Supplementary Files

Optimal composition of movement behaviours for healthy weight across the lifespan: a one-stage individual participant data meta-analysis of 11 studies

Adjustments for confounding

All regression models were adjusted for age, sex, and socioeconomic status. These potential confounding variables were selected based on previous literature. Given that data on socioeconomic status were collected using different methods across the included studies, they were harmonised before the analysis. Socioeconomic status was reported as an ordinal variable with 3 to 10 levels, depending on the study. One study provided the Socio-Economic Index for Areas (SEIFA), while other studies used data on education status or the number of books at home, as a proxy indicators of socioeconomic status. To make the data across studies more comparable, the original variable was recoded as “Low”, “Middle”, or “High”. Based on data availability the following cut-points were used to categorise “Middle” socioeconomic status: 1) the SEIFA score ranged between 4 and 7 points; 2) the education status corresponded to completed secondary education or equivalent degree (mother’s education status was used for participants under the age of 18 years); or 3) having enough books at home to fill a bookcase (i.e., 26–100 books).

There were a total of 795 missing values for socioeconomic status in the dataset. Although values for socioeconomic status were missing completely at random in most studies, they were completely missing by design in two studies. The iterative robust model-based imputation technique was selected to replace missing values [1]. The imputation was based on several individual- and study-level predictors available in the dataset (e.g., body mass index, physical activity volume and intensity, and human development index). The imputation procedure was performed 100 times, and 10 imputed datasets were generated in each iteration. A different response variable was chosen in each step, resulting in multiple imputed datasets which we then combined using the Rubin’s rule [2]. Based on the Akaike information criterion, socioeconomic status was included as a categorical variable in models with BMIz/BMI as dependent variable and as a continuous variable in models with waist circumference.

Other individual-level (e.g., ethnicity, maturational status) and study-level data (e.g., Human development index, Gini index, Non-communicable disease policy implementation score [3]) were also considered as potential confounders. To get adjusted for in the final models, the potential confounders had to meet the following criteria: 1) the data were available across the included studies; 2) the variable is significantly associated with a given weight status indicator; 3) after including it in the model, the Akaike information criterion decreased; and 4) after included it in the model, the random intercept remained significant. No additional variables met these criteria. Given that the analyses were adjusted only for age, sex, and socioeconomic status, it is possible that some of our findings were affected by residual confounding.

