

Age-dependent association between early inpatient motor activity and subsequent length of stay in depressive disorders: a retrospective cohort study

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Abstract

Background

Objective motor behavior may provide complementary information about psychiatric inpatient trajectories, but higher movement is not necessarily clinically favorable and may have different meanings at different ages. We examined whether the association between early inpatient motor activity and subsequent length of stay (LOS) varies across adulthood in depressive disorders.

Methods

In this retrospective cohort study, we analyzed 255 adults hospitalized with ICD-10 depressive disorders during 2024–2025. Motor activity was averaged across the earliest three valid actigraphy days within the first inpatient week, and a dynamic landmark at the end of the third valid day separated exposure assessment from subsequent LOS. Gamma generalized linear models with a log link tested interactions between standardized activity measures and age modeled continuously with a 3-degree-of-freedom restricted cubic spline. Benjamini-Hochberg false-discovery-rate correction was applied across four activity-by-age interaction tests.

Results

Age modified the adjusted associations of vector magnitude per minute (VM/min), steps/hour, and moderate-activity percentage with post-landmark LOS after false-discovery-rate correction, whereas the sedentary-percentage interaction was not significant. Per 1-SD higher VM/min, expected post-landmark LOS was 14.3% shorter at age 20 (95% CI, -22.0% to -5.9%), near null at age 40 (-0.1%; 95% CI, -14.4% to 16.6%), and 18.6% longer at age 60 (95% CI, 7.7% to 30.7%). The principal interaction was supported by alternative outcome models, spline specifications, medication-adjustment strategies, influence analyses, and bootstrap resampling.

Conclusions

The clinical information conveyed by early inpatient motor activity varied with age rather than following a uniform direction. Age should therefore be considered when interpreting actigraphy in depressive-disorder inpatients, although external validation is needed before clinical use.

Background

Length of stay (LOS) is a clinically, operationally, and socioeconomically relevant outcome that reflects the duration of inpatient care, bed utilization, and burdens borne by patients, families, and health systems. In psychiatric services with high inpatient demand, avoiding unnecessarily prolonged

hospitalization while ensuring safe and clinically appropriate discharge can improve bed availability and reduce resource burden. Studies in China and other settings show that LOS among patients hospitalized with depressive disorders varies with demographic characteristics, episode severity, comorbidity, treatment, and health-service factors, while depressive-disorder hospitalization itself carries substantial healthcare utilization and economic costs [1–4]. Objective behavioral measures collected early in hospitalization may provide information about the subsequent inpatient course beyond conventional clinical and administrative variables.

Psychomotor disturbance is a core feature of depressive disorders and may involve retardation or agitation [5]. Actigraphy provides continuous, naturalistic quantification of motor behavior with relatively little burden on patients or clinical staff. Systematic reviews and meta-analytic evidence show lower activity in depression than in healthy individuals and changes in activity over the course of treatment [6, 7]. However, movement magnitude is not clinically valence-specific: lower activity may reflect psychomotor slowing or reduced behavioral activation, whereas higher activity may indicate preserved mobility, restlessness, or psychomotor agitation [8]. Motor activity can also be influenced by treatment exposure because sedative medications may suppress objectively recorded movement [9].

Age may be an important source of this contextual variation. Depressive presentations differ across adulthood in affective, cognitive, neurovegetative, somatic, and psychomotor features [10, 11]. East Asian studies likewise report age-related differences in depressive symptom profiles and somatic symptom burden [12, 13]. Baseline mobility, medical complexity, treatment tolerability, and discharge-related needs may also vary with age. Consequently, a given level of recorded movement may represent different combinations of functional capacity, psychomotor slowing, behavioral activation, treatment effects, and restlessness at different points in adulthood. Although age has shown inconsistent associations with LOS in depression [1, 3], whether age modifies the activity-LOS relationship remains unclear.

In a retrospective cohort of adults hospitalized with depressive disorders, we used a landmark design to temporally separate motor activity assessed during the earliest three valid days of the first inpatient week from subsequent LOS. We examined whether higher early inpatient motor activity was uniformly associated with shorter subsequent LOS and assessed age as a continuous effect modifier to determine whether the activity-LOS association varied across adulthood.

