

Stop Measuring Age. Start Measuring Recovery.

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**Research series:* Aging Is Not a Clock*

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Abstract (original summary). Biological age is often reduced to a date or predicted biomarker score. This paper instead examines recovery kinetics: the speed and completeness of return toward personal baseline following physiological disturbance. It considers the promise of longitudinal resilience measures, the influence of disease and social context, and the evidence required to show added clinical utility.

The question behind the birthday

Chronological age counts time; a molecular age clock estimates an age-associated pattern; neither tells a clinician exactly how long a person will require to regain function after a physiological disturbance. A proposed alternative is to study *recovery kinetics*: the speed, completeness and stability of return toward an individual's ordinary level of function after an observable perturbation. Research using repeated blood measurements and activity patterns has reported age-associated slowing of recovery-related dynamics. The novel clinical question is whether these kinetics can become useful across tissues without reducing aging to a single number.

What recovery might mean

Recovery must be specified, not admired abstractly. Following exercise, one might measure strength restoration, fatigue and heart-rate normalization. After an infection, return of activity, weight, sleep and cognitive attention may be relevant. In hospital, delirium resolution, gait velocity, functional independence and return to baseline oxygen requirements may matter more than a transient biomarker change. These trajectories contain more information than one snapshot because they reveal how the organism responds to demand. Yet not every slow trajectory reflects intrinsic aging: medication use, inadequate nutrition, acute illness severity, poverty, caregiving responsibilities and limited rehabilitation opportunities can alter the curve.

From one number to a response curve

A hypothetical resilience profile would characterize response amplitude, time to partial recovery, time to stable recovery and residual impairment. This is not a request to deliberately stress frail patients. Passive observation of naturally occurring perturbations may often be more ethical and informative. A person who returns slowly but completely may be biologically different from someone who initially rebounds and then relapses. An organ may show normal resting performance while having very low reserve. Such distinctions could sharpen conventional frailty and rehabilitation frameworks rather than displace them.

Rival interpretations and the test

Recovery rates may simply reproduce established measures of disease burden, socioeconomic context or baseline fitness. Moreover, persistent deficits may result from fixed structural loss rather than a sluggish regulatory system. To matter, the model must offer added prediction after adjusting for those explanations. The ultimate standard would be improved decisions: can recovery curves identify modifiable barriers or help distinguish patients needing different forms of support? Until then, the proper claim is that recovery trajectories deserve attention, not that they are a proven replacement for chronological or molecular age.

A clinical thought experiment

Picture two older adults with similar blood pressure, body mass and usual walking speed. Following a mild respiratory illness, one returns to routine activity within days, while the other never resumes previous daily steps. The contrast could involve illness severity, but repeated observations can reveal that the second patient recovers more slowly even from comparable disturbances. A longitudinal account asks why; a one-time biomarker can only describe a moment.

What would discriminate among explanations

The test requires more than collecting wearables. Investigators must establish reliable baselines, detect changes without mistaking device artifacts for biology, and distinguish a new injury from delayed recovery. They must specify whether a measured trajectory changes management beyond accepted rehabilitation and geriatric assessments. Otherwise a high-tech curve merely renames information already available from careful clinical follow-up.

What a recovery curve actually contains

One can imagine two patients with the same resting heart rate, gait speed and inflammatory marker profile. After comparable infections, the first returns to baseline activity within a fortnight; the second continues to experience lower endurance after six weeks. A static visit may classify them similarly just before infection and again after they have partly recovered. Repeated observation exposes a difference in dynamics. Recovery has at least four dimensions: the magnitude of initial displacement, the time needed to recover part of the lost function, the eventual plateau, and the frequency of secondary setbacks. These dimensions should not automatically be aggregated; a person who recovers slowly and completely is different from someone who recovers quickly but remains permanently below baseline.

Longitudinal measurements can also distinguish low reserve from high vulnerability. Consider a person who can walk a short distance comfortably but becomes disproportionately exhausted after a longer walk. The resting measurement is normal relative to their lifestyle; the stress response is not. There is a temptation to measure this through standardized challenge tests, but aggressive perturbation of frail individuals may be unsafe. An ethically stronger approach is often to analyze naturally occurring changes—hospital discharge, infection recovery, routine rehabilitation, a shift in physical activity—alongside carefully selected low-risk assessments.

The mathematics should serve the patient

A simplified response may be represented by a return toward baseline over time, but human recovery rarely follows one smooth exponential. Infection, sleep loss, medication adjustments and the availability of rehabilitation can introduce step changes. A recovery half-time is interpretable only when the measured variable has a stable baseline, the intervention or perturbation is clearly defined, and the observation period is sufficiently frequent. Wearable-derived activity is especially vulnerable to changes in weather, employment, caregiving duties and device adherence. A fall in daily steps does not necessarily identify reduced biological resilience.

Pyrkov and colleagues analyzed longitudinal blood measurements and activity variability, describing an age-related loss of dynamic resilience at the population level. Their findings are provocative but do not establish an individual's maximum lifespan or a clinically validated bedside recovery test. Models derived from repeated population measurements may fail when applied to a single patient with medication changes, acute disease or limited access to care. A useful Institute proposal must resist turning a mathematical extrapolation into a biological law.

A prospective clinical application

Take rehabilitation after elective orthopedic surgery. The outcome should not be 'improved biological age' but a specified endpoint: return to walking without assistance, restoration of preoperative walking speed, fewer falls, or resumption of ordinary activities. Important predictors include preoperative function, nutritional status, pain control, mood, sleep, social support and surgical complications. A proposed recovery-kinetics metric would have to improve prediction beyond these familiar variables. It might help distinguish patients needing closer follow-up from those whose progress is typical for their operation. However, a slow trajectory could also indicate a complication requiring investigation; it should never be explained away as an expected terrain pattern.

Another application concerns chronic illness with fluctuating symptoms. A person may report intermittent 'good days' while the overall ability to tolerate ordinary activities progressively contracts. Measuring only average symptoms obscures the narrowing range of activities that can be performed without substantial worsening. The relevant signal could be a decline in tolerance or an increase in time needed to resume baseline activities, but these patterns are not disease-specific and should be interpreted alongside history and examination.

Competing explanations and a decisive evaluation

Recovery duration is strongly shaped by the severity of the insult. An individual who takes longer to recover from pneumonia may have had more extensive infection, a different pathogen or a previously undiagnosed pulmonary condition; none of those observations alone demonstrates accelerated aging. Some people also choose to reduce activity for reasons unrelated to illness, including employment patterns or injury fear. A theory that ignores those variables confuses biology with context.

A credible study would define the perturbation, measure pre-event baseline as accurately as possible, document treatment and competing diagnoses, then determine whether longitudinal recovery variables predict function or subsequent illness independently. It should test reproducibility: does an individual's slow recovery after one type of disturbance predict slow recovery after another, or are the differences mostly tissue-specific? If they are tissue-specific, that is scientifically informative and argues against a universal resilience score.

Recovery deserves greater prominence because patients ultimately care about living and functioning, not merely possessing youthful biomarkers. The radical proposal is not to discard clocks, but to insist that a clock unable to predict meaningful recovery has only a limited claim to medical significance.

Selected scientific readings

- Pyrkov TV et al. (2021). Longitudinal analysis of blood markers reveals progressive loss of resilience and predicts human lifespan limit. *Nature Communications*. <https://www.nature.com/articles/s41467-021-23014-1>
- Oh HSH et al. (2025). Plasma proteomics links brain and immune system aging with healthspan and longevity. *Nature Medicine*. <https://www.nature.com/articles/s41591-025-03798-1>

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