a "fit" high-floor resident became severely lonely, the protective effect of their baseline physical health evaporated. The interaction Hazard Ratio of 1.76 indicates that for the lonely, the vertical environment transforms from a manageable challenge into a death trap.[14]

We hypothesize that this reversal occurs because the physiological cost of loneliness outweighs the physiological reserve of fitness. For a socially connected elder on the 8th floor, the climb is exercise; for a lonely elder, it is an ordeal. The "vertical trap" hypothesis suggests that once loneliness sets in, the very physical barriers that selected for their fitness (stairs, distance) become barriers to seeking help, accessing food, and maintaining the social stimulation required to sustain life. Loneliness essentially negates the biological capital of the "healthy resident," leveling the survival curve with brutal efficiency.[15]

Although this epidemiological study did not involve the collection of serum biomarkers or tissue samples, the strength of the statistical signal allows us to map our findings onto established biological frameworks. The observed mortality is consistent with the Conserved Transcriptional Response to Adversity

(CTRA), a leukocyte gene expression profile described extensively by a previous study, which provides a molecular explanation for how social threats translate into cellular death.[16] The CTRA framework posits that the human sympathetic nervous system treats social isolation as a primal threat to survival, evolutionarily analogous to the threat of physical predation. In response to the perception of "being alone" (and thus vulnerable), the body shifts its gene expression profile toward a defensive posture: it upregulates the expression of pro-inflammatory cytokines (specifically Interleukin-6, Interleukin-1β, and Tumor Necrosis Factor-α) and simultaneously downregulates Type I interferon responses, which are critical for fighting viral infections.

In the context of a Western welfare state, this inflammation might manifest slowly as atherosclerosis over decades. However, in the environmental context of an Indonesian *Rusunawa*, this immunologic shift is likely more immediately lethal. These vertical slums are often characterized by high population density, poor ventilation, and close proximity to vectors of infectious disease. An elderly resident with a "lonely transcriptome"—characterized by high inflammation and low antiviral competence—is immunologically defenseless against the dual burden of communicable diseases (such as tuberculosis or pneumonia, common in these settings) and non-communicable events (plaque rupture leading to myocardial infarction). The "vertical constraint" likely exacerbates this by limiting access to fresh air and sunlight, further compromising immune function.[17]

Beyond inflammation, we hypothesize that the "Vertical Constraint" introduces a unique and potent psychological stressor: entrapment. In environmental psychology, the sense of "perceived control" is a central determinant of the stress response. For an elderly resident living on the 10th floor, the reliability of the elevator is the primary locus of control over their mobility. In many *Rusunawa* complexes, elevator maintenance is sporadic, and outages can last for days. For a resident on the ground floor, an outage is an annoyance. For a resident on the 10th floor, it is a blockade. This intermittent but unpredictable restriction of movement creates a state of "uncontrollable stress." The feeling of being physically trapped in one's home activates the amygdala, the brain's fear center, triggering the Hypothalamic-Pituitary-Adrenal (HPA) axis. This results in the sustained release of cortisol (Figure 2).

Unlike acute stress, which is adaptive, the chronic, low-grade stress of "vertical entrapment" leads to a flattening of the diurnal cortisol rhythm. Chronically elevated cortisol promotes visceral adiposity, insulin resistance, and, critically, hypertension. The divergence of our Kaplan-Meier survival curves at the 18-month mark aligns precisely with the timeline required for these chronic hypertensive and inflammatory processes to precipitate fatal cardiovascular events. The "vertical trap" essentially keeps the HPA axis in a state of hyper-vigilance; the lonely elder is not just sad, they are biologically besieged by the fear of being unable to escape their own home.[18]