Methods

Study design and participants

This retrospective cohort study included consecutive eligible admissions to a psychiatric ward at Chengdu Fourth People's Hospital between January 2024 and December 2025. Eligible admissions involved patients aged 18 years or older with an International Classification of Diseases, 10th Revision

(ICD-10) depressive-disorder discharge diagnosis and inpatient actigraphy data. Depressive episodes were categorized as mild, moderate, or severe from the discharge diagnosis.

Actigraphy measures and landmark design

Actigraphy was recorded using an ActiGraph wGT3X-BT triaxial accelerometer (ActiGraph, LLC, Pensacola, FL, USA), worn on the non-dominant wrist throughout the monitoring period. Daily summary reports were generated using ActiLife 6. Wear-time classification in the source reports was based on the Troiano algorithm [14], and report-derived activity-intensity categories were based on the Freedson Adult algorithm [15].

For the final structured analysis, four actigraphy measures were selected as representative measures of clinically interpretable activity domains based on measurement domain, clinical interpretability, algorithm dependence, and redundancy, while avoiding analysis of the full set of highly redundant device outputs. VM/min was the principal measure of overall triaxial movement and was calculated as accumulated vector magnitude counts divided by valid wear minutes. Steps/hour represented ambulatory activity and was calculated as total steps divided by valid wear hours. Moderate-activity percentage represented the proportion of valid wear time classified by the device algorithm as moderate-intensity activity and was included as a supporting measure of activity intensity. Sedentary percentage represented the proportion of valid wear time classified as sedentary and was included as a secondary low-activity measure. Further details on measure selection and correlations among activity measures are provided in Supplementary Material.

Inpatient day 1 was defined as the calendar date of admission. A valid day required at least 600 min of wear during inpatient days 1–7. For each admission, the earliest three valid days were selected, and daily activity measures were averaged across these days. The exposure window ended at 24:00 on the third valid day, which defined the dynamic landmark. Post-landmark LOS was calculated as the discharge calendar date minus the third valid calendar date; the landmark day was excluded and the discharge date was included.

Statistical analysis

Continuous variables are reported as mean (standard deviation) or median [interquartile range], and categorical variables as n (%). Activity measures were standardized to z scores using the mean and sample standard deviation of the primary cohort and were analyzed in separate models.

No a priori sample-size calculation was performed because this retrospective study included all consecutive eligible admissions during the predefined study period. All variables required for the primary analyses were complete in the 255-patient primary cohort; therefore, no imputation was performed.

All primary models adjusted for sex, depressive-episode severity, landmark day, mean wear time, the proportion of selected days occurring on weekends, the standardized number of distinct sedative-related

medications administered from admission through the landmark, and any temporary sedative or antipsychotic injection administered during the same period. Medication exposure was derived from electronic medication administration records. Sex was recorded as female or male in the electronic medical record.

Because post-landmark LOS was a positive, right-skewed duration outcome, the principal analysis used a Gamma generalized linear model with a log link and Huber-White HC0 robust covariance. Age was modeled continuously using a restricted cubic spline with 3 degrees of freedom, with boundary knots at 18 and 80 years and internal knots at 36 and 54 years. Each standardized activity measure was interacted with the three age-spline basis functions, and the global interaction was assessed using a joint 3-df Wald test. Benjamini-Hochberg false-discovery-rate correction was applied across the four activity-by-age interaction tests. Effects at ages 20, 40, and 60 years were reported as representative points on the continuous curve rather than as age groups or thresholds.

Robustness analyses examined alternative outcome distributions and spline specifications, restriction of the upper age range, influential observations, sleep adjustment, repeated admissions, winsorization, and alternative medication-adjustment strategies; detailed specifications are provided in Supplementary Material. All statistical analyses were performed in Python 3.13.5 using statsmodels 0.14.6, patsy 1.0.2, SciPy 1.17.0, and NumPy 2.3.5. For the four activity-by-age interaction tests, statistical significance was defined as an FDR-adjusted $q < 0.05$; other tests were two-sided with $P < 0.05$.

