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**sFigure 1 Flow of participants**

|  |
| --- |
|  |
| MI, myocardial infarction; DM, diabetes mellitus; BMI, body mass index |

The validation cohort consisted of 70,535 participants aged 20-74 years in the first wave of HUNT (1984-86). We excluded 4487 participants on the basis of self-reported history of myocardial infarction, angina pectoris, stroke, and diabetes mellitus. We further excluded those with motion impairment (n=5598), and somatic diseases (n=5605) hampering physical activity participation. In addition, 12,898 participants who failed to return the questionnaire about physical activity, and 2649 participants with missing values on various covariates were excluded. Therefore, a total of 39,298 (20,029 women and 19,269 men) were included in the analyses of this study (sFigure 1)

**Supplementary Text**

***Personalized Activity Intelligence (PAI)***

The following assumptions found the basis of the model design:

1. Intensity of exercise at individual level is appropriately assessed by using % of heart rate reserve [heart rate relative to resting heart rate and maximum heart rate].
2. Very low intensity does not contribute to increased cardiorespiratory fitness, suggesting that a threshold exist before PAI can be accumulated1.
3. Increased intensity has been shown to dramatically reduce the amount of exercise needed to increase cardiorespiratory fitness, suggesting a non-linear scaling of intensity for the model2.
4. Exercise level is fundamentally a product of intensity and time, where assessment from a continuous data stream of heart rate is achieved by integrating the nonlinearly scaled intensity over time.
5. Effect of exercise is most prominent from an inactive baseline, where increased levels show a gradually decaying effect on cardiorespiratory fitness improvement.
6. When an individual increases cardiorespiratory fitness; resting heart rate, as well as heart rates during submaximal physical activity, become reduced, securing that the absolute levels of physical activity needed to reach 100 PAI becomes higher.

Heart rate is normalized according to assumption 1:

where *y(t)* [beats per minute] is measured heart rate at time *t*, *ymax* is maximum heart rate and *yth* is the threshold for heart rate according to assumption 2. For computer implementation is capped,. Normalized intensity is further scaled with an exponential function containing two unknown coefficients *c1* and *c2*:

where *z(t)* is referred to as the intensity score (nonlinearly scaled intensity). To assess the exercise level for one week the time-integral (assumption 4) is calculated to give an activity score:

where *–T* is the time one week since time *t* [minutes]. Finally, a health-predictive activity score is calculated according to assumption 5 containing two unknown coefficients c3 and c4, representing offset and decay level respectively:

The derivation cohort was used to estimate the coefficients c1 to c4. We used the findings from our previous work3 where a non-exercise model to estimate VO2peak was developed. The same four parameters was used to set up a VO2peak estimator; i.e., physical activity, age, BMI/WC and RHR, where the model presented above, *V(t, {yt, T}, ymax, yth, c1, c2, c3, c4, T) replaced the static index for physical activity used in the previous study3.*

A least-square cost function was then designed, fitting estimated VO2peak with measured VO2peak, and solved using nonlinear programming (quasi-newton method) in Matlab (R2013a). Estimated model coefficients were:

|  |  |  |
| --- | --- | --- |
| *Coefficient* | *Men* | *Women* |
| *c1* | *10.1817* | *9.8556* |
| *c2* | *5.7808* | *5.0167* |
| *c3* | *41.9374* | *34.2325* |
| *c4* | *9.8382* | *9.7581* |

The predictor V is inconvenient for practical implementation and readability. Therefore, PAI was designed as a linear scaling ranging from 0 at complete inactivity to 100 representing recommended activity level. PAI=100, approximated to two sessions per week of 4x4 minutes bouts of high-intensity exercise interspersed with 3 minutes’ active recovery, as previously suggested to be adequate activity level.2, 4-7. PAI will further increase above 100 but not expected provide additional significant health benefit.

**Examples of exercise to achieve PAI**

PAI can be achieved by performing exercise/physical activity at various doses of quantity and intensity. For example, performing 150 minutes at light intensity exercise (~44 %HRR) per week contributes to approximately 38 PAI. The recommended amount of 100 PAI can be achieved by a minimum of 40 minutes of vigorous intensity exercise (~85 %heart rate reserve) per week, or 60 minutes of moderate intensity exercise (~75 %heart rate reserve) per week or a combination of light, moderate or vigorous intensity exercise.

