**SUPPLEMENTARY MATERIALS**

Section A

For the sensitivity analysis we handled missing data with Multiple Imputation using Fully Conditioned Specification as implemented in the R Package *mice* [1] with number of imputations set to 5. Multiple imputation preserves the sample size while accounting for uncertainty by incorporating randomness in missing value estimation with multiple data sets. Covariate balancing propensity scores [2] were used to estimate propensity weights on each imputed dataset as implemented in the R Package *WeightThem* [3], and the results were combined using the *Within* approach where weights are estimated for each imputed data set, exposure effects are computed for each individual data set and then the coefficients and standard errors are subsequently pooled using Rubin’s Rules [4] to produce a point estimate of the exposure effect. The within approach demonstrates unbiased estimates when compared to other approaches [5,6].

Section B

Covariate balancing was assessed using the R package *cobalt* [7]. Pre-weighting and pre-imputation assessment indicated 26/41 covariate levels were unbalanced. After GBM weighting, perfect balance was achieved across all covariate levels using a difference threshold of > 0.01. After multiple imputation and covariate balancing propensity score weighting, perfect covariate balance was also achieved. Both love plots are shown in Figures 1 & 2 to visualize the standardized mean differences of covariates before and after weighting.

**References**

1. Van Buuren S, Groothuis-Oudshoorn K: mice: Multivariate imputation by chained equations in R. J Stat Softw. 2011; 45:1–67.

2. Imai K, Ratkovic M: Covariate balancing propensity score. J R Stat Soc Ser B Stat Methodol. 2014; 243–263.

3. Pishgar F, Greifer N, Leyrat C, Stuart E: MatchThem:: matching and weighting after multiple imputation. ArXiv Prepr ArXiv200911772. 2020; .

4. Rubin DB: Multiple imputation for nonresponse in surveys. John Wiley & Sons, 2004.

5. Granger E, Sergeant JC, Lunt M: Avoiding pitfalls when combining multiple imputation and propensity scores. Stat Med. 2019; 38:5120–5132.

6. Leyrat C, Seaman SR, White IR, et al.: Propensity score analysis with partially observed covariates: how should multiple imputation be used? Stat Methods Med Res. 2019; 28:3–19.

7. Greifer N: cobalt: Covariate Balance Tables and Plots. 2022.

Figure 1. Love plot displaying covariate balance before and after GBM adjustment.

Diagram

Description automatically generated

Figure 2. Love plot displaying covariate balance before and after multiple imputation and covariate balancing propensity score adjustment.