Use of generative artificial intelligence

During manuscript preparation, ChatGPT (OpenAI) was used to assist with language editing, manuscript organization, and reference checking. All AI-assisted output was reviewed and verified by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

Results

Participants and cohort characteristics

Among 951 linked actigraphy reports, 436 represented admissions with an ICD-10 depressive-disorder discharge diagnosis and 299 were adult admissions. During inpatient days 1–7, 21 admissions had no valid day, seven had one valid day, and 11 had two valid days; 260 admissions completed three valid days. After excluding five later eligible admissions from patients already represented, the primary cohort comprised 255 unique patients (Fig. 1). Characteristics of landmark-eligible versus excluded adult admissions are shown in Supplementary Table S1. Mean age was 38.7 years (SD 15.7), 190 (74.5%) were female, and 181 (71.0%) had a moderate depressive episode. Median total LOS was 22 days [15–30], median post-landmark LOS was 18 days [11–26], and the median landmark occurred on inpatient day 5 [4–5] (Table 1).

Table 1
Characteristics of the primary cohort

Characteristic	Value (N = 255)
Age, years	38.7 (15.7)
Female sex	190 (74.5%)
Depressive episode severity	
Mild	25 (9.8%)
Moderate	181 (71.0%)
Severe	49 (19.2%)
Total LOS, days	22 [15–30]
Post-landmark LOS, days	18 [11–26]
Landmark day	5 [4–5]
Mean wear time, min/day	1192.8 (138.0)
Weekend proportion	0.30 (0.29)
VM/min	1063.9 (375.2)
Steps/hour	389.3 (147.2)
Moderate activity, %	6.03 (3.76)
Sedentary, %	60.2 (8.4)
Any sedative-related medication administered before landmark	248 (97.3%)
Distinct sedative-related medications administered, n	2.24 (1.10)
Temporary sedative/antipsychotic injection	12 (4.7%)
<i>Note. Values are mean (SD), median [IQR], or n (%). LOS, length of stay; VM, Vector Magnitude.</i>	

Age-dependent associations with post-landmark LOS

Age significantly modified the adjusted association between vector magnitude per minute (VM/min) and post-landmark LOS (Wald $\chi^2(3) = 35.72$; false-discovery-rate [FDR] $q < 0.001$). Significant interactions were also observed for steps/hour ($\chi^2(3) = 13.45$; $q = 0.005$) and moderate-activity percentage ($\chi^2(3) = 30.10$; $q < 0.001$), whereas the sedentary-percentage interaction was not significant ($\chi^2(3) = 6.50$; $q = 0.090$) (Table 2).

Table 2
Global age-by-activity interaction tests for post-landmark LOS

Activity measure	Role	Wald χ^2	df	Raw P	FDR q
VM/min	Principal	35.72	3	< 0.001	< 0.001
Steps/hour	Supporting	13.45	3	0.0038	0.0050
Moderate activity, %	Supporting	30.10	3	< 0.001	< 0.001
Sedentary, %	Secondary	6.50	3	0.090	0.090
<p><i>Note. Separate Gamma-log models were fitted for each standardized activity measure. All models adjusted for sex, depressive-episode severity, landmark day, mean wear time, weekend proportion, standardized number of distinct sedative-related medications administered before landmark, and temporary sedative/antipsychotic injection. FDR, false discovery rate. For readability, P and q values below 0.001 are reported as < 0.001.</i></p>					

Effects at representative ages

Per 1-SD higher VM/min, expected post-landmark LOS was 14.3% shorter at age 20 (95% CI, -22.0% to -5.9%; $P = 0.0013$), near null at age 40 (-0.1%; 95% CI, -14.4% to 16.6%; $P = 0.990$), and 18.6% longer at age 60 (95% CI, 7.7% to 30.7%; $P < 0.001$) (Fig. 2; Table 3). Moderate-activity percentage showed a similar pattern (-17.2% at age 20, -2.2% at age 40, and + 18.1% at age 60). For steps/hour, the age-60 estimate was + 20.2% (95% CI, 8.2% to 33.6%; $P < 0.001$), whereas the age-20 estimate was imprecise.