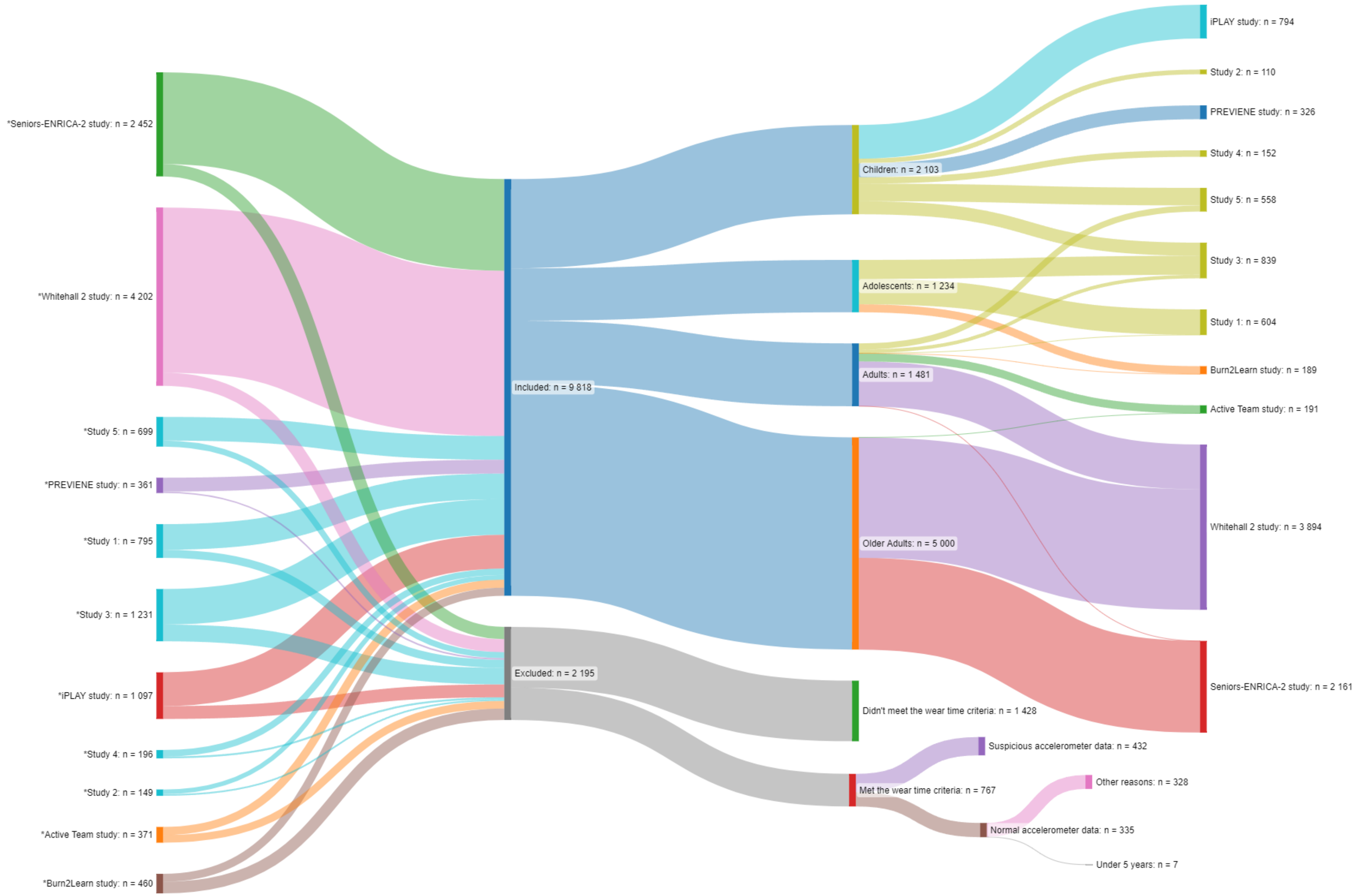

Figure S1: Flow chart of the data pooling process

Table S1. Characteristics of included studies

Study name	**Country**	**Study design**[a]	**Year of data collection**	**No. of participants** (% females, % included in the analytic sample)	**Age group(s)**	**Weight status indicator(s)**[b]	**Accelerometer type** (wear location[c], sampling interval, wear days)
Active-Start [4]	Chile	RCT	2018	149 (39%, 74%)	Children	BMI	GENEActiv (NDW, 87.5 Hz, 7)
Active Team [5]	Australia	RCT	2017–2018	371 (73%, 52%)	Adults, older adults	BMI[d]	GENEActiv (NDW, 50 Hz, 7)
Burn 2 Learn [6]	Australia	RCT	2018–2019	460 (47%, 41%)	Adolescents, adults	BMI	ActiGraph GT9X (NDW, 30 Hz, 7)
iPLAY [7]	Australia	RCT	2016–2017	1097 (50%, 72%)	Children	BMI	GENEActiv (NDW, 87.5 Hz, 8)
MOVI-da10! [8]	Spain	RCT	2017–2018	196 (48%, 78%)	Children	BMI, WC	GENEActiv (NDW, 30 Hz, 7)
PEDALS [9]	New Zealand	Cross-sectional	2015	699 (61%, 81%)	Children, adults	BMI, WC	ActiGraph GT3X+ (NDW, 30 Hz, 8)
PREVIENE [10]	Spain	RCT	2017	361 (47%, 90%)	Children	BMI, WC	ActiGraph wGT3X-BT+ (NDW, 90 Hz, 7)
Seniors-ENRICA-2 [11]	Spain	Prospective cohort	2015–2017	2452 (53%, 88%)	Older adults	BMI, WC	ActiGraph GT9X (NDW, 100 Hz, 7)
Study 1 [12]	Brazil	Cross-sectional	2019	795 (50%, 76%)	Adolescents, adults	BMI	ActiGraph GT3X+ (NDW, 30 Hz, 7)
Study 2 [13]	Czechia	Cross-sectional	2018–2022[e]	1231 (52%, 68%)	Children, adolescents, adults	BMI	ActiGraph GT3X+ and GT9X (NDW, 100 Hz, 7)
Whitehall 2 [14]	United Kingdom	Cross-sectional	2012–2013	4202 (26%, 93%)[f]	Adults, older adults	BMI, WC	GENEActiv (NDW, 87.5 Hz, 9)

