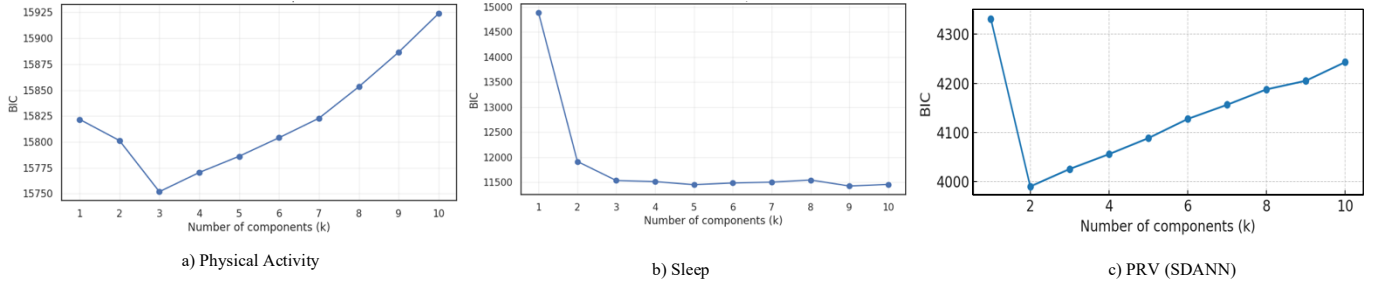
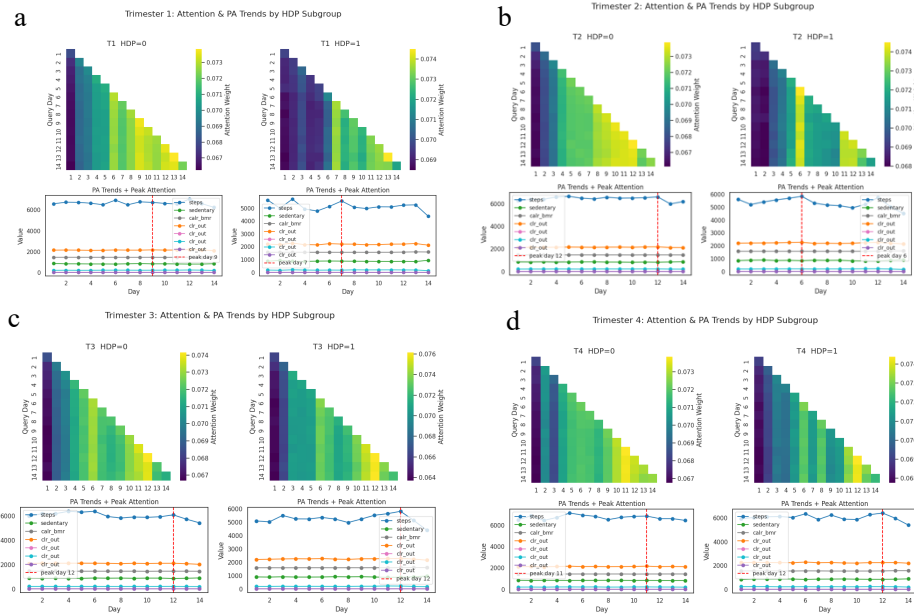


