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FunnelScore: A Versioned, Longitudinal Framework for Clinician-Reviewed Health Resilience Measurement

A transparent architecture for organizing multimodal health information, measuring data coverage and following change over time—while keeping clinical judgment primary.

MICHAEL J. HALL, MD, MSc
Hall Longevity Clinic · WellSkor

DEVELOPMENT STATUS

FunnelScore is a development-stage measurement framework. It has not yet been clinically validated for diagnosis, prognosis, treatment selection or prediction of lifespan. The framework is intended to support clinician review—not replace it.

Abstract

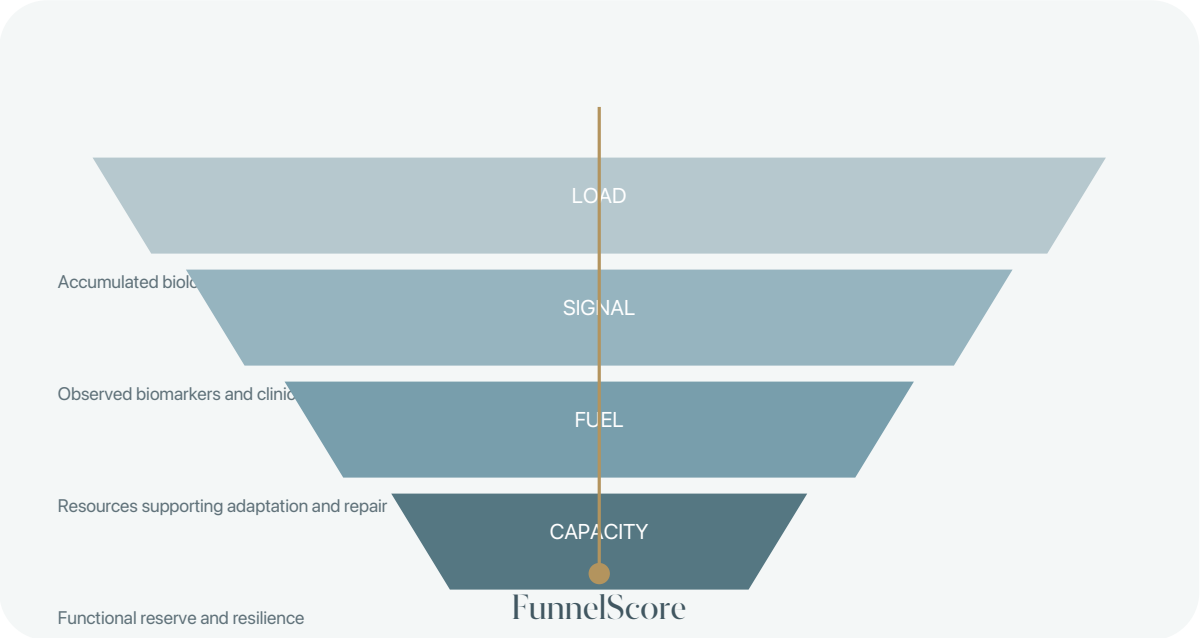
Longitudinal health programs often collect heterogeneous information but lack a reproducible way to describe how the available evidence changes through time. FunnelScore is a proposed framework for transforming versioned laboratory and clinical measurements into interpretable domain scores, explicit data-coverage estimates and a longitudinal composite that remains subordinate to the underlying observations.

The architecture separates configuration from code, preserves provenance and model version, normalizes heterogeneous markers onto a common 0–100 scale, calculates weighted domain scores with transparent missing-data handling and stores immutable outputs for comparison. Four organizing domains—Load, Signal, Fuel and Capacity—provide a systems-oriented view of biological pressure, observed information, adaptive resources and functional reserve.

This paper describes the conceptual model, mathematical conventions, data architecture, governance requirements and staged validation plan. It does not present performance claims. Prospective evaluation, calibration, reproducibility analysis and outcome-linked validation are required before clinical utility can be established.

Key proposition

A trustworthy longitudinal score should make uncertainty visible. A number without its inputs, coverage, model version and clinical context is not an adequate scientific or clinical record.



1. Why a longitudinal framework is needed

Routine medicine, advanced diagnostics and functional assessment generate measurements on different units, schedules and reference scales. A composite framework can help organize this complexity, but only if it preserves the original values and makes its transformations inspectable.

Single-time-point scores can create false precision. Acute illness, fasting state, exercise, medication changes, assay platform, specimen handling and missing observations can alter a result. FunnelScore is therefore designed around repeated observations, explicit provenance and version-controlled interpretation.