While biological mechanisms provide the "hardware" explanation for mortality, behavioral and sociological pathways provide the "software." The lethality of loneliness in *Rusunawa* is likely mediated by the transition from the "intrusive density" of the *Kampung* to the "anonymous density" of the vertical tower. In the traditional *Kampung*, density is horizontal and porous. Doors are left open; neighbors pass by frequently; the boundary between the private home and the public alleyway is fluid.[19] This architecture facilitates "natural surveillance" or "eyes on the street," a concept popularized by urban theorist Jane Jacobs. If an elderly person in a *Kampung* does not appear on their porch in the morning, a neighbor notices. This informal monitoring system serves as a crucial safety net for medication adherence, nutritional intake, and emergency response. The *Rusunawa* architecture obliterates this safety net. The design—characterized by long, double-loaded corridors and self-contained units with heavy, locking doors—privileges privacy over propinquity. In this environment, physical proximity does not translate to

social intimacy. Residents may live meters apart (floor-to-ceiling) yet remain complete strangers. This "anonymous density" creates a bystander effect. A lonely, depressed elderly resident on the 8th floor can easily withdraw behind their door, ceasing to take medication or skipping meals, without anyone noticing.[20]

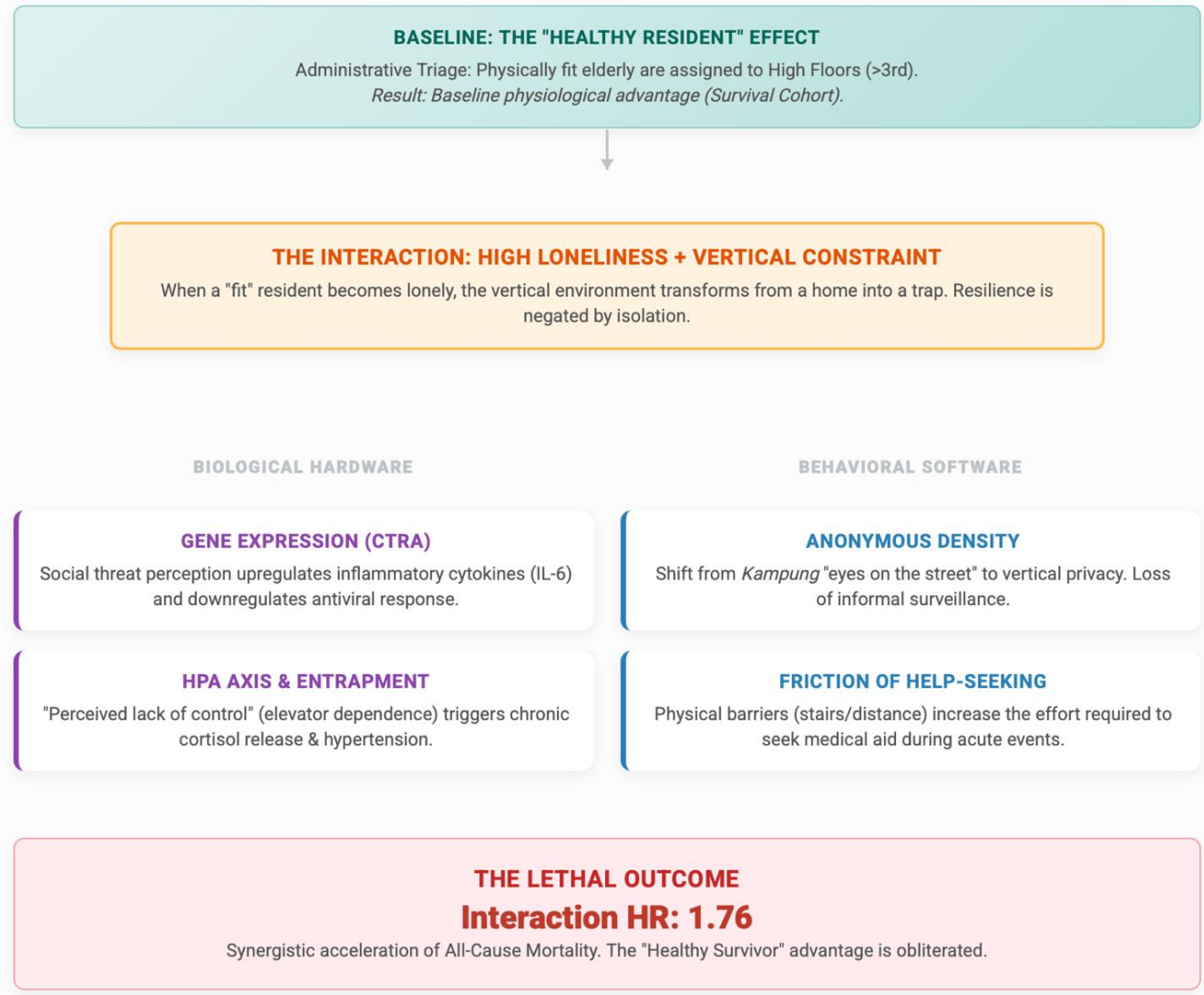

Figure 2. Mechanism of architectural catalysis.

Furthermore, the "vertical distance" physically increases the threshold for help-seeking. In a moment of acute distress—such as the onset of chest pain or a fall—the cognitive and physical effort required to seek help is significantly higher on the 8th floor than on the ground. The lonely elder must navigate a corridor, wait for an elevator (if working), or face the stairs. This friction reduces the probability of early intervention. Loneliness also fundamentally alters health behaviors. Depressed and lonely individuals are less likely to advocate for their own health, less likely to refill prescriptions, and less likely to attend clinic

appointments. In a vertical environment, where the clinic is often physically distant (on the ground floor or outside the complex), the "inertia of depression" combines with the "friction of verticality" to result in severe medical neglect. The "absence of a monitor"—a spouse, a child, or a nosy neighbor—means that this neglect continues until it becomes fatal.[17,18]