## Supplementary Material

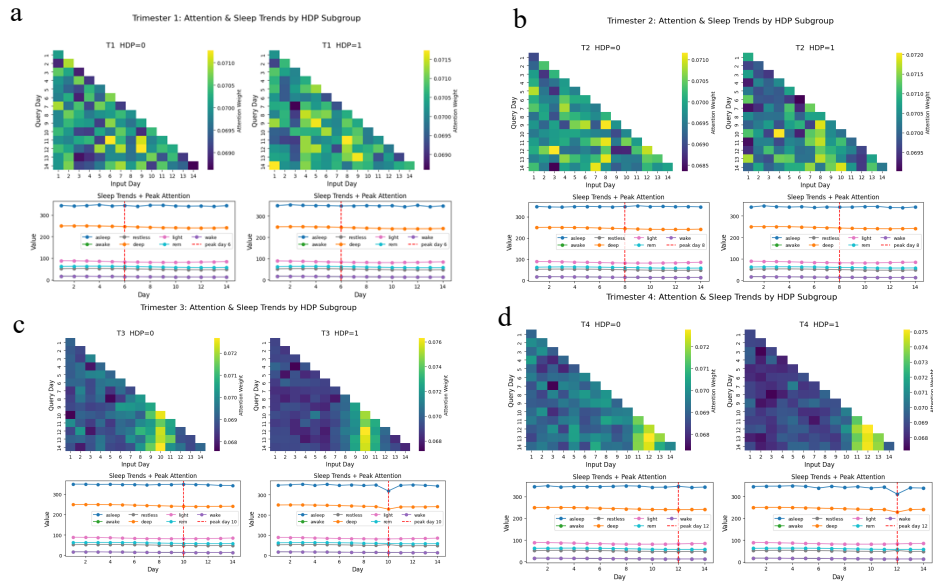
### Supplementary Figures



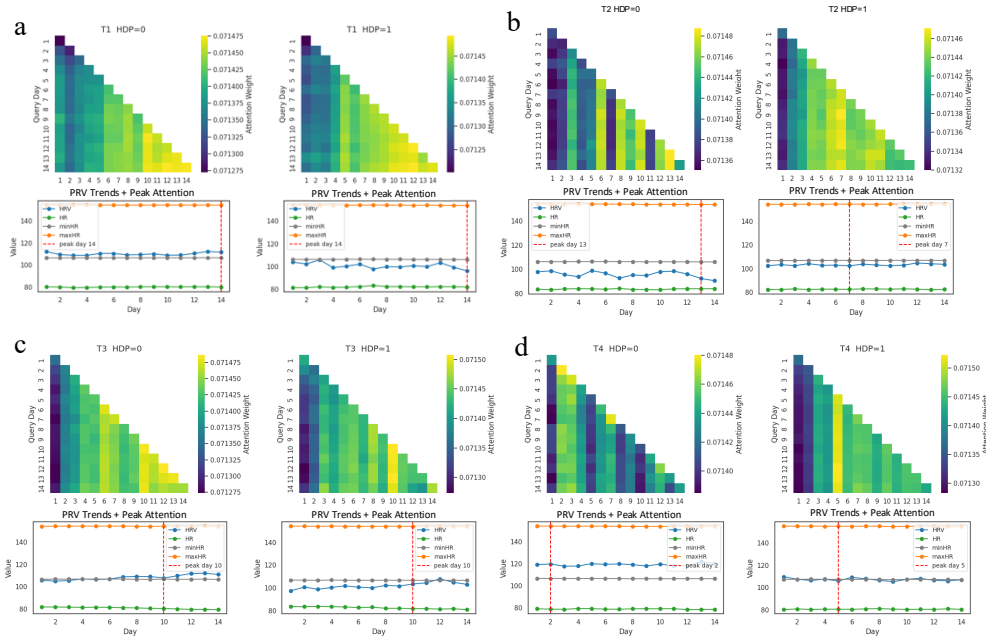
**Supplementary Figure 1. Bayesian information criterion curves characterize candidate cluster numbers for each wearable modality a) Physical activity. b) Sleep. c) Pulse rate variability.** Blue points joined by lines show the Bayesian information criterion (BIC) for Gaussian mixture models fitted to the learned embeddings across candidate numbers of components. Lower BIC values indicate a better balance between model fit and complexity. The analyses used three physical activity clusters, two sleep clusters, and two pulse rate variability clusters. The horizontal axis denotes the number of mixture components, k. PRV, pulse rate variability; SDANN, standard deviation of average normal-to-normal intervals.