Table 3
Adjusted activity effects at representative ages

Activity measure	Age, years	Change in expected post-landmark LOS per 1 SD, %	95% CI	P value
VM/min	20	-14.3	-22.0 to -5.9	0.0013
VM/min	40	-0.1	-14.4 to 16.6	0.990
VM/min	60	18.6	7.7 to 30.7	< 0.001
Steps/hour	20	-6.8	-20.3 to 9.0	0.379
Steps/hour	40	-3.6	-15.2 to 9.5	0.572
Steps/hour	60	20.2	8.2 to 33.6	< 0.001
Moderate activity, %	20	-17.2	-26.7 to -6.5	0.0023
Moderate activity, %	40	-2.2	-16.1 to 14.1	0.781
Moderate activity, %	60	18.1	6.4 to 31.0	0.0017
<p><i>Note. Ages 20, 40, and 60 are representative points on the continuous spline curve and are not group boundaries or clinical thresholds. Sedentary percentage is not shown because its global age interaction was not significant.</i></p>				

Robustness analyses

The VM/min-by-age interaction remained significant in negative-binomial and log-normal models, with alternative spline specifications, after restriction to patients aged 65 years or younger, after additional adjustment for sleep duration and sleep efficiency, and in all 260 eligible admissions using patient-clustered robust standard errors (all $P < 0.004$). Separate exclusion of the highest 1% of post-landmark LOS values or the lowest and highest 1% of VM/min values retained the interaction, as did winsorization of the upper LOS tail and both VM/min tails. No single participant determined the result: deleting the most influential participant and all leave-one-out refits retained significance. In 1000 patient-level bootstrap resamples generated with a fixed random seed of 2026, median VM/min effects were -14.6% at age 20 (95% percentile interval, -22.9% to -1.4%) and $+17.8\%$ at age 60 ($+2.9\%$ to $+30.8\%$). Results were also similar across alternative medication-administration coding strategies (Supplementary Tables S4-S8).

Discussion

Age significantly modified the association between early inpatient motor activity and subsequent LOS. Higher VM/min was associated with a shorter post-landmark LOS at younger ages, approached the null around mid-adulthood, and was associated with a longer LOS at later ages within the observed distribution. Moderate-activity percentage showed a similar pattern, steps/hour was positively associated with LOS at later ages, and sedentary percentage showed no significant age interaction. The convergence across active-movement measures supports an age-dependent interpretation of the activity-LOS relationship rather than a uniform direction across adulthood.

Previous actigraphy research has established motor activity as an objective behavioral correlate of depression: reduced activity is frequently observed during depressive states, and actigraphic measures can change over the course of treatment [6, 7, 16, 17]. Lower activity has also been associated with depressive severity and psychomotor disturbance [18–20]. In depressed psychiatric inpatients, Peis et al. [21] showed that early actigraphic activity contained information relevant to the subsequent clinical course and hospital discharge. Our findings identify age as an important source of heterogeneity in this relationship. Rather than carrying a fixed clinical meaning across adulthood, the information conveyed by objectively measured movement appears to depend on the age context in which it is observed.

At younger ages, the inverse activity-LOS association is consistent with the established relationship between reduced movement and psychomotor retardation in depression. Psychomotor retardation includes reduced spontaneous movement, slowed speech and cognition, and impaired initiation of goal-directed behavior [5, 22]. Objective motor measures correspond particularly well with clinically assessed retardation [18, 19, 23]. Higher early VM/min and moderate-activity percentage in younger inpatients may therefore reflect relatively preserved spontaneous activity, behavioral activation, and functional capacity. Their stronger associations than steps/hour also suggest that overall movement and activity intensity may capture information not fully represented by ambulatory step counts alone.