Design principles

- Configuration, not hidden code: marker definitions, ranges, transformations, weights and domain assignments are versioned records.
- Reproducibility: every score is bound to a model version, observation date, source data and calculation timestamp.
- Coverage awareness: missing data do not silently disappear; available evidence is quantified and displayed.
- Longitudinal by construction: change is interpreted only across comparable methods and model versions.
- Clinician-reviewed decision support: the output is an organizing aid, never an autonomous diagnosis or treatment instruction.

Relationship to published aging measures

A published phenotypic-age estimator may be included as one contextual component when its required variables, units and transformation are implemented exactly. The 2018 Phenotypic Age work used nine clinical chemistry and hematology variables plus chronological age to estimate mortality-related phenotypic age. That published estimator should not be represented as a WellSkor validation, and its use does not validate the broader FunnelScore composite.

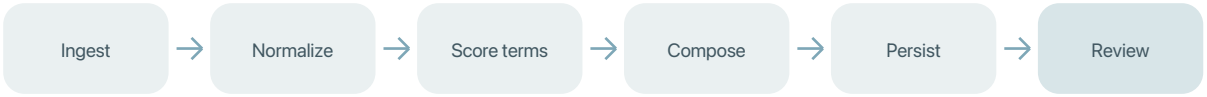
2. Conceptual model

The four domains are not diagnoses. They are a disciplined way to organize heterogeneous information so that clinicians and patients can see both the individual observations and the higher-level pattern.

DOMAIN	OPERATIONAL QUESTION	ILLUSTRATIVE INPUT TYPES
Load	What pressures or burdens are present?	Inflammatory, metabolic, environmental and disease-risk indicators
Signal	What is the body and the clinical record showing now?	Laboratory observations, symptoms, imaging and physiologic measurements
Fuel	What resources support maintenance and repair?	Nutritional status, sleep, recovery and selected metabolic resources
Capacity	What reserve and function remain available?	Strength, aerobic capacity, cognition, body composition and resilience

Interpretive discipline

A domain label is meaningful only when its marker registry, directionality and evidence are specified. The same marker should not be assigned different meanings across software releases without a new model version and a documented rationale.



Every output is tied to a model version, timestamp, source panel and coverage record.

The normalized marker

For marker j at time t, a versioned transformation maps the observed value to an interpretable scale:

$$n_j(t) = f_{j,v}(x_j(t)) \in [0, 100]$$

The transformation may be monotonic or banded. Directionality must be explicit: for some markers higher values represent greater concern; for others, both low and high values may be unfavorable.

3. Transparent scoring and missingness

A domain score is the weighted mean of the normalized markers observed for that domain. Missing markers are excluded from the numerator and denominator, while coverage is reported separately.

$$T_{k,v}(t) = \left[\sum_{i \in O_k(t)} w_{i,v}\, n_{i,v}(t)\right] / \left[\sum_{i \in O_k(t)} w_{i,v}\right]$$

$$C_{k,v}(t) = \left[\sum_{j \in O_k(t)} w_{j,v}\right] / \left[\sum_{j \in R_{k,v}} w_{j,v}\right]$$

Here, O denotes observed markers and R denotes the complete versioned registry for a domain. Renormalization avoids treating a missing result as a biological zero, while C makes the evidence gap visible.

Composite formulation

The overall score is a versioned function of age context and the four domain scores. The exact implementation, weights and calibration parameters must be documented within the controlled model registry.

$$F_v(t) = g_v\left[A(t), \mathrm{Load}(t), \mathrm{Signal}(t), \mathrm{Fuel}(t), \mathrm{Capacity}(t)\right]$$

A composite should never conceal a clinically important outlier. The report should present the score beside domain values, coverage, source observations and flags requiring clinician review.

Comparing change

Within a stable model version, the simplest change measure is $\Delta F_v = F_v(t_2) - F_v(t_1)$. Comparisons across model versions require a documented recalibration method or parallel rescoring of historical observations under the newer version.

> Guardrail

No threshold should be labeled ‘healthy,’ ‘diseased’ or ‘reversed aging’ until the construct, population, reference distribution and clinically meaningful outcomes have been prospectively defined and evaluated.

4. Data architecture and provenance

The data layer should preserve raw observations and calculation context. A practical minimum includes patient identity, consent records, source laboratory panels, atomic biomarker results, versioned marker definitions, domain scores, composite scores and model versions.