**References**

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**sTable 1 Comparison of participants included in the study analyses Vs. those who were excluded**

|  |  |  |
| --- | --- | --- |
|  | **Included** | **Excluded\*** |
|  | n=39,298 | n=31,237 |
| **Women, No. (%)** | 20029 (51.0) | 15342 (49.1) |
| **Age, mean (SD), y** | 42.6 (14.1) | 49.5 (15.9) |
| **All-cause death, No. (%)** |  |  |
| Yes | 10062 (25.6) | 15001 (48.0) |
| No | 29236 (74.4) | 16236 (52.0) |
| **Cardiovascular death, No. (%)** |  |  |
| Yes | 3867 (9.8) | 6906 (22.1) |
| No | 35431 (90.2) | 24331 (77.9) |
| **Body mass index, mean (SD), kg/m2** |  |  |
| <18.5 | 17.7 (0.6) | 17.6 (0.8) |
| 18.5-24.9 | 22.4 (1.5) | 22.5 (1.6) |
| ≥25.0 | 28.0 (3.0) | 28.7 (3.3) |
| Missing, No. (%) | - | 3217 (10.3) |
| **Hypertension status, No. (%)a** |  |  |
| Yes | 15709 (40.0) | 15279 (48.9) |
| No | 23589 (60.0) | 12852 (41.1) |
| Missing | - | 3106 (9.9) |
| **Smoking status, No. (%)** |  |  |
| Yes | 14367 (36.6) | 5578 (17.9) |
| No | 24931 (63.4) | 10467 (33.5) |
| Missing | - | 15192 (48.6) |
| **Alcohol consumption, No. (%)b** |  |  |
| Abstainer | 3001 (7.6) | 2652 (8.5) |
| Zero | 16567 (42.2) | 8070 (25.8) |
| 1-4 times | 17335 (44.1) | 4524 (14.5) |
| 5-10 times | 1241 (3.2) | 411 (1.3) |
| >10 times | 1154 (2.9) | 604 (1.9) |
| Missing | - | 14976 (47.9) |
| **Education** |  |  |
| <10 y | 20855 (53.1) | 12483 (40.0) |
| 10-12 y | 13428 (34.2) | 2685 (8.6) |
| ≥13 y | 5015 (12.7) | 790 (2.5) |
| Missing | - | 15282 (48.9) |
| **Physical activity recommendations, No. (%)** | | |
| Yes | 7520 (19.1) | 2418 (7.7) |
| No | 31778 (80.9)) | 12563 (40.2) |
| Missing | - | 16256 (52.1) |

\*Sequential exclusion was due to history of myocardial infarction or angina pectoris or prevalent diabetes mellitus or stroke or motion impairment or somatic disease or no report on physical activity or missing values on various covariates (see the Methods section for details)

aDefined as systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg and/or taking blood pressure medications in HUNT-1 study.

bBased on consumption over a 2-week period.