[a] RCT; randomised controlled trial

[b] BMI; body mass index, WC; waist circumference

[c] LW; left wrist, NDW; non-dominant wrist

[d] Self-reported data

[e] Data were collected before (2018–2019) and after (2022) the COVID-19 pandemic temporary restrictions

[f] National sample

Table S2. Sensitivity analysis of associations between the movement behaviour composition and weight indicators across age groups

	Children		Adolescents		Adults		Older adults	
	F[a]	*p*[b]	*F*[a]	*p*[b]	*F*[a]	*p*[b]	*F*[a]	*p*[b]
After imputation of missing socioeconomic status data								
Body mass index[c]	15.83	<0.001[d]	4.28	0.005[d]	29.20	<0.001[d]	119.05	<0.001[d]
Waist circumference	4.68	0.003	–	–	25.38	<0.001[d]	137.88	<0.001[d]
After case-wise deletion of participants with missing socioeconomic status data								
Body mass index[c]	11.28	<0.001	3.92	0.009	22.78	<0.001	118.74	<0.001
Waist circumference	2.13	0.096	–	–	25.38	<0.001	137.85	<0.001

[a] *F*-statistic from Type II analysis of variance. All models were adjusted for age, sex, and socioeconomic status.

[b] *P*-value from Type II analysis of variance.

[c] Body mass index *z*-score was used for children and adolescents.

[d] The given model was used to estimate the optimal movement behaviour composition.

Table S3. Optimal movement behaviour composition for "healthy" body mass index among children, stratified by sex and socioeconomic status

	Sleep (min/day)		**Sedentary behaviour** (min/day)		**Light physical activity** (min/day)		**Moderate-to-vigorous physical activity** (min/day)	
	x^{*a}	95% CI[b]	x^{*a}	95% CI[b]	x^{*a}	95% CI[b]	x^{*a}	95% CI[b]
Total sample	545	(545, 546)	594	(593, 594)	227	(227, 228)	74	(73, 74)
Males	542	(542, 543)	595	(594, 595)	221	(220, 221)	82	(82, 83)
Females	547	(547, 548)	592	(592, 593)	234	(233, 234)	66	(66, 67)
Low SES[c]	546	(546, 547)	576	(575, 577)	234	(233, 234)	84	(84, 85)
Middle SES[c]	543	(543, 544)	605	(604, 605)	223	(223, 223)	69	(69, 69)
High SES[c]	548	(547, 548)	584	(584, 585)	232	(231, 232)	76	(76, 77)

[a] Optimal value
[b] 95% bootstrap confidence interval for x^*
[c] Socioeconomic status

Table S4. Optimal movement behaviour composition for "healthy" body mass index among adolescents, stratified by sex and socioeconomic status

	Sleep (min/day)		**Sedentary behaviour** (min/day)		**Light physical activity** (min/day)		**Moderate-to-vigorous physical activity** (min/day)	
	*x**[a]	95% CI[b]	*x**[a]	95% CI[b]	*x**[a]	95% CI[b]	*x**[a]	95% CI[b]
Total sample	441	(441, 442)	754	(753, 754)	211	(211, 212)	34	(34, 34)
Males	436	(435, 436)	763	(762, 764)	205	(205, 206)	36	(36, 36)
Females	446	(446, 447)	744	(743, 745)	217	(216, 217)	33	(32, 33)
Low SES[c]	435	(434, 437)	763	(761, 765)	211	(209, 212)	31	(30, 31)
Middle SES[c]	443	(443, 444)	752	(751, 753)	211	(210, 212)	34	(34, 34)
High SES[c]	440	(439, 441)	753	(752, 754)	212	(211, 212)	35	(35, 35)

