

# A Composite Health Engagement Score from Consumer Wearable Telemetry

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February 2, 2026

## Abstract

We present a composite Health Engagement Score that summarizes longitudinal physical-activity adherence using consumer wearable telemetry. The metric aggregates: (1) daily activity-intensity goal attainment, (2) ambulatory volume consistency, and (3) streak persistence. Activity intensity is quantified as a weighted ratio of observed to prescribed targets for active energy, move time, exercise minutes, and stand hours. Ambulatory volume is captured by the proportion of days exceeding a step threshold, and streak persistence scales the length of the most recent consecutive high-step days. The composite score is a weighted average of these components and is mapped to a letter-grade rubric for interpretability. Supporting indicators include cumulative distance, count of goal-achievement days, and total tracked days. This formulation yields a transparent, decomposable summary suitable for cohort analytics, adherence monitoring, and downstream modeling of engagement-risk stratification.

## 1 Introduction

Consumer wearables produce dense longitudinal data streams that can approximate daily physical-activity behaviors. Translating these signals into a concise, interpretable engagement metric can aid population monitoring, user feedback, and risk stratification. We define and operationalize a composite Health Engagement Score using readily available Apple Health exports, focusing on energy expenditure, movement, exercise duration, standing behavior, and step counts.

## 2 Data Sources and Preprocessing

- **Inputs:** Apple Health daily summaries (steps, distance, flights, basal and active energy) and activity summaries (active energy, move time, exercise time, stand hours, and their respective goals).
- **Temporal normalization:** Dates are normalized to calendar days (UTC ISO 8601). Invalid or missing dates are discarded. Numerical fields are coerced to finite numbers; missing values remain null.
- **Uniqueness:** Daily summaries are unique on (userId, date); activity summaries are unique on (userId, dateComponents).
- **Sampling for long ranges:** For ranges exceeding 180 days, uniform thinning via windowed row-number sampling maintains at least 45 and at most 80 points to bound payload size while preserving temporal coverage.

### 3 Component Scores

Let  $d$  index days with valid observations. All component scores are scaled to  $[0, 100]$  unless stated otherwise.

#### 3.1 Activity-Intensity Score $s_a$

For day  $d$ , define ratio  $r_k(d) = \min\left(1, \frac{v_k(d)}{g_k(d)}\right)$  when goal  $g_k(d)$  and value  $v_k(d)$  are finite and  $g_k(d) > 0$ ; otherwise  $r_k(d)$  is null. Components  $k$  include: active energy, move time, exercise minutes, and stand hours. With weights  $w = \{0.4, 0.2, 0.2, 0.2\}$ , the daily activity score is

$$s_a(d) = 100 \cdot \frac{\sum_k w_k r_k(d)}{\sum_{k \in K_d} w_k}, \quad K_d = \{k : r_k(d) \text{ is finite}\}. \quad (1)$$

The aggregate activity score is the mean over days with finite  $s_a(d)$ .

#### 3.2 Steps Score $s_s$

Let  $D$  be the set of tracked days and  $D_{10k} \subseteq D$  the days with steps  $\geq 10,000$ . The steps score is

$$s_s = 100 \cdot \frac{|D_{10k}|}{|D|}. \quad (2)$$

#### 3.3 Streak Score $s_p$

Let  $L$  be the length (in days) of the most recent consecutive streak where steps  $\geq 10,000$ . The streak score is

$$s_p = 100 \cdot \min\left(1, \frac{L}{30}\right). \quad (3)$$

### 4 Composite Score and Grade

Weights reflect relative emphasis on intensity, consistency, and persistence:  $\alpha = 0.6$ ,  $\beta = 0.25$ ,  $\gamma = 0.15$ . The composite Health Engagement Score is

$$H = \frac{\alpha s_a + \beta s_s + \gamma s_p}{\alpha + \beta + \gamma}. \quad (4)$$

A letter-grade rubric supports interpretability: A+ ( $\geq 97$ ), A ( $\geq 93$ ), A- ( $\geq 90$ ), B+ ( $\geq 87$ ), B ( $\geq 83$ ), B- ( $\geq 80$ ), C+ ( $\geq 77$ ), C ( $\geq 73$ ), C- ( $\geq 70$ ), D+ ( $\geq 67$ ), D ( $\geq 63$ ), D- ( $\geq 60$ ), otherwise F.

### 5 Supporting Indicators

- Cumulative distance over the range.
- Goal-achievement count: days where active energy meets or exceeds its goal.
- Days tracked: number of days with any daily summary.
- Component breakdown:  $s_a$ ,  $s_s$ ,  $s_p$  for debugging and user feedback.

## 6 Implementation Notes

The metric is implemented server-side in Node.js with Sequelize models for daily and activity summaries. Date normalization uses ISO strings; numerical coercion guards against non-finite inputs. For extended ranges, windowed sampling reduces payload while preserving coverage. Scores are computed per user query bounds and returned with the composite grade.

## 7 Evaluation Plan

- **Construct validity:** Correlate  $H$  and components with independent activity logs or VO2max estimates where available.
- **Temporal stability:** Assess week-to-week variance under stable behavior to quantify metric noise.
- **Sensitivity:** Detect expected jumps following known behavior changes (e.g., increase in daily steps by 2,000).
- **User interpretability:** Qualitative feedback on grade thresholds and component breakdowns.

## 8 Limitations and Ethics

- Dependent on device wear-time and data completeness; missingness can bias scores.
- Step thresholds (10,000) and weights are heuristic; may require personalization.
- Grades can influence behavior; present with supportive context to avoid discouragement.
- Data privacy: all processing should comply with applicable data protection regulations and minimize data retention.

## 9 Conclusion

The Health Engagement Score provides a concise, decomposable summary of daily activity adherence from wearable telemetry. Its components align with common movement goals, enable user-friendly grading, and support downstream analytics for engagement monitoring and risk stratification.