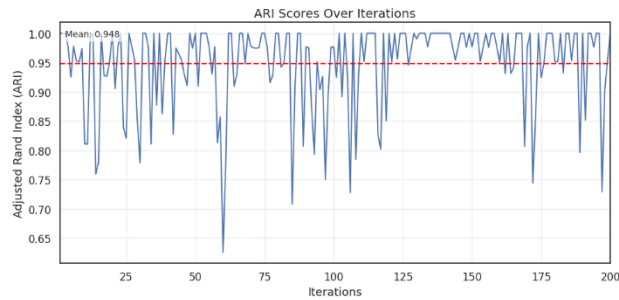
**Supplementary Figure 2. Physical activity attention maps and daily feature profiles are displayed by pregnancy period and HDP status.** a) First trimester. b) Second trimester. c) Third trimester. d) Postpartum. Within each panel, the left and right columns show HDP-negative and HDP-positive windows, respectively. Upper plots display attention weights by query day and input day within the 14-day observation window. Colors progress from purple for lower attention weights to yellow for higher weights, according to the individual color bars. Lower plots display daily physical activity feature profiles; circular markers indicate daily values, and red dashed vertical lines mark the indicated peak-attention day. HDP, hypertensive disorders of pregnancy; PA, physical activity. HDP=0 and HDP=1 denote negative and positive outcome labels, respectively.



**Supplementary Figure 3. Sleep attention maps and daily sleep profiles are displayed by pregnancy period and HDP status.** a) First trimester. b) Second trimester. c) Third trimester. d) Postpartum. Within each panel, the left and right columns show HDP-negative and HDP-positive windows, respectively. Upper heatmaps display attention weights by query day and input day across the 14-day window. Purple indicates lower weights and yellow higher weights, according to the individual color bars. Lower plots display daily sleep measures in minutes. Circular markers indicate daily values, and red dashed vertical lines mark the indicated peak-attention day. HDP, hypertensive disorders of pregnancy; REM, rapid eye movement. HDP=0 and HDP=1 denote negative and positive outcome labels, respectively.



**Supplementary Figure 4. Pulse rate variability and heart rate profiles are displayed alongside temporal attention maps.** a) First trimester. b) Second trimester. c) Third trimester. d) Postpartum. Within each panel, the left and right columns show HDP-negative and HDP-positive windows, respectively. Upper heatmaps display attention weights by query day and input day across the 14-day window. Purple indicates lower weights and yellow higher weights, according to the individual color bars. Lower plots display SDANN in blue, mean heart rate in green, minimum heart rate in grey, and maximum heart rate in orange. Circular markers indicate daily values, and red dashed vertical lines mark the indicated peak-attention day. The narrow attention-weight ranges should be considered when interpreting apparent color differences. HDP, hypertensive disorders of pregnancy; HR, heart rate; PRV, pulse rate variability; SDANN, standard deviation of average normal-to-normal intervals. HDP=0 and HDP=1 denote negative and positive outcome labels, respectively.



**Supplementary Figure 5: Cluster stability in the external cohort.** The discovery-trained encoder was kept frozen. For each participant-level subsample, a three-component GMM was refitted using the reduced external embedding set, and labels for retained participants were compared with labels from the complete external-cohort GMM using ARI. The blue line shows the adjusted Rand index (ARI) across the 200 displayed iterations. The red dashed horizontal line indicates the mean ARI of 0.948. Higher ARI values indicate greater agreement between cluster assignments.