[a] Optimal value
[b] 95% bootstrap confidence interval for *x**
[c] Socioeconomic status

Table S5. Optimal movement behaviour composition for healthy weight among adults, stratified by sex and socioeconomic status

	Sleep (min/day)		**Sedentary behaviour** (min/day)		**Light physical activity** (min/day)		**Moderate-to-vigorous physical activity** (min/day)	
	x^{*}[a]	95% CI[b]	x^{*}[a]	95% CI[b]	x^{*}[a]	95% CI[b]	x^{*}[a]	95% CI[b]
Body mass index								
Total sample	474	(474, 475)	720	(719, 721)	152	(151, 152)	94	(93, 94)
Males	471	(470, 472)	731	(730, 732)	144	(143, 144)	95	(94, 95)
Females	478	(477, 479)	706	(705, 708)	163	(162, 164)	93	(92, 93)
Low SES[c]	461	(457, 465)	740	(734, 746)	160	(157, 162)	80	(76, 84)
Middle SES[c]	476	(475, 477)	712	(711, 714)	156	(156, 157)	95	(94, 96)
High SES[c]	471	(470, 472)	730	(729, 732)	145	(145, 146)	93	(92, 94)
Waist circumference								
Total sample	474	(473, 474)	737	(736, 738)	138	(137, 138)	92	(91, 92)
Males	473	(472, 474)	738	(737, 739)	135	(135, 136)	94	(93, 94)
Females	476	(474, 477)	734	(732, 736)	145	(144, 146)	85	(84, 86)
Low SES[c]	471	(467, 475)	735	(730, 739)	144	(142, 146)	90	(88, 93)
Middle SES[c]	475	(474, 476)	733	(732, 735)	140	(139, 140)	91	(91, 92)
High SES[c]	471	(469, 472)	743	(741, 744)	134	(133, 135)	93	(92, 93)

[a] Optimal value
[b] 95% bootstrap confidence interval for x^{*}
[c] Socioeconomic status

Table S6. Optimal movement behaviour composition for healthy weight among older adults, stratified by sex and socioeconomic status

	Sleep (min/day)		**Sedentary behaviour** (min/day)		**Light physical activity** (min/day)		**Moderate-to-vigorous physical activity** (min/day)	
	x^{*a}	95% CI[b]	x^{*a}	95% CI[b]	x^{*a}	95% CI[b]	x^{*a}	95% CI[b]
Body mass index								
Total sample	476	(475, 476)	746	(745, 747)	143	(142, 143)	76	(75, 76)
Males	475	(475, 476)	749	(748, 750)	136	(136, 137)	79	(78, 79)
Females	475	(474, 476)	738	(737, 740)	156	(155, 156)	71	(70, 72)
Low SES[c]	475	(473, 476)	740	(738, 742)	150	(149, 151)	76	(75, 76)
Middle SES[c]	478	(477, 479)	743	(741, 744)	143	(142, 144)	76	(76, 77)
High SES[c]	472	(471, 473)	757	(755, 758)	136	(135, 137)	75	(74, 76)
Waist circumference								
Total sample	473	(472, 473)	762	(761, 762)	137	(137, 137)	69	(68, 69)
Males	472	(471, 472)	762	(762, 763)	132	(132, 132)	74	(73, 74)
Females	473	(472, 474)	760	(759, 761)	146	(145, 146)	61	(60, 62)
Low SES[c]	471	(470, 472)	763	(762, 764)	141	(140, 141)	66	(65, 66)
Middle SES[c]	475	(474, 476)	758	(757, 759)	137	(137, 138)	70	(70, 71)
High SES[c]	470	(469, 471)	768	(767, 770)	132	(131, 132)	70	(69, 71)

[a] Optimal value
[b] 95% bootstrap confidence interval for x^*
[c] Socioeconomic status

