Multimodal Prioritization Using Wearable Activity Data in Type 1 Diabetes

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Background

The Stanford 4T study manages newly diagnosed type 1 diabetes (T1D) using continuous glucose monitoring (CGM) and the TIDE dashboard, which supports diabetes care and education specialists (CDCES) in reviewing CGM data and triaging interventions.

Physical activity substantially affects glycemic control, but wearable activity data are not routinely incorporated into T1D care.

We integrated wearable activity data with CGM to evaluate whether exercise metrics can support patient prioritization for review.

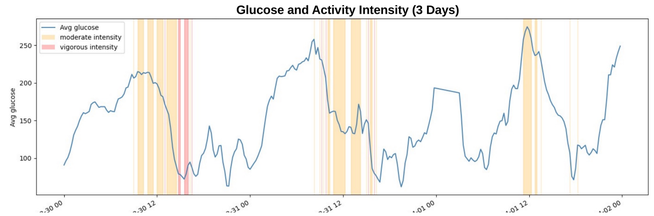
Methods

Data. Garmin wearable data integrated and reconciled with Dexcom CGM data from 4T participants (n = 59 with usable activity data).

Wear-time filter. ≥6 h/day and ≥3 days/week for a patient-week to qualify.

Exercise goal. A day is classified as an exercise day if it contains ≥60 min of moderate-to-vigorous physical activity (MVPA), following the WHO youth guideline.

Outcome. Time-in-Range (TIR), glucose 70–180 mg/dL, compared between exercise and non-exercise days: pooled across all 59 participants, and separately within each patient.



One participant over three days. Moderate (orange) and vigorous (red) activity bands, classified by metabolic equivalent thresholds, overlaid on mean glucose.

Limitations

Wear-time filtering is unlikely to be missing-at-random: participants who wear the tracker consistently may differ systematically in self-management.

The pooled comparison treats patient-observations as independent; without accounting for within-patient clustering its standard error is understated.

Between-patient heterogeneity in effect size was not formally quantified — no I^2 or τ^2 is reported.

Single-site cohort of newly diagnosed patients; generalizability is untested.

Results

Population-level comparison

Pooling all 59 participants, the proportion of observations meeting the Time-in-Range goal (glucose 70–180 mg/dL) differed by under two percentage points between observations where the daily exercise goal was met and those where it was not.

The pooled comparison provides no evidence of an association between exercise-goal attainment and glycemic-goal attainment.

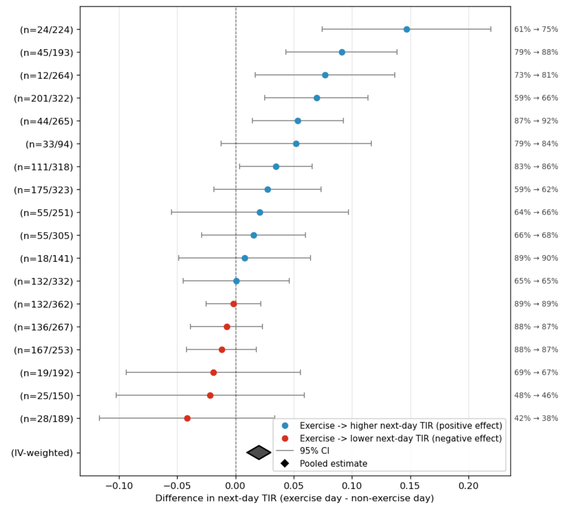
Observations	Met TIR goal	Sample size
Daily exercise goal met	64.3%	221
Daily exercise goal not met	66.0%	1,197
Difference	**−1.7 pp**	**p = 0.62**

Proportion meeting the TIR goal by exercise-goal attainment across all 1,418 qualifying observations. Two-proportion comparison.

Within-patient comparison

A within-patient contrast requires each patient to contribute enough exercise days to be estimable. Restricting to the 18 participants with ≥10 qualifying exercise days, we compared next-day TIR on days the daily exercise goal was met with days it was not.

Point estimates were positive in 12 of 18 patients; the inverse-variance-weighted pooled estimate was approximately +2 percentage points of next-day TIR. Six patients had 95% confidence intervals excluding zero, all favouring exercise, the largest at +14 points. No interval excluded zero in the direction of harm.



Each row is one patient; n = exercise days / total qualifying days. Bars are 95% CIs, diamond the pooled estimate. Right labels: TIR on non-exercise → exercise days.

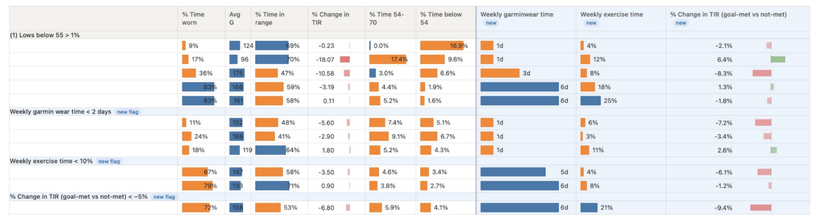
Proposed Integration into TIDE

Three exercise metrics and associated flagging rules were added to the existing TIDE review queue:

Weekly Garmin wear time — days in the week with sufficient wear data.

Weekly exercise time — proportion of the weekly MVPA target met.

% change in TIR (goal-met vs. not-met) — each patient's own response to exercise.



Prototype TIDE view. Existing glucose columns at left, the three new exercise columns at right. Row groups show which flagging rule surfaced each patient.

Conclusions

Meeting the daily exercise goal was associated with higher next-day Time-in-Range within patients: a small average effect, larger in roughly a third of those analysed, and directionally consistent across the cohort.

The within-patient signal is not recoverable from the pooled comparison, so rules keyed to population-level exercise thresholds will not surface the patients who benefit most. Prioritization should be indexed to each patient's own response.

Wearable data can be integrated with CGM and surfaced inside an existing dashboard without changing the CDCES review workflow.

Future Directions

Refine flagging thresholds so weekly review volume matches available CDCES capacity.

Validate the change-in-TIR metric out of sample; it is currently estimated from the same observations used to evaluate it.

Prospectively test the flags against clinician judgement and measure their effect on care delivery and glycemic outcomes.

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