**sTable 2 Descriptive characteristics of derivation cohort (HUNT Fitness study) and validation cohort (HUNT-1 study)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **HUNT Fitness Study** | |  | **HUNT-1 Study** | |
|  | **Men** | **Women** | **Men** | **Women** |
|  | (n=2263) | (2368) |  | (19269) | (20,029) |
| **Age, mean (SD), y** | 48.9 (13.5) | 48.0 (13.7) |  | 42.5 (14.0) | 42.7 (14.2) |
| **Body mass index, mean (SD), kg/m2** |  |  |  |  |  |
| <18.5 | 17.9 (0.4) | 17.9 (0.4) |  | 17.7 (0.6) | 17.7 (0.6) |
| 18.5-24.9 | 23.2 (1.4) | 22.6 (1.5) | 22.9 (1.4) | 22.1 (1.6) |
| ≥25.0 | 28.1 (2.5) | 28.6 (3.0) | 27.6 (2.4) | 28.6 (3.5) |
| **Hypertension status, No. (%)a** |  |  |  |  |
| Yes | 558 (24.6) | 323 (13.5) |  | 9011 (46.8) | 6698 (33.4) |
| No | 1472 (64.8) | 1808 (75.8) | 10258 (53.2) | 13,331 (66.6) |
| **Smoking status, No. (%)** |  |  |  |  |  |
| Yes | 398 (17.5) | 457 (19.1) |  | 7169 (37.2) | 7198 (35.9) |
| No | 1829 (81.0) | 1893 (79.3) |  | 12,100 (62.8) | 12,831 (64.1) |
| **Alcohol consumption, No. (%)b** |  |  |  |  |  |
| Abstainer | 43 (1.9) | 72 (3.0) |  | 932 (4.8) | 2069 (10.3) |
| Zero | 207 (9.1) | 385 (16.1) | | 6230 (32.3) | 10,337 (51.6) |
| 1-4 times | 756 (33.3) | 1134 (47.5) |  | 10,407 (54.0) | 6928 (34.6) |
| 5-10 times | 757 (33.3) | 561 (23.5) | 916 (4.8) | 325 (1.6) |
| >10 times | 441 (19.4) | 139 (5.8) | 784 (4.1) | 370 (1.9) |
| **Physical activity habits, No. (%)** |  |  |  |  |  |
| Frequency |  |  |  |  |  |
| Inactive/<Once a week | 420 (18.5) | 236 (9.8) |  | 8222 (42.7) | 7766 (38.8) |
| Once a week | 492 (21.7) | 442 (18.5) | 4787 (24.8) | 6656 (27.8) |
| 2-3 times a week | 991 (43.6) | 1209 (50.7) | 4385 (22.8) | 4613 (23.0) |
| Almost everyday | 355 (15.6) | 490 (21.0) | 1875 (9.7) | 2085 (10.4) |
| Duration per session |  |  |  |  |  |
| <30 minutes | 314 (13.8) | 289 (12.1) |  | 3047 (15.8) | 5147 (25.7) |
| ≥30 minutes | 1707 (75.2) | 1965 (82.4) | 8000 (41.5) | 7116 (35.5) |
| Intensity |  |  |  |  |  |
| Take it easy | 496 (21.8) | 677 (28.4) |  | 3657 (33.1) | 6945 (56.6) |
| Heavy breath/sweat | 1276 (56.2) | 1443 (60.5) | 6536 (59.2) | 5090 (41.5) |
| Near exhaustion | 210 (9.2) | 102 (4.3) | 854 (7.7) | 228 (1.9) |
| **Cardiorespiratory fitness, mean (SD)c** | 44.3 (9.2) | 35.9 (7.8) |  | - | - |

aDefined as systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg in HUNT Fitness Study, and systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg and/or taking blood pressure medications in HUNT-1 study.

bBased on consumption over a 2-week period.

cCardiorespiratory fitness was objectively measured by ergospirometry test running on a treadmill, and expressed as mL.kg-1.min-1.