A picture containing diagram

Description automatically generated

**Table 1.** *Descriptive statistics for the full sample and by each age group*

|  | Total | 18-24 years | 25-34 years | 35-44 years | 45-54 years | 55-64 years | 65-74 years | 75-84 years | 85+ years |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | (*N* = 341,956) | *(n =* 64,648) | *(n =* 47,249) | *(n =* 55,241) | *(n =* 57,259) | (*n* = 63,113) | (*n* = 40*,*881) | (*n* = 12,029) | (*n* = 1,536) |
| Sex |  |  |  |  |  |  |  |  |  |
| Female | 189226 (55.3%) | 39831 (61.6%) | 27344 (57.9%) | 31203 (56.5%) | 30890 (53.9%) | 32729 (51.9%) | 20256 (49.5%) | 6141 (51.1%) | 832 (54.2%) |
| Male | 148624 (43.5%) | 23206 (35.9%) | 19427 (41.1%) | 23584 (42.7%) | 25815 (45.1%) | 29827 (47.3%) | 20299 (49.7%) | 5807 (48.3%) | 659 (42.9%) |
| Other/Intersex | 819 (0.2%) | 268 (0.4%) | 63 (0.1%) | 92 (0.2%) | 163 (0.3%) | 136 (0.2%) | 63 (0.2%) | 14 (0.1%) | 20 (1.3%) |
| Missing | 3287 (1.0%) | 1343 (2.1%) | 415 (0.9%) | 362 (0.7%) | 391 (0.7%) | 421 (0.7%) | 263 (0.6%) | 67 (0.6%) | 25 (1.6%) |
| Education |  |  |  |  |  |  |  |  |  |
| Associate’s Degree | 21259 (6.2%) | 3921 (6.1%) | 2512 (5.3%) | 2643 (4.8%) | 3174 (5.5%) | 4381 (6.9%) | 3398 (8.3%) | 1093 (9.1%) | 137 (8.9%) |
| Bachelor’s Degree | 105724 (30.9%) | 17800 (27.5%) | 19818 (41.9%) | 20404 (36.9%) | 18197 (31.8%) | 17066 (27.0%) | 9753 (23.9%) | 2455 (20.4%) | 231 (15.0%) |
| Graduate Degree | 56764 (16.6%) | 3386 (5.2%) | 8580 (18.2%) | 11690 (21.2%) | 11725 (20.5%) | 11671 (18.5%) | 7423 (18.2%) | 2038 (16.9%) | 251 (16.3%) |
| High School | 77434 (22.6%) | 23451 (36.3%) | 7871 (16.7%) | 9293 (16.8%) | 10880 (19.0%) | 12985 (20.6%) | 9321 (22.8%) | 3155 (26.2%) | 478 (31.1%) |
| Less than High School | 34040 (10.0%) | 6836 (10.6%) | 2902 (6.1%) | 4720 (8.5%) | 5674 (9.9%) | 7249 (11.5%) | 4811 (11.8%) | 1620 (13.5%) | 228 (14.8%) |
| Other | 16246 (4.8%) | 3578 (5.5%) | 2248 (4.8%) | 2552 (4.6%) | 2733 (4.8%) | 2997 (4.7%) | 1649 (4.0%) | 412 (3.4%) | 77 (5.0%) |
| Vocational Certification | 21823 (6.4%) | 1922 (3.0%) | 2613 (5.5%) | 3054 (5.5%) | 3842 (6.7%) | 5487 (8.7%) | 3762 (9.2%) | 1043 (8.7%) | 100 (6.5%) |
| Missing | 8666 (2.5%) | 3754 (5.8%) | 705 (1.5%) | 885 (1.6%) | 1034 (1.8%) | 1277 (2.0%) | 764 (1.9%) | 213 (1.8%) | 34 (2.2%) |
| Employment |  |  |  |  |  |  |  |  |  |
| Employed /Self employed | 163401 (47.8%) | 12630 (19.5%) | 29040 (61.5%) | 39198 (71.0%) | 41026 (71.6%) | 33075 (52.4%) | 7391 (18.1%) | 960 (8.0%) | 81 (5.3%) |
| Homemaker | 31570 (9.2%) | 2260 (3.5%) | 5383 (11.4%) | 8198 (14.8%) | 7162 (12.5%) | 5874 (9.3%) | 2124 (5.2%) | 478 (4.0%) | 91 (5.9%) |
| Not able to work | 7210 (2.1%) | 1212 (1.9%) | 806 (1.7%) | 966 (1.7%) | 1444 (2.5%) | 2193 (3.5%) | 473 (1.2%) | 81 (0.7%) | 35 (2.3%) |
| Retired | 61333 (17.9%) | 102 (0.2%) | 93 (0.2%) | 317 (0.6%) | 1924 (3.4%) | 17194 (27.2%) | 30038 (73.5%) | 10380 (86.3%) | 1285 (83.7%) |