## Supplementary Tables

**Supplementary Table 1. Cluster Subtype Analysis and Characteristics (Physical Activity)**

| Feature                   | Cluster 0 (N=103)<br>[High Activity] | Cluster 1 (N=85)<br>[Moderate Activity] | Cluster 2 (N=84)<br>[Low Activity] | p_value  | p_adj    | eta2      |
|---------------------------|--------------------------------------|-----------------------------------------|------------------------------------|----------|----------|-----------|
| Sedentary Minutes         | 683.26 ± 222.04                      | 902.05 ± 272.50                         | 1016.43 ± 294.24                   | 5.02E-28 | 3.51E-27 | 0.373346  |
| Calories Out              | 2316.07 ± 381.59                     | 2310.19 ± 495.40                        | 1815.16 ± 286.82                   | 1.79E-27 | 9.42E-27 | 0.367378  |
| Fairly Active Minutes     | 11.76 ± 17.38                        | 8.23 ± 14.15                            | 10.92 ± 23.35                      | 1.44E-01 | 2.09E-01 | 0.014324  |
| Lightly Active Minutes    | 276.39 ± 102.11                      | 190.02 ± 89.16                          | 163.81 ± 101.59                    | 6.03E-29 | 6.33E-28 | 0.383135  |
| Steps                     | 7991.40 ± 3666.18                    | 5646.83 ± 3472.57                       | 4676.94 ± 3377.50                  | 1.22E-18 | 5.12E-18 | 0.264113  |
| Very Active Minutes       | 11.31 ± 20.13                        | 8.22 ± 15.39                            | 6.79 ± 15.44                       | 1.34E-02 | 3.53E-02 | 0.03153   |
| Average Pulse rate        | 77.07 ± 9.24                         | 77.99 ± 10.56                           | 78.40 ± 8.54                       | 7.02E-01 | 7.90E-01 | 0.003645  |
| Pulse rate Variability    | 127.92 ± 36.81                       | 112.78 ± 34.87                          | 110.93 ± 39.21                     | 1.28E-02 | 3.53E-02 | 0.043946  |
| Minimum Pulse rate        | 106.02 ± 5.72                        | 105.99 ± 7.14                           | 104.49 ± 6.41                      | 8.51E-01 | 8.51E-01 | 0.001201  |
| Maximum Pulse rate        | 150.52 ± 5.72                        | 153.49 ± 7.17                           | 153.99 ± 6.40                      | 8.51E-01 | 8.51E-01 | 0.001201  |
| Minute Asleep             | 384.49 ± 94.81                       | 352.02 ± 127.40                         | 350.58 ± 138.34                    | 9.03E-02 | 1.90E-01 | 0.017719  |
| Minute Awake during Sleep | 46.98 ± 22.21                        | 41.20 ± 23.34                           | 49.06 ± 34.03                      | 1.43E-01 | 2.09E-01 | 0.014368  |
| Minute Deep Sleep         | 65.35 ± 17.25                        | 63.78 ± 23.09                           | 61.78 ± 16.80                      | 4.96E-01 | 6.13E-01 | 0.005196  |
| Minute Light Sleep        | 254.96 ± 42.40                       | 246.25 ± 49.80                          | 248.94 ± 41.43                     | 4.17E-01 | 5.48E-01 | 0.006475  |
| Minute REM Sleep          | 91.06 ± 22.44                        | 87.88 ± 24.17                           | 89.79 ± 28.12                      | 7.15E-01 | 7.90E-01 | 0.002494  |
| Fragmented Sleep          | 53.86 ± 30.69                        | 66.02 ± 42.43                           | 68.27 ± 54.54                      | 6.85E-02 | 1.60E-01 | 0.019735  |
| Categorical               |                                      |                                         |                                    | p_value  | p_adj    | chi2_stat |
| Age Group                 |                                      |                                         |                                    |          |          |           |
| 20-39                     | 53                                   | 54                                      | 56                                 | 0.02     | 0.09     | 11.82     |
| 40-50                     | 44                                   | <20                                     | 23                                 |          |          |           |
| 50+                       | <20                                  | <20                                     | <20                                |          |          |           |
| Gestational Age           |                                      |                                         |                                    |          |          |           |
| 20-39                     | 68                                   | 52                                      | 50                                 | 0.77     | 1.00     | 1.83      |
| 40-50                     | <20                                  | <20                                     | <20                                |          |          |           |
| 50+                       | <20                                  | <20                                     | <20                                |          |          |           |
| Race                      |                                      |                                         |                                    |          |          |           |
| Non-White                 | <20                                  | 21                                      | <20                                | 0.02     | 0.09     | 7.66      |
| White                     | 92                                   | 64                                      | 64                                 |          |          |           |
| Ethnicity                 |                                      |                                         |                                    |          |          |           |