At later ages, higher motor activity may represent a broader range of clinical states. Actigraphy quantifies movement but does not identify its behavioral purpose. Distinct actigraphic patterns have been reported in depression with psychomotor retardation versus agitation [8], while the correspondence between clinical psychomotor symptoms and objective movement can vary with age [23]. Higher activity later in adulthood may therefore reflect combinations of preserved mobility, restlessness, anxiety-related movement, psychomotor activation, or treatment-related effects. This interpretation is compatible with age-related heterogeneity in depressive presentations documented in both Asian and non-Asian samples [10–13]. The opposite directions across age thus suggest that similar amounts of movement can index different clinical states at different stages of adulthood.

The pattern across activity dimensions adds further nuance. Significant interactions were observed for VM/min, moderate-activity percentage, and steps/hour, which primarily characterize active movement, but not for sedentary percentage. Age-related heterogeneity may therefore be expressed more clearly in the amount and intensity of active behavior than in low-activity time alone. Different actigraphic outputs are nevertheless influenced by sensor placement, analytic strategy, and activity thresholds [16].

Treatment exposure is also relevant because sedative medication can suppress objectively measured movement [9], and antidepressant treatment can alter 24-hour activity profiles [24]. The persistence of the principal interaction after sleep adjustment and across medication-adjustment strategies strengthens the interpretation of an age-dependent behavioral pattern.

The age-dependent pattern also has practical implications for psychiatric inpatient care. LOS is shaped by illness severity, comorbidity, treatment, and health-service factors [1, 3, 4], and depressive-disorder hospitalization carries substantial healthcare utilization and economic burden [2]. Actigraphy adds a continuous, objective, and relatively low-burden measure of patients' behavior during hospitalization. Interpreting this information together with age may allow a more refined characterization of early inpatient trajectories than activity level alone. Future models integrating age-sensitive motor information with symptoms, treatment exposure, and functional status could test whether this information improves characterization of inpatient trajectories and resource use.

Several limitations should be acknowledged. The retrospective single-center design limits causal inference and external generalizability, and requiring three valid actigraphy days may underrepresent very short admissions. Standardized contemporaneous ratings of psychomotor retardation and agitation were unavailable, and residual confounding from medication dose and timing, physical comorbidity, functional status, anxiety, and discharge-related social factors remains possible. Report-derived moderate-activity and sedentary percentages were based on algorithmic classifications from wrist-worn recordings, and sleep-classified periods were not removed from sedentary percentage; these measures should therefore be interpreted as device-derived activity dimensions rather than precise physiological intensity or waking sedentary behavior. Statistical support was more limited at the upper end of the age distribution, so ages 20, 40, and 60 should be interpreted only as representative points on a continuous curve. Finally, activity was recorded in a structured inpatient environment, where ward routines and movement restrictions may affect behavior.

Conclusions

Early inpatient motor activity showed an age-dependent association with subsequent LOS in adults hospitalized with depressive disorders. Higher activity was associated with a shorter subsequent inpatient course at younger ages but a longer course at later ages within the observed age range. These findings suggest that age is an important context for interpreting actigraphy-derived motor behavior during psychiatric hospitalization; multicenter external validation is needed before the pattern is used for clinical decision-making.

Abbreviations

LOS
length of stay
VM

vector magnitude
FDR
false discovery rate
CI
confidence interval
GLM
generalized linear model.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Chengdu Fourth People's Hospital (approval no. 2026-53-01). The requirement for informed consent was waived by the Ethics Committee of Chengdu Fourth People's Hospital because this retrospective study used de-identified clinical data. The study was conducted in accordance with the Declaration of Helsinki and applicable institutional guidelines.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

X.M.L. contributed to writing the original draft, data curation, visualization, validation, methodology, investigation, and formal analysis. M.J.D. contributed to investigation and supervision. G.Y. contributed to supervision and conceptualization. S.J. contributed to investigation and project administration. Y.W. contributed to investigation and resources. J.I.F. contributed to supervision and conceptualization. C.M. contributed to investigation and resources. Z.Y. contributed to investigation. J.X. contributed to

resources and investigation. Y.Z. contributed to writing—review and editing, supervision, and conceptualization. C.L. contributed to writing—review and editing, supervision, conceptualization, and project administration. All authors reviewed and approved the final manuscript.

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Not applicable.