References

1. Templ M, Kowarik A, Filzmoser P. Iterative stepwise regression imputation using standard and robust methods. Comput Stat Data Anal 2011; 55: 2793-806. https://doi.org/10.1016/j.csda.2011.04.012

2. Rubin DB. Multiple imputation for nonresponse in surveys. Hoboken, NJ: Wiley-Interscience; 2004.

3. Allen LN, Wigley S, Holmer H, Barlow P. Non-communicable disease policy implementation from 2014 to 2021: a repeated cross-sectional analysis of global policy data for 194 countries. Lancet Glob Health 2023; 11: e525-e33. https://doi.org/10.1016/S2214-109X(23)00042-6

4. García-Hermoso A, Hormazábal-Aguayo I, Fernández-Vergara O, et al. A before-school physical activity intervention to improve cognitive parameters in children: The Active-Start study. Scand J Med Sci Sports 2020; 30: 108-16. https://doi.org/10.1111/sms.13537

5. Edney S, Plotnikoff R, Vandelanotte C, et al. “Active Team” a social and gamified app-based physical activity intervention: randomised controlled trial study protocol. BMC Public Health 2017; 17: 859. https://doi.org/10.1186/s12889-017-4882-7

6. Lubans DR, Smith JJ, Eather N, et al. Time-efficient intervention to improve older adolescents' cardiorespiratory fitness: findings from the 'Burn 2 Learn' cluster randomised controlled trial. Br J Sports Med 2020; 55: 751-8. https://doi.org/10.1136/bjsports-2020-103277

7. Lonsdale C, Sanders T, Cohen KE, et al. Scaling-up an efficacious school-based physical activity intervention: Study protocol for the ‘Internet-based Professional Learning to help teachers support Activity in Youth’ (iPLAY) cluster randomized controlled trial and scale-up implementation evaluation. BMC Public Health 2016; 16: 873. https://doi.org/10.1186/s12889-016-3243-2

8. Sánchez-López M, Ruiz-Hermosa A, Redondo-Tébar A, et al. Rationale and methods of the MOVI-da10! Study –a cluster-randomized controlled trial of the impact of classroom-based physical activity programs on children’s adiposity, cognition and motor competence. BMC Public Health 2019; 19: 417. https://doi.org/10.1186/s12889-019-6742-0

9. Harrex HAL, Skeaff SA, Black KE, et al. Sleep timing is associated with diet and physical activity levels in 9–11-year-old children from Dunedin, New Zealand: the PEDALS study. J Sleep Res 2018; 27: e12634. https://doi.org/10.1111/jsr.12634

10. Tercedor P, Villa-González E, Ávila-García M, et al. A school-based physical activity promotion intervention in children: rationale and study protocol for the PREVIENE Project. BMC Public Health 2017; 17: 748. https://doi.org/10.1186/s12889-017-4788-4

11. Cabanas-Sánchez V, Esteban-Cornejo I, Migueles JH, et al. Twenty four-hour activity cycle in older adults using wrist-worn accelerometers: The seniors-ENRICA-2 study. Scand J Med Sci Sports 2020; 30: 700-08. https://doi.org/10.1111/sms.13612

12. da Costa BGG, Chaput J-P, Lopes MVV, Malheiros LEA, Tremblay MS, Silva KS. Prevalence and sociodemographic factors associated with meeting the 24-hour movement guidelines in a sample of Brazilian adolescents. PLoS One 2020; 15: e0239833. https://doi.org/10.1371/journal.pone.0239833

13. Rubín L, Gába A, Dygrýn J, Jakubec L, Materová E, Vencálek O. Prevalence and correlates of adherence to the combined movement guidelines among Czech children and adolescents. BMC Public Health 2020; 20: 1692. https://doi.org/10.1186/s12889-020-09802-2

14. Menai M, van Hees VT, Elbaz A, Kivimaki M, Singh-Manoux A, Sabia S. Accelerometer assessed moderate-to-vigorous physical activity and successful ageing: results from the Whitehall II study. Sci Rep 2017; 7: 45772. https://doi.org/10.1038/srep45772