|                                                                 |     |     |     |        |        |       |
|-----------------------------------------------------------------|-----|-----|-----|--------|--------|-------|
| <b>Hispanic or Latino</b>                                       | <20 | <20 | <20 | 0.36   | 0.58   | 2.02  |
| <b>Not Hispanic or Latino</b>                                   | 94  | 76  | 80  |        |        |       |
| <b>Preterm Status</b>                                           |     |     |     |        |        |       |
| <b>No</b>                                                       | 59  | 38  | 43  | 0.23   | 0.46   | 2.95  |
| <b>Yes</b>                                                      | 44  | 47  | 41  |        |        |       |
| <b>Pre Pregnancy Chronic Conditions (diabetes/obesity)</b>      |     |     |     |        |        |       |
| <b>yes</b>                                                      | 23  | <20 | 30  | <0.001 | <0.001 | 8.41  |
| <b>no</b>                                                       | <20 | <20 | <20 |        |        |       |
| <b>missing *</b>                                                | 69  | 51  | 49  |        |        |       |
| <b>Non Hypertension Gestation Conditions (diabetes/obesity)</b> |     |     |     |        |        |       |
| <b>yes</b>                                                      | 35  | <20 | 29  | 0.96   | 1      | 12.16 |
| <b>no</b>                                                       | <20 | <20 | <20 |        |        |       |
| <b>missing *</b>                                                | 64  | 65  | 51  |        |        |       |

To comply with All of Us Research Program participant privacy requirements, all cell counts smaller than 20 were masked and are reported as “<20.”

\* Missing includes responses coded as unknown, skipped, or not reported.