Availability of data and materials

The participant-level data underlying the findings of this study are not publicly available because they derive from clinical records and may contain sensitive information even after de-identification. De-identified data necessary to reproduce the reported analyses may be available from the corresponding authors upon reasonable request, subject to applicable ethical, privacy, and institutional data-governance requirements. The custom Python scripts used for data processing and statistical analyses are available from the corresponding authors on reasonable request.

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Figures

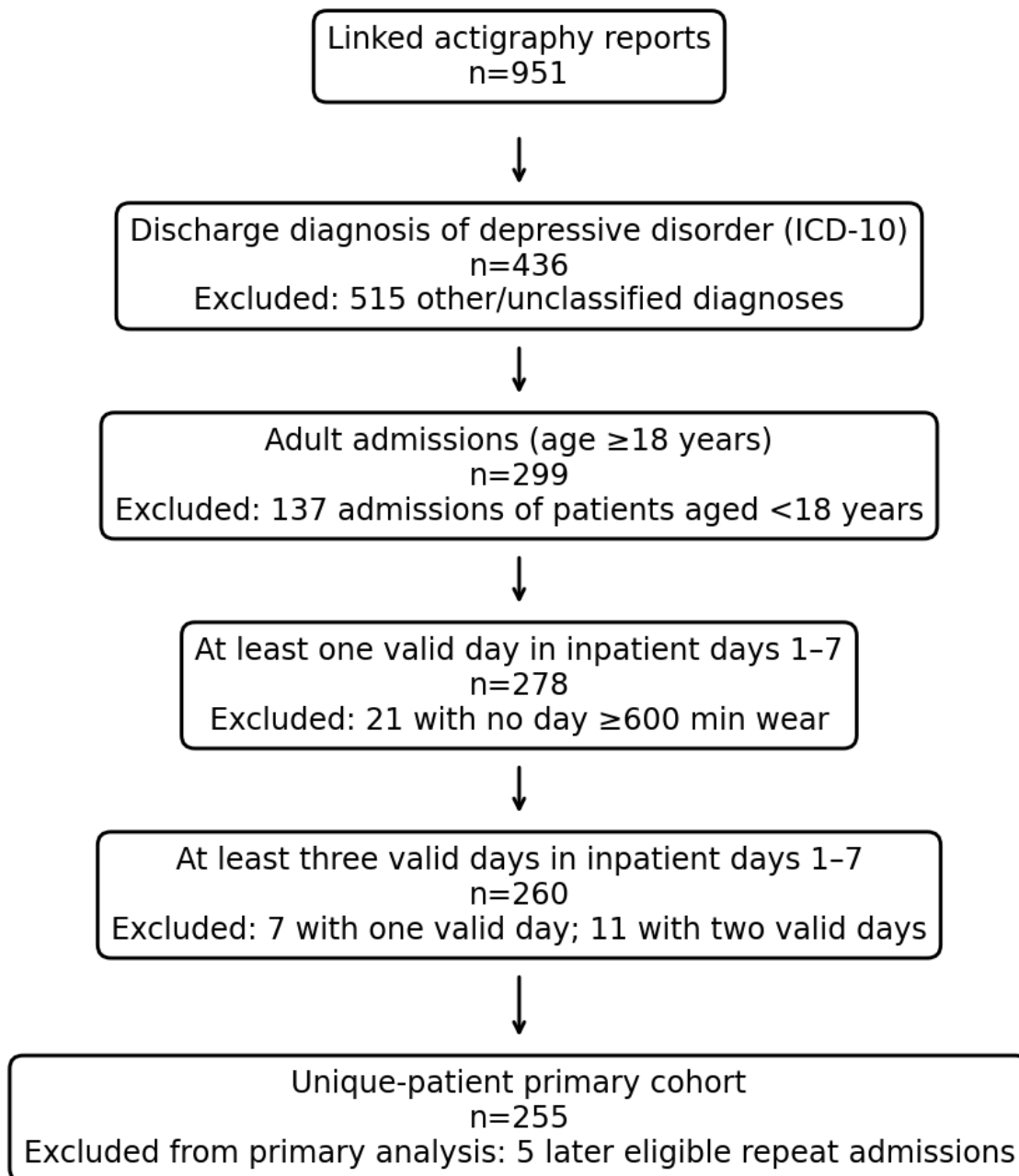


Figure 1

Participant flow for the adult depressive-disorder landmark cohort. A valid day required at least 600 minutes of wear during inpatient days 1-7. The primary cohort retained the earliest eligible admission for each patient.