**sTable 3 Hazard ratio of mortality by PAI, stratified by diabetes and hypertension status**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All-cause** | | | | |  | **CVD** | | | | |
|  |  |  |  |  | P-value for interaction |  |  |  |  |  | P-value for interaction |
| **PAI** | Inactive | ≤50 | 51-99 | ≥100 |  | Inactive | ≤50 | 51-99 | ≥100 |
| **Diabetes** |  |  |  |  |  |  |  |  |  |  |  |
| **No** |  |  |  |  |  |  |  |  |  |  |  |
| Deaths | 4035 | 3810 | 870 | 1347 |  |  | 1531 | 1537 | 333 | 466 |  |
| HRa | 1.00 | 0.89 | 0.80 | 0.74 |  |  | 1.00 | 0.91 | 0.80 | 0.67 |  |
| (95% CI) | Ref. | (0.85-0.93) | (0.74-0.86) | (0.69-0.78) |  |  | Ref. | (0.85-0.98) | (0.71-0.90) | (0.61-0.75) |  |
| **Yes** |  |  |  |  |  |  |  |  |  |  |  |
| Deaths | 104 | 120 | 22 | 32 |  |  | 54 | 73 | 11 | 15 |  |
| HRa | 1.00 | 0.89 | 0.88 | 0.52 |  |  | 1.00 | 1.08 | 0.88 | 0.46 |  |
| (95% CI) | Ref. | (0.68-1.17) | (0.55-1.39) | (0.35-0.79) |  |  | Ref. | (0.75-1.54) | (0.46-1.68) | (0.25-0.83) |  |
|  |  |  |  |  | 0.14 |  |  |  |  |  | 0.19 |
| **Hypertension** |  |  |  |  |  |  |  |  |  |  |  |
| **No** |  |  |  |  |  |  |  |  |  |  |  |
| Deaths | 1392 | 1125 | 276 | 515 |  |  | 371 | 333 | 77 | 124 |  |
| HRa | 1.00 | 0.89 | 0.74 | 0.74 |  |  | 1.00 | 0.96 | 0.80 | 0.66 |  |
| (95% CI) | Ref. | (0.83-0.97) | (0.65-0.84) | (0.67-0.82) |  |  | Ref. | (0.83-1.12) | (0.62-1.02) | (0.54-0.81) |  |
| **Yes** |  |  |  |  |  |  |  |  |  |  |  |
| Deaths | 2643 | 2685 | 594 | 832 |  |  | 1160 | 1204 | 256 | 342 |  |
| HRa | 1.00 | 0.88 | 0.83 | 0.75 |  |  | 1.00 | 0.89 | 0.81 | 0.70 |  |
| (95% CI) | Ref. | (0.84-0.93) | (0.76-0.91) | (0.69-0.81) |  |  | Ref. | (0.82-0.96) | (0.71-0.93) | (0.62-0.79) |  |
|  |  |  |  |  | 0.40 |  |  |  |  |  | 0.69 |

Abbreviations: PAI, personalized activity intelligence; CVD, cardiovascular disease; HR, hazard ratio; CI, confidence interval.

aAdjusted for age by including the attained age as the time scale, and sex.

**sTable 4 Hazard ratios\* (95% CI) for all-cause and cardiovascular mortality**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **All-cause mortality** | |  |  |  |  |
|  |  | Deaths | HR (95% CI) | Chi2 | *P*>chi2 |
| PAI | <100 | 8715 | 1.00 |  |  |
|  | ≥100 | 1347 | 0.90 (0.84-0.97) | 7.47 | <0.01 |
| Physical activity | Below | 8317 | 1.00 |  |  |
|  | Following | 1745 | 0.97 (0.91-1.04) | 0.79 | 0.37 |
| Smoking | No | 6123 | 1.00 |  |  |
|  | Yes | 3939 | 1.91 (1.83-1.99) | 862.05 | <0.01 |
| Hypertension | No | 3308 | 1.00 |  |  |
|  | Yes | 6754 | 1.37 (1.31-1.43) | 190.87 | <0.01 |
| Body mass index | <18.5 | 81 | 1.65 (1.33-2.06) |  |  |
|  | 18.5-24.9 | 4218 | 1.00 |  |  |
|  | ≥25.0 | 5763 | 1.10 (1.05-1.14) | 35.32 | <0.01 |
| Alcohol | Abstainer | 1242 | 1.00 |  |  |
|  | Zero | 4982 | 0.89 (0.84-0.95) |  |  |
|  | 1-4 times | 3074 | 0.85 (0.79-0.91) |  |  |
|  | 5-10 times | 331 | 0.99 (0.87-1.12) |  |  |
|  | >10 times | 433 | 1.02 (0.91-1.14) | 33.78 | <0.01 |
| Education | <10 y | 7682 | 1.00 |  |  |
|  | 10-12 y | 1751 | 0.91 (0.86-0.96) |  |  |
|  | ≥13 y | 629 | 0.81 (0.74-0.88) | 31.78 | <0.01 |
| Sex | Women | 4535 | 1.00 |  |  |
|  | Men | 5527 | 1.61 (1.55-1.68) | 496.08 | <0.01 |
| **CVD mortality** |  |  |  |  |  |
| PAI | <100 | 3401 | 1.00 |  |  |
|  | ≥100 | 466 | 0.82 (0.73-0.92) | 11.23 | <0.01 |
| Physical activity | Below | 3198 | 1.00 |  |  |
|  | Following | 669 | 1.00 (0.90-1.10) | 0.01 | 0.98 |
| Smoking | No | 2425 | 1.00 |  |  |
|  | Yes | 1442 | 1.99 (1.85-2.13) | 367.15 | <0.01 |
| Hypertension | No | 905 | 1.00 |  |  |
|  | Yes | 2962 | 1.96 (1.81-2.12) | 286.30 | <0.01 |
| Body mass index | <18.5 | 22 | 1.45 (0.95-2.21) |  |  |
|  | 18.5-24.9 | 1441 | 1.00 |  |  |
|  | ≥25.0 | 2404 | 1.20 (1.12-1.29) | 29.91 | <0.01 |
| Alcohol | Abstainer | 545 | 1.00 |  |  |
|  | Zero | 2016 | 0.83 (0.75-0.91) |  |  |
|  | 1-4 times | 1022 | 0.68 (0.61-0.77) |  |  |
|  | 5-10 times | 99 | 0.70 (0.56-0.87) |  |  |
|  | >10 times | 185 | 0.98 (0.83-1.16) | 56.28 | <0.01 |
| Education | <10 y | 3065 | 1.00 |  |  |
|  | 10-12 y | 582 | 0.89 (0.81-0.98) |  |  |
|  | ≥13 y | 220 | 0.85 (0.74-0.98) | 9.57 | <0.01 |
| Sex | Women | 1660 | 1.00 |  |  |
|  | Men | 2207 | 1.87 (1.75-2.01) | 323.13 | <0.01 |