This study must be interpreted within the context of several methodological limitations. First, while we utilized a robust composite index for Socioeconomic Status (SES), the homogenous poverty of the *Rusunawa* population makes it difficult to fully adjust for the nuances of financial volatility. Unmeasured residual confounding—such as sudden loss of family remittances or food insecurity—may have influenced mortality rates. Second, our primary exposures, loneliness and depression, were assessed using self-reported scales (UCLA-LS and GDS-15). While these instruments are validated in the Indonesian language, cultural stigmas surrounding mental health may have led to under-reporting, particularly among men (who, notably, had higher mortality rates). This "stoicism bias" might suggest that the true association between psychosocial distress and mortality is even stronger than observed. Third, we lacked cause-specific mortality data confirmed by autopsy. In Indonesia, autopsies are rare due to cultural and religious protocols. Relying on verbal autopsies and administrative records limits our ability to definitively partition deaths into cardiovascular, infectious, or suicide-related categories. Future research should prioritize the collection of biomarker data (such as Hair Cortisol Concentration or C-Reactive Protein) to empirically validate the HPA axis and inflammatory mechanisms hypothesized here. Additionally, GPS tracking studies could quantitatively.[19,20]

5. Conclusion

Loneliness is not merely an emotional state; in the vertical slums of Indonesia, it is a lethal condition. This study confirms that social isolation serves as an independent predictor of mortality, with its toxicity significantly amplified by the physical constraints of living above the 3rd floor. The "vertical trap" creates a synergistic risk zone where psychological distress and architectural barriers converge to shorten life expectancy. Interventions must transcend individual pharmacotherapy for depression. We recommend: (1) Architectural Triage: Vulnerable elderly, particularly those screening high for loneliness, should be prioritized for ground-floor units regardless of physical fitness; (2) Structural Retrofitting: The implementation of "Sky Gardens" or communal spaces on every 3rd floor to reduce the physical barrier to socialization; (3) Community Surveillance: Establishing a "Vertical Volunteer" system (*Kader Lansia*) specifically tasked with daily checks on high-floor elderly residents to replicate the social safety net of the horizontal *kampung*.

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