| Studying | 48583 (14.2%) | 40925 (63.3%) | 4306 (9.1%) | 1476 (2.7%) | 1101 (1.9%) | 574 (0.9%) | 149 (0.4%) | 30 (0.2%) | 22 (1.4%) |
| Unemployed | 29859 (8.7%) | 7519 (11.6%) | 7621 (16.1%) | 5086 (9.2%) | 4602 (8.0%) | 4203 (6.7%) | 706 (1.7%) | 100 (0.8%) | 22 (1.4%) |
| Relationship Status |  |  |  |  |  |  |  |  |  |
| Divorced/ Separated | 32484 (9.5%) | 876 (1.4%) | 2137 (4.5%) | 4738 (8.6%) | 6849 (12.0%) | 9677 (15.3%) | 6535 (16.0%) | 1536 (12.8%) | 136 (8.9%) |
| In a cohabiting relationship | 15388 (4.5%) | 1318 (2.0%) | 2861 (6.1%) | 3170 (5.7%) | 3062 (5.3%) | 3022 (4.8%) | 1576 (3.9%) | 345 (2.9%) | 34 (2.2%) |
| In a relationship | 32066 (9.4%) | 12729 (19.7%) | 7347 (15.5%) | 3650 (6.6%) | 3146 (5.5%) | 3103 (4.9%) | 1669 (4.1%) | 390 (3.2%) | 32 (2.1%) |
| Married/Civil Partnership | 145166 (42.5%) | 2022 (3.1%) | 14235 (30.1%) | 31501 (57.0%) | 33622 (58.7%) | 35037 (55.5%) | 22295 (54.5%) | 5897 (49.0%) | 557 (36.3%) |
| Other | 2313 (0.7%) | 803 (1.2%) | 470 (1.0%) | 439 (0.8%) | 339 (0.6%) | 208 (0.3%) | 46 (0.1%) | 5 (0.0%) | 3 (0.2%) |
| Single (never married or in a civil partnership) | 85117 (24.9%) | 42004 (65.0%) | 18279 (38.7%) | 9084 (16.4%) | 6653 (11.6%) | 5955 (9.4%) | 2583 (6.3%) | 508 (4.2%) | 51 (3.3%) |
| Widowed | 14744 (4.3%) | 139 (0.2%) | 158 (0.3%) | 557 (1.0%) | 1490 (2.6%) | 3860 (6.1%) | 4895 (12.0%) | 2984 (24.8%) | 661 (43.0%) |
| Missing | 14678 (4.3%) | 4757 (7.4%) | 1762 (3.7%) | 2102 (3.8%) | 2098 (3.7%) | 2251 (3.6%) | 1282 (3.1%) | 364 (3.0%) | 62 (4.0%) |
| Socialize Frequency |  |  |  |  |  |  |  |  |  |
| Rarely/Never | 86212 (25.2%) | 14926 (23.1%) | 14063 (29.8%) | 16429 (29.7%) | 16052 (28.0%) | 15390 (24.4%) | 7446 (18.2%) | 1683 (14.0%) | 223 (14.5%) |
| 1-3 times a month | 79457 (23.2%) | 13115 (20.3%) | 11989 (25.4%) | 12973 (23.5%) | 13545 (23.7%) | 15310 (24.3%) | 9591 (23.5%) | 2655 (22.1%) | 279 (18.2%) |
| Once a week | 63389 (18.5%) | 11242 (17.4%) | 8055 (17.0%) | 9235 (16.7%) | 9847 (17.2%) | 12275 (19.4%) | 9352 (22.9%) | 3019 (25.1%) | 364 (23.7%) |
| Several days a week | 112898 (33.0%) | 25365 (39.2%) | 13142 (27.8%) | 16604 (30.1%) | 17815 (31.1%) | 20138 (31.9%) | 14492 (35.4%) | 4672 (38.8%) | 670 (43.6%) |
| Adequate Sleep Frequency |  |  |  |  |  |  |  |  |  |
| Hardly ever | 42262 (12.4%) | 10071 (15.6%) | 6175 (13.1%) | 7270 (13.2%) | 7113 (12.4%) | 7180 (11.4%) | 3498 (8.6%) | 836 (6.9%) | 119 (7.7%) |
| Some of the time | 117966 (34.5%) | 25492 (39.4%) | 18234 (38.6%) | 21289 (38.5%) | 20129 (35.2%) | 19465 (30.8%) | 10499 (25.7%) | 2569 (21.4%) | 289 (18.8%) |
| Most of the time | 140096 (41.0%) | 22792 (35.3%) | 17866 (37.8%) | 21383 (38.7%) | 23592 (41.2%) | 27803 (44.1%) | 19799 (48.4%) | 6106 (50.8%) | 755 (49.2%) |
| All of the time | 41632 (12.2%) | 6293 (9.7%) | 4974 (10.5%) | 5299 (9.6%) | 6425 (11.2%) | 8665 (13.7%) | 7085 (17.3%) | 2518 (20.9%) | 373 (24.3%) |