\*Adjusted for age by including attained age as timescale and other covariates.

**sTable 5 Hazard ratios for all-cause and cardiovascular mortality after excluding 3 years of follow-up**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All-cause** |  |  |  | **CVD** |  |  |
| **PAI** | **Men** |  |  |  |  |  |  |
|  | Person-years | Deaths | HR (95% CI)a |  | Person-years | Deaths | HR (95% CI)a |
| Inactive | 170,768 | 2131 | 1.00 |  | 170,768 | 823 | 1.00 |
| ≤50 | 79,255 | 1624 | 1.01 (0.94-1.07) |  | 79,256 | 693 | 1.07 (0.97-1.18) |
| 51-99 | 36,567 | 430 | 0.89 (0.80-0.98) |  | 36,567 | 177 | 0.93 (0.79-1.09) |
| ≥100 | 112,318 | 950 | 0.88 (0.81-0.95) |  | 112,317 | 338 | 0.81 (0.71-0.92) |
|  |  |  | *P*-trend<0.001 |  |  |  | *P*-trend<0.01 |
|  | **Women** |  |  |  |  |  |  |
| Inactive | 168,284 | 1655 | 1.00 |  | 168,284 | 607 | 1.00 |
| ≤50 | 149,046 | 1984 | 0.90 (0.84-0.96) |  | 149,046 | 751 | 0.87 (0.84-0.97) |
| 51-99 | 49,745 | 406 | 0.88 (0.79-0.98) |  | 49,745 | 147 | 0.89 (0.74-1.07) |
| ≥100 | 68,379 | 325 | 0.83 (0.74-0.94) |  | 68,379 | 96 | 0.79 (0.63-0.98) |
|  |  |  | *P*-trend<0.001 |  |  |  | *P*-trend=0.01 |

CVD, cardiovascular disease; HR, hazard ratio

aAdjusted for age, smoking (smoker, non-smoker), body mass index (underweight, normal-weight, overweight), hypertension (normal, hypertensive), alcohol consumption, and education.

**sFigure 2 Years of life lost according to PAI**

|  |
| --- |
|  |
| Based on proportional hazard regression models using attained age as underlying metric, and adjusted for smoking (smoker, non-smoker), body mass index (underweight, normal-weight, overweight), hypertension (normal, hypertensive), alcohol consumption, and education. A) Men; B) Women |