Physical fitness of children and adolescents in Germany in 2023–2024

Current age- and sex-specific profiles from a nationwide cross-sectional study MoMo 2.0 Study

Preprint version 1 — November 2026

This manuscript has not been peer reviewed.

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Running title: Physical fitness in German youth

Article type: Original Paper

Author declarations

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable data protection requirements and institutional approval. Access for analysis may also be arranged through a guest researcher workstation at the authors' institution. The dataset is intended to be made available through the MO|RE data platform (https://www.mo-re-data.org/); deposition has not yet been completed.

Ethics and informed consent

All procedures performed in studies involving human participants or on human tissue were in accordance with the ethical standards of the Institutional Research Committee and with the Declaration of Helsinki of 1975 and its subsequent amendments or comparable ethical standards. Ethical approval for the MoMo 2.0-Study was obtained from the Ethics Committee of the Karlsruhe Institute of Technology on 6 November 2023 (application number A2023-077). Informed consent was provided by legal guardians or participants (for those over 15 years).

Author contributions

CN: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. AHD: Investigation, Data curation, Formal analysis, Writing – review & editing. JF: Formal analysis, Writing – review & editing, including critical revision of the Results and Discussion sections. TK, SH and CZ: Investigation, Data curation, Writing – review & editing. LK: Methodology, Data curation, Formal analysis, Writing – review & editing. SK: Interpretation of the findings from a public health perspective, Writing – review & editing. Annette Worth and Alexander Woll: Conceptualization, Methodology, Investigation, Writing – review & editing.

All authors approved the final version of the manuscript and agreed to be accountable for all aspects of the work, including ensuring that any questions concerning its accuracy or integrity are appropriately investigated and resolved.

Funding

This work was developed in the research project 'MoMo 2.0' (2022–2025). The national study on the development of physical activity, motor performance and the health of children and adolescents against the background of changing social conditions is funded by the German Federal Ministry of Health (BMG) under the funding code ZMI5-2522KIG01 based on a resolution of the German Bundestag.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Acknowledgements and study group

We would like to express our sincere gratitude to the dedicated student assistants and test instructors who contributed significantly to the successful data collection of this study. Without their dedicated support and tireless work, this research would not have been possible. Special thanks also go to the MoMo 2.0-Study Group for their outstanding work in the planning, design and data preparation of this study. Their technical expertise, coordination and commitment were invaluable and contributed to the successful achievement of the research objectives. We acknowledge support by the KIT Publication Fund of the Karlsruhe Institute of Technology.

MoMo 2.0-Study Group

The MoMo 2.0-Study Group was responsible for the design of the study and acquisition of the data.

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Use of generative artificial intelligence

ChatGPT (OpenAI) assisted with language editing. The authors reviewed and verified the final text, references, tables and figures and take responsibility for the content.

Abstract

This study aimed to provide a nationally representative description of physical fitness across age groups and by sex among children and adolescents in Germany following the COVID-19 pandemic. The MoMo 2.0 study included 3,973 participants aged 4–17 years recruited using a two-stage random sampling procedure. Assessments were conducted between September 2023 and December 2024 using a standardised motor performance test profile. Weighted means and 95% confidence intervals were estimated using complex-samples analyses accounting for municipality-level clustering. In cross-sectional comparisons across age groups, older children and adolescents generally demonstrated higher strength and absolute cycle ergometry performance and fewer static balance errors than younger participants. Sex differences favouring boys were most pronounced in strength and cycle ergometry performance in adolescence, whereas girls in all age groups performed better in balancing backwards and the stand-and-reach test. Flexibility showed contrasting age-group patterns in boys and girls. These findings were contextualised through comparisons with three earlier MoMo waves. Compared with weighted data of the 2003–2006 baseline, mean physical working capacity at a heart rate of 170 beats/min (PWC170) values were approximately 11.2% lower in boys and 9.1% lower in girls, while standing long jump performance was 7.9% and 3.2% lower, respectively. Other motor performance tests showed heterogeneous historical differences. These findings provide a post-pandemic population reference for physical fitness among children and adolescents in Germany. Differences across age groups, sexes, and motor performance domains highlight the importance of differentiated population fitness monitoring.

Keywords: physical fitness; motor performance; children; adolescents; population monitoring

Highlights

- Physical fitness profiles differ across age groups, sexes and motor performance domains.
- Sex differences are most pronounced in adolescent strength and cycle ergometry performance.
- Earlier survey waves provide context for current population monitoring.

1 Introduction

Physical fitness is a well-established marker of current and future health in children and adolescents. The evidence linking fitness to health varies across components and is strongest for cardiorespiratory and muscular fitness, which are associated with cardiometabolic, skeletal, and mental health outcomes (Ortega et al., 2025). Longitudinal MoMo findings also suggest reciprocal relationships between motor abilities and physical activity, partly mediated by physical self-concept, although these associations differ across motor domains (Jekauc et al., 2017). At the population level, fitness surveillance therefore complements physical activity monitoring by identifying groups and fitness domains requiring attention, informing prevention priorities, and providing an evidence base for public health decision-making (Lang et al., 2023).

Cardiorespiratory fitness has declined globally since the 1980s (Tomkinson et al., 2019), while trends in strength and coordination are more heterogeneous, with standing long jump performance declining internationally since the early 2000s (Tomkinson et al., 2021) despite increases in handgrip strength in some populations (Dooley et al., 2020). In Germany, the Motorik-Modul (MoMo) has monitored physical activity and motor performance in nationally representative cross-sectional cohorts since 2003 (Baseline 2003–2006, Wave 1 2009–2012, Wave 2 2014–2017), as an in-depth module of the German Health Interview and Examination Survey for Children and Adolescents (KiGGS) (Wagner et al., 2014). These cohorts showed that motor performance did not deteriorate between 2003 and 2012, but remained largely at a stable, comparatively low level through 2017, with only isolated declines in coordination-under-precision tasks (Albrecht et al., 2016; Hanssen-Doose et al., 2021).

The MoMo 2.0-Study was established as a new, independent representative cohort to continue fitness monitoring into 2023–2024 and provide updated national population estimates for motor performance, physical activity, and biopsychosocial health (Woll et al., 2025). Pandemic-related changes in physical activity further underline the need for contemporary population data (Ludwig-Walz et al., 2023; Schmidt et al., 2020).

The primary aim was to provide nationally representative estimates of current physical fitness and describe age- and sex-specific cross-sectional patterns among children and adolescents aged 4–17 years living in Germany. The overarching public health objective was to establish a contemporary reference for interpreting future population changes and identifying groups and motor domains requiring preventive or research attention (Lang et al., 2023). The data can also support subsequent analyses of socioeconomic inequalities and associations with physical activity and health. A secondary aim was to contextualise current findings through descriptive comparisons with earlier MoMo assessments conducted in 2003–2006, 2009–2012, and 2014–2017 (Supplementary Tables S2 and S3).

2 Materials and methods

2.1 Study design and participants

The Motorik-Modul Study (MoMo 2.0) is a nationwide study of motor performance, physical activity, and health-related determinants among children and adolescents aged 4–17 years living in Germany. MoMo 2.0 represents the continuation of four previous MoMo assessment waves conducted between

2003 and 2022 and includes a newly recruited, nationally representative cross-sectional sample. The present data collection was conducted between September 2023 and December 2024. A detailed description of the overall MoMo study design, procedures, and assessment instruments has been published elsewhere (Woll et al., 2025).

Participants were recruited using a two-stage random sampling procedure developed in cooperation with GESIS – Leibniz Institute for the Social Sciences. In the first stage, 185 municipalities were randomly selected from the German National Register of Municipalities, covering 195 study sample points throughout Germany. Municipalities were selected with a probability proportional to the number of residents in the target age range. To ensure sufficient recruitment of 4-year-old children at the time of examination, children aged 3 years at the reference date could additionally be included in the sampling frame, accounting for the time interval between sampling and data collection.

In the second stage, the local registration offices of the selected municipalities were asked to provide contact information for 140 randomly selected individuals within the relevant age range. Selected families received a postal invitation containing study information and an individual login for the online registration system. Participants were asked to register and schedule an examination appointment approximately 4–6 weeks before the respective local assessment period. Non-responders received up to two reminder letters.

To minimise confounding of regional and urban–rural differences with seasonal effects, the order of data collection was balanced across federal states and levels of urbanicity. This procedure aimed to distribute influences such as weather, school holidays, and seasonal variation in physical activity and motor performance across regions. The target sample of approximately 4,500 participants reflected statistical power considerations and the requirements for national representativeness across study locations.

The present analysis concerns the newly recruited cross-sectional sample. Earlier assessments comprise Baseline (2003–2006), Wave 1 (2009–2012), Wave 2 (2014–2017), and Wave 3 (2018–2022) (Woll et al., 2021, 2025). Wave 3 was not included in the present historical comparison because weighted comparison data were unavailable for the present analysis.

Analytical sample sizes varied across motor performance tests and are reported in Tables 1 and 2. Age- and sex-specific estimates and corresponding analytical sample sizes are provided in Supplementary Table S1. The analytical sample was restricted to participants aged 4–17 years; participants aged 18 years or older at assessment were excluded. Participants recorded in the diverse sex category (n = 2) were retained in the overall sample description and overall estimates but were not included in the sex-specific analyses because of the small group size. Test-specific age eligibility was additionally applied: PWC170, push-ups, sit-ups, handgrip strength, and the additional cycle ergometry outcomes were analysed among participants aged 6–17 years, whereas the remaining tests covered ages 4–17 years.

Table 1. Unweighted overall sample sizes by motor performance test

Test	Age (years)	Overall N
Standing long jump	4–17	3,949
Push-ups	6–17	3,352
Sit-ups	6–17	3,368