| Medical Diagnosis (Y/N) |  |  |  |  |  |  |  |  |  |
| Yes | 53164 (15.5%) | 7584 (11.7%) | 5438 (11.5%) | 6702 (12.1%) | 8628 (15.1%) | 12133 (19.2%) | 8917 (21.8%) | 3286 (27.3%) | 476 (31.0%) |
| Missing | 8080 (2.4%) | 2187 (3.4%) | 998 (2.1%) | 1203 (2.2%) | 1212 (2.1%) | 1290 (2.0%) | 874 (2.1%) | 255 (2.1%) | 61 (4.0%) |
| Mental Health Treatment in Past Year (Y/N) |  |  |  |  |  |  |  |  |  |
| Yes | 50606 (14.8%) | 12028 (18.6%) | 8183 (17.3%) | 8221 (14.9%) | 8181 (14.3%) | 8732 (13.8%) | 4192 (10.3%) | 979 (8.1%) | 90 (5.9%) |
| Missing | 3832 (1.1%) | 850 (1.3%) | 434 (0.9%) | 586 (1.1%) | 624 (1.1%) | 725 (1.1%) | 450 (1.1%) | 134 (1.1%) | 29 (1.9%) |
| Experienced Childhood Trauma (Y/N) |  |  |  |  |  |  |  |  |  |
| Yes | 210952 (61.7%) | 48130 (74.4%) | 31960 (67.6%) | 33581 (60.8%) | 33036 (57.7%) | 35712 (56.6%) | 21646 (52.9%) | 6071 (50.5%) | 816 (53.1%) |
| Experienced Adult Trauma (Y/N) |  |  |  |  |  |  |  |  |  |
| Yes | 252869 (73.9%) | 47240 (73.1%) | 34676 (73.4%) | 38578 (69.8%) | 41473 (72.4%) | 47681 (75.5%) | 31854 (77.9%) | 10030 (83.4%) | 1337 (87.0%) |
| Physical Activity |  |  |  |  |  |  |  |  |  |
| Inactive | 135525 (39.6%) | 27949 (43.2%) | 23082 (48.9%) | 27178 (49.2%) | 24080 (42.1%) | 20054 (31.8%) | 9828 (24.0%) | 2883 (24.0%) | 471 (30.7%) |
| Active | 206431 (60.4%) | 36699 (56.8%) | 24167 (51.1%) | 28063 (50.8%) | 33179 (57.9%) | 43059 (68.2%) | 31053 (76.0%) | 9146 (76.0%) | 1065 (69.3%) |
| MHQ |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 67.9 (72.7) | 21.2 (69.6) | 45.4 (69.2) | 64.6 (68.4) | 80.2 (67.6) | 92.6 (65.5) | 103 (59.7) | 111 (55.1) | 111 (63.7) |
| Core Cognition |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 81.4 (67.0) | 39.5 (63.2) | 61.0 (64.7) | 78.6 (64.7) | 92.3 (63.0) | 104 (60.4) | 113 (54.7) | 119 (51.3) | 116 (58.3) |
| Adaptability and Resilience |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 89.8 (67.4) | 50.7 (67.5) | 70.6 (66.7) | 88.3 (64.6) | 101 (62.7) | 110 (61.3) | 118 (55.2) | 125 (49.7) | 123 (55.4) |
| Drive and Motivation |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 83.4 (66.6) | 43.5 (64.7) | 62.6 (65.2) | 80.4 (63.9) | 94.3 (62.4) | 105 (60.1) | 114 (53.8) | 118 (49.7) | 114 (57.1) |
| Mood and Outlook |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 67.2 (71.1) | 24.4 (64.8) | 44.1 (66.3) | 62.0 (67.1) | 78.1 (67.6) | 91.2 (66.2) | 102 (61.5) | 111 (57.2) | 114 (61.7) |
| Social Self |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 70.7 (76.6) | 23.1 (69.5) | 50.2 (72.5) | 69.7 (72.8) | 83.5 (72.8) | 94.3 (71.8) | 103 (68.2) | 112 (64.6) | 116 (67.3) |
| Mind-Body |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 73.4 (64.7) | 44.6 (64.3) | 57.7 (63.8) | 68.7 (63.8) | 80.5 (62.9) | 90.1 (60.8) | 98.5 (55.5) | 102 (52.0) | 99.3 (57.0) |