OBJECT	PURPOSE
Patient and consent	Identity, authorization scope, dates and research/clinical separation
Panel and result	Source laboratory, collection time, units, ranges, flags and original value
Marker definition	Canonical name, synonyms, units, transformation, weight and domain assignment
Model version	Controlled registry snapshot, code revision, release status and effective date
Score record	Domain/composite output, coverage, missingness, calculation time and provenance

Interoperability

Laboratory data may be represented using standard healthcare data structures. HL7 FHIR distinguishes a DiagnosticReport from the atomic Observation resources it references, providing a useful model for retaining both report-level context and discrete results.

Quality controls

- Reject or quarantine unit mismatches; do not infer conversions silently.
- Retain reference intervals and assay/platform identifiers when available.
- Detect duplicates by patient, analyte, specimen, collection time and source.
- Flag implausible values and manual corrections for human review.
- Record code revision, configuration checksum and all transformations used for each score.

5. Validation roadmap

A working calculation engine is not a validated clinical model. Validation must be planned before claims are made and should distinguish technical correctness, measurement reliability, statistical performance and clinical usefulness.

STAGE	PRIMARY QUESTION	EXAMPLE EVIDENCE
Analytical verification	Does the software calculate the specification correctly?	Unit tests, reference cases, boundary tests, repeatability
Data-quality validation	Are inputs complete, comparable and correctly mapped?	Coverage, missingness, unit and provenance audits
Construct validity	Do domains behave as the intended concepts imply?	Pre-specified associations and factor/cluster analyses
Predictive validation	Does the model estimate a defined future outcome?	Prospective cohorts, discrimination, calibration, external validation
Clinical utility	Does using the framework improve decisions or outcomes?	Workflow studies, decision impact, patient-centered and safety outcomes

Pre-specification

The intended population, prediction horizon, outcomes, exclusion criteria, handling of missing data and analysis plan should be defined before outcome analysis. Reporting should include calibration—not only discrimination—and should follow an appropriate prediction-model reporting framework such as TRIPOD when applicable.

Equity and generalizability

Performance should be examined across age, sex, race and ethnicity, relevant comorbidities, medication use, socioeconomic context and sites of care. A model developed in one highly selected longevity-clinic population may not generalize to primary care or the public.

Minimum viable scientific claim

Before prospective validation, the defensible claim is that FunnelScore is a versioned data-organization and longitudinal measurement framework. It should not be described as demonstrating reversal of aging, improved survival or clinical benefit.

6. Governance, safety and clinical use

Clinical data systems require governance beyond software accuracy. The HIPAA Security Rule requires administrative, physical and technical safeguards for electronic protected health information, including appropriate access control, audit controls, authentication, integrity and transmission security.

Clinical decision support

FDA guidance emphasizes that a health professional must be able to independently review the basis for a recommendation if the software is to fit the relevant non-device clinical decision support criteria. FunnelScore reports should therefore identify the purpose, intended user, required inputs, data-quality expectations, logic, validation status and patient-specific limitations.

Operational controls

- Role-based access, multifactor authentication and least-privilege permissions.
- Encryption in transit and at rest, supported by risk analysis and documented policies.
- Immutable audit logs for access, edits, imports, calculation and report generation.
- Separate clinical consent from research authorization; do not treat care as automatic research enrollment.
- Change control for marker definitions, weights, code, reference ranges and report language.
- Incident response, backup restoration testing and business-associate agreements where required.

Clinician responsibility

The clinician should review source observations, medications, symptoms, acute illness, laboratory methodology and conventional standards of care. A composite trend should never delay appropriate diagnostic evaluation or override evidence-based prevention and treatment.

Patient communication

Reports should explain uncertainty in plain language. They should state what changed, why it may have changed, how complete the evidence was and which findings require ordinary medical follow-up.

7. Conclusion

FunnelScore offers a disciplined way to structure multimodal health information for longitudinal review. Its scientific value will depend less on the visual appeal of a composite number than on provenance, transparency, coverage, reproducibility, careful validation and the quality of clinical interpretation.

The recommended development path is deliberately staged: establish the versioned data model and deterministic compute engine; verify transformations and missing-data behavior; produce clinician-readable reports; build longitudinal comparisons; and only then evaluate model fitting and prospective outcome associations. This sequence supports an honest evidence flywheel without overstating what has been shown.

Status statement

This white paper describes a concept and validation framework. FunnelScore remains development-stage and should be used, if at all, only as clinician-reviewed decision support with access to the underlying data and limitations.

References

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Prepared from the WellSkor FunnelScore integration specification and publicly available scientific and regulatory sources. This document is educational and technical; it is not medical advice.