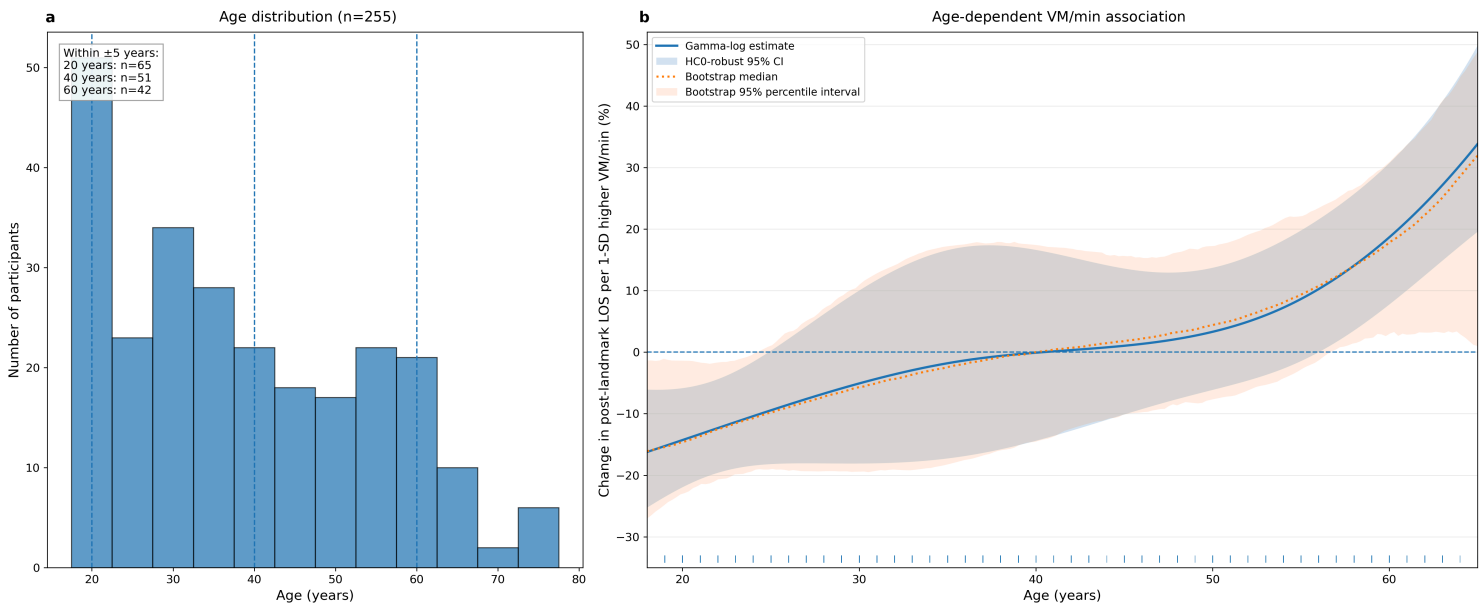


Figure 2

Age distribution and age-dependent VM/min association with post-landmark LOS. Panel a shows the age distribution of the primary cohort; dashed vertical lines mark the representative ages 20, 40, and 60 years. Panel b shows the adjusted percentage change in expected post-landmark LOS per 1-SD higher VM/min. For visualization, the fitted curve is displayed from ages 18 to 65 years because observations were sparse above 65; all observed ages were retained in the primary spline model. The solid line represents the Gamma-log model estimate, the shaded band the HC0-robust 95% CI, the dotted line the bootstrap median, and the lighter band the 95% bootstrap percentile interval. Bootstrap estimates were generated using a fixed random seed of 2026.

Supplementary Files

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