**Table 2.** *ATC’s of physical activity across age groups and subcategories*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 18-24 | 25-34 | 35-44 | 45-54 | 55-64 | 65-74 | 75-84 | 85+ |
| MHQ |  |  |  |  |  |  |  |  |
| ATC | 17.77 | 19.79 | 20.41 | 18.65 | 15.76 | 12.37 | 11.24 | 23.37 |
| SE | 1.23 | 1.35 | 1.462 | 1.78 | 1.93 | 1.38 | 1.69 | 5.49 |
| SMD | 0.26 | 0.29 | 0.30 | 0.28 | 0.24 | 0.20 | 0.20 | 0.35 |
| Core Cognition |  |  |  |  |  |  |  |  |
| ATC | 17.29 | 18.56 | 18.79 | 16.66 | 13.78 | 9.74 | 7.84 | 19.25 |
| SE | 0.92 | 1.11 | 1.32 | 1.45 | 1.45 | 1.22 | 1.66 | 4.29 |
| SMD | 0.28 | 0.29 | 0.30 | 0.27 | 0.23 | 0.17 | 0.15 | 0.32 |
| Adaptability and Resilience |  |  |  |  |  |  |  |  |
| ATC | 20.10 | 18.71 | 18.96 | 16.87 | 14.79 | 14.50 | 12.18 | 21.93 |
| SE | 1.37 | 1.59 | 1.60 | 1.79 | 1.90 | 1.60 | 1.76 | 3.97 |
| SMD | 0.30 | 0.28 | 0.30 | 0.27 | 0.24 | 0.25 | 0.24 | 0.37 |
| Mood and Outlook |  |  |  |  |  |  |  |  |
| ATC | 13.71 | 16.64 | 17.94 | 16.81 | 13.90 | 10.74 | 9.98 | 19.40 |
| SE | 1.06 | 1.31 | 1.44 | 1.79 | 2.03 | 1.36 | 1.46 | 5.01 |
| SMD | 0.22 | 0.26 | 0.27 | 0.25 | 0.21 | 0.17 | 0.17 | 0.30 |
| Drive and Motivation |  |  |  |  |  |  |  |  |
| ATC | 18.27 | 18.34 | 17.94 | 15.65 | 11.71 | 9.88 | 8.29 | 20.14 |
| SE | 1.21 | 1.47 | 1.66 | 1.87 | 1.93 | 1.61 | 1.87 | 4.07 |
| SMD | 0.29 | 0.29 | 0.29 | 0.25 | 0.19 | 0.18 | 0.16 | 0.34 |
| Social Self |  |  |  |  |  |  |  |  |
| ATC | 10.96 | 14.33 | 15.42 | 14.84 | 12.45 | 9.04 | 8.02 | 19.22 |
| SE | 1.28 | 1.49 | 14.84 | 1.76 | 1.84 | 1.39 | 1.76 | 5.72 |
| SMD | 0.16 | 0.20 | 0.21 | 0.21 | 0.17 | 0.13 | 0.12 | 0.28 |
| Mind-Body |  |  |  |  |  |  |  |  |
| ATC | 19.54 | 21.38 | 21.12 | 19.46 | 16.67 | 15.38 | 15.36 | 25.52 |
| SE | 1.03 | 1.33 | 1.29 | 1.86 | 2.17 | 1.79 | 2.25 | 4.38 |
| SMD | 0.31 | 0.34 | 0.34 | 0.32 | 0.28 | 0.27 | 0.29 | 0.44 |