**Supplementary Table 2. Cluster Subtype Analysis and Characteristics (Sleep)**

| Features                  | Cluster 0 (167)<br>[Restorative Sleep] | Cluster 1 (105)<br>[Fragmented Sleep] | p_value  | p_adj    | cohens_d  |
|---------------------------|----------------------------------------|---------------------------------------|----------|----------|-----------|
| Minute REM Sleep          | 93.93 ± 13.87                          | 76.70 ± 14.15                         | 3.44E-19 | 7.23E-18 | -1.233281 |
| Minute Asleep             | 392.25 ± 64.53                         | 286.56 ± 95.90                        | 1.44E-18 | 1.51E-17 | -1.352935 |
| Minute Awake during Sleep | 37.89 ± 16.81                          | 54.99 ± 24.41                         | 5.48E-11 | 3.84E-10 | -0.784571 |
| Minute Deep Sleep         | 63.72 ± 11.52                          | 55.15 ± 12.12                         | 2.50E-08 | 1.31E-07 | -0.729629 |
| Fragment Sleep            | 48.05 ± 24.46                          | 72.26 ± 50.63                         | 2.79E-07 | 1.17E-06 | -0.56967  |
| Minute Light Sleep        | 261.05 ± 28.39                         | 243.85 ± 30.51                        | 5.93E-06 | 1.56E-05 | -0.588508 |
| Sedentary Minute          | 816.93 ± 316.18                        | 990.11 ± 316.26                       | 1.70E-05 | 3.97E-05 | 0.547698  |
| Average Pulse rate        | 76.70 ± 8.77                           | 79.51 ± 10.52                         | 5.80E-02 | 1.22E-01 | 0.297157  |
| Pulse rate Variability    | 121.36 ± 38.77                         | 113.48 ± 35.98                        | 1.52E-01 | 2.90E-01 | -0.208732 |
| Light Active Minutes      | 233.96 ± 149.44                        | 211.64 ± 132.60                       | 2.00E-01 | 3.49E-01 | -0.15588  |
| Minimum Pulse rate        | 100.52 ± 6.21                          | 105.57 ± 6.73                         | 2.43E-01 | 3.65E-01 | -0.148398 |
| Maximum Pulse rate        | 154.02 ± 6.78                          | 153.07 ± 6.73                         | 2.43E-01 | 3.65E-01 | -0.148399 |
| Calories Out              | 2198.96 ± 483.83                       | 2162.73 ± 528.13                      | 5.70E-01 | 7.48E-01 | -0.072254 |
| Fairly Active Minutes     | 15.32 ± 28.45                          | 13.94 ± 19.35                         | 6.36E-01 | 7.86E-01 | -0.054258 |
| Very Active Minutes       | 11.49 ± 20.76                          | 10.85 ± 17.17                         | 7.93E-01 | 8.33E-01 | 0.034105  |
| Steps                     | 7029.90 ± 4195.24                      | 6965.48 ± 4669.61                     | 9.08E-01 | 9.08E-01 | -0.014695 |
| Categorical               |                                        |                                       | p value  | p adj    | chi2_stat |
| <b>Age Group</b>          |                                        |                                       |          |          |           |
| 20-39                     | 102                                    | 61                                    | 0.76     | 1.00     | 0.54      |
| 40-50                     | 53                                     | 34                                    |          |          |           |
| 50+                       | <20                                    | <20                                   |          |          |           |
| <b>Gestational Age</b>    |                                        |                                       |          |          |           |
| 20-39                     | 109                                    | 61                                    | 0.87     | 1.00     | 0.29      |
| 40-50                     | <20                                    | <20                                   |          |          |           |
| 50+                       | <20                                    | <20                                   |          |          |           |
| <b>Race</b>               |                                        |                                       |          |          |           |
| Non-White                 | 27                                     | 25                                    | 0.16     | 0.80     | 1.97      |
| White                     | 140                                    | 80                                    |          |          |           |
| <b>Ethnicity</b>          |                                        |                                       |          |          |           |
| Hispanic or Latino        | <20                                    | <20                                   | 1.00     | 1.00     | 0.00      |
| Not Hispanic or Latino    | 153                                    | 97                                    |          |          |           |
| <b>Preterm Status</b>     |                                        |                                       |          |          |           |
| No                        | 90                                     | 50                                    | 0.38     | 0.94     | 0.78      |

|                                                                 |     |     |      |      |      |
|-----------------------------------------------------------------|-----|-----|------|------|------|
| Yes                                                             | 77  | 55  |      |      |      |
| <b>Pre Pregnancy Chronic Conditions (diabetes/obesity)</b>      |     |     |      |      |      |
| yes                                                             | 43  | 24  | 0.54 | 0.79 | 0.37 |
| no                                                              | 26  | <20 |      |      |      |
| missing *                                                       | 98  | 71  |      |      |      |
| <b>Non Hypertension Gestation Conditions (diabetes/obesity)</b> |     |     |      |      |      |
| yes                                                             | 52  | 30  | 1    | 1    | 0    |
| no                                                              | <20 | <20 |      |      |      |
| missing *                                                       | 109 | 71  |      |      |      |

To comply with All of Us Research Program participant privacy requirements, all cell counts smaller than 20 were masked and are reported as “<20.”

\* Missing includes responses coded as unknown, skipped, or not reported.

**Supplementary Table 3. Cluster Subtype Analysis and Characteristics (PRV (SDANN))**

| Feature                        | Cluster 0 [Lower PRV (SDANN)] (162) | Cluster 1 [Higher PRV (SDANN)] (110) | p_value  | p_adj    | cohens_d  |
|--------------------------------|-------------------------------------|--------------------------------------|----------|----------|-----------|
| Average Pulse rate             | 85.94 ± 6.39                        | 75.38 ± 6.12                         | 1.53E-29 | 3.82E-28 | -1.685247 |
| Average Pulse rate Variability | 91.88 ± 18.18                       | 127.02 ± 24.87                       | 4.25E-26 | 5.31E-25 | 1.633309  |
| Minimum Pulse rate             | 109.77 ± 5.39                       | 102.28 ± 6.51                        | 2.51E-19 | 1.57E-18 | -1.27678  |
| Maximum Pulse rate             | 157.27 ± 5.39                       | 149.78 ± 6.51                        | 2.51E-19 | 1.57E-18 | -1.276816 |
| Lightly Active Minutes         | 200.45 ± 117.42                     | 242.24 ± 156.65                      | 1.26E-02 | 6.30E-02 | -0.294023 |
| Very Active Minutes            | 8.77 ± 13.54                        | 12.53 ± 23.86                        | 2.31E-02 | 7.22E-02 | 0.312868  |
| Fairly Active Minutes          | 10.95 ± 16.31                       | 17.40 ± 29.66                        | 2.21E-02 | 7.22E-02 | -0.256529 |
| Sedentary Minutes              | 907.67 ± 325.23                     | 867.56 ± 327.76                      | 3.21E-01 | 7.29E-01 | 0.122762  |
| Minute REM Sleep               | 88.08 ± 22.59                       | 90.61 ± 27.04                        | 4.03E-01 | 8.40E-01 | -0.099964 |
| Minute Asleep                  | 359.70 ± 129.82                     | 370.02 ± 107.63                      | 4.77E-01 | 9.16E-01 | 0.085008  |
| Fragmented Sleep               | 63.49 ± 50.24                       | 62.06 ± 33.06                        | 7.77E-01 | 9.19E-01 | -0.032436 |
| Steps                          | 6964.61 ± 4310.13                   | 7064.55 ± 4490.60                    | 8.55E-01 | 9.19E-01 | 0.022798  |
| Calories Out                   | 2165.24 ± 525.36                    | 2198.38 ± 484.51                     | 5.99E-01 | 9.19E-01 | -0.066095 |
| Minute Light Sleep             | 249.54 ± 43.29                      | 250.13 ± 48.28                       | 9.19E-01 | 9.19E-01 | 0.012813  |
| Minute Deep Sleep              | 60.47 ± 19.79                       | 63.89 ± 19.49                        | 8.61E-01 | 9.19E-01 | 0.021599  |
| Minute Awake                   | 46.53 ± 30.61                       | 42.76 ± 20.56                        | 5.69E-01 | 9.19E-01 | -0.065571 |
| Categorical                    |                                     |                                      | p_value  | p_adj    | chi2_stat |
| Age Group                      |                                     |                                      |          |          |           |
| 20-39                          | 106                                 | 57                                   | 0.042638 | 0.17     | 6.31      |
| 40-50                          | 47                                  | 40                                   |          |          |           |
| 50+                            | <20                                 | <20                                  |          |          |           |
| Gestational Age                |                                     |                                      |          |          |           |
| 20-39                          | 102                                 | 68                                   | 0.03     | 0.17     | 7.07      |
| 40-50                          | <20                                 | <20                                  |          |          |           |
| 50+                            | <20                                 | <20                                  |          |          |           |
| Race                           |                                     |                                      |          |          |           |
| Non-White                      | 32                                  | 20                                   | 0.03     | 0.83     | 4.22      |
| White                          | 130                                 | 90                                   |          |          |           |
| Ethnicity                      |                                     |                                      |          |          |           |
| Hispanic or Latino             | <20                                 | <20                                  | 0.24     | 0.64     | 1.39      |
| Not Hispanic or Latino         | 152                                 | 98                                   |          |          |           |
| Preterm Status                 |                                     |                                      |          |          |           |
| No                             | 82                                  | 58                                   | 0.83     | 1.00     | 0.05      |

|                                                                 |     |     |      |      |      |
|-----------------------------------------------------------------|-----|-----|------|------|------|
| Yes                                                             | 80  | 52  |      |      |      |
| <b>Pre Pregnancy Chronic Conditions (diabetes/obesity)</b>      |     |     |      |      |      |
| yes                                                             | 43  | 72  | 0.93 | 1.00 | 0.01 |
| no                                                              | 22  | <20 |      |      |      |
| missing *                                                       | 43  | 24  |      |      |      |
| <b>Non Hypertension Gestation Conditions (diabetes/obesity)</b> |     |     |      |      |      |
| yes                                                             | 103 | 68  | 0.04 | 0.05 | 0.82 |
| no                                                              | <20 | <20 |      |      |      |
| missing *                                                       | 55  | 36  |      |      |      |

To comply with All of Us Research Program participant privacy requirements, all cell counts smaller than 20 were masked and are reported as “<20.”

\* Missing includes responses coded as unknown, skipped, or not reported.

**Supplementary Table 4. Feature Distribution for Discovery and External Validation Activity Data**

| Features                                          | mean    | std     |
|---------------------------------------------------|---------|---------|
| <b>Discovery (<i>All of Us</i>)</b>               |         |         |
| Sedentary minutes                                 | 854.52  | 297.51  |
| Calories out                                      | 2159.27 | 458.74  |
| Fairly active minutes                             | 10.40   | 18.64   |
| Lightly active minutes                            | 214.63  | 109.77  |
| Steps                                             | 6235.14 | 3795.46 |
| Very active minutes                               | 8.95    | 17.46   |
| <b>External Validation (<i>WUMOD</i>)</b>         |         |         |
| Total activity sum of log (TLAC)                  | 2464.98 | 1562.37 |
| Moderate-to-vigorous active minutes (MVPA)        | 17.03   | 16.23   |
| Light active minutes (LIPA)                       | 171.44  | 116.21  |
| Sedentary minutes (ST)                            | 824.96  | 244.68  |
| Sedentary-to-active transition probability (SATP) | 0.07    | 0.04    |
| Active-to-sedentary transition probability (ASTP) | 0.26    | 0.11    |

**Supplementary Table 5. Sensitivity analysis comparing candidate window lengths**

| Window  | Participants with complete coverage | Activity AUC | Sleep AUC | PRV (SDANN) AUC |
|---------|-------------------------------------|--------------|-----------|-----------------|
| 7 days  | 315                                 | 0.674        | 0.701     | 0.704           |
| 14 days | 272                                 | 0.692        | 0.720     | 0.720           |
| 28 days | 205                                 | 0.688        | 0.712     | 0.709           |

**Supplementary Table 6. Participant-level 5-fold cross-validation**

| Modality          | AUC, mean [SD] | Reconstruction MSE, mean [SD] |
|-------------------|----------------|-------------------------------|
| Physical activity | 0.694 [0.031]  | 0.067 [0.005]                 |
| Sleep             | 0.716 [0.028]  | 0.006 [0.001]                 |
| PRV (SDANN)       | 0.711 [0.034]  | 0.061 [0.006]                 |

**Supplementary Table 7. Sensitivity analysis restricted to high-confidence GMM cluster assignments**

| Modality          | Windows retained, n/N (%) | Transitions retained, n/N (%) | Interval         | Worsening transition               | Coefficient    | p-value        |
|-------------------|---------------------------|-------------------------------|------------------|------------------------------------|----------------|----------------|
| Physical activity | 921/1,088 (84.7%)         | 590/816 (72.3%)               | T2 to T3         | C0→C2                              | 1.12           | 0.018          |
| Physical activity | 921/1,088 (84.7%)         | 590/816 (72.3%)               | T3 to postpartum | C0→C2                              | 1.34           | 0.006          |
| Sleep             | 956/1,088 (87.9%)         | 637/816 (78.1%)               | T2 to T3         | C0→C1                              | 1.47           | 0.020          |
| Sleep             | 956/1,088 (87.9%)         | 637/816 (78.1%)               | T3 to postpartum | C0→C1                              | 1.29           | 0.029          |
| PRV (SDANN)       | 979/1,088 (90.0%)         | 672/816 (82.4%)               | All intervals    | No consistent worsening transition | Not applicable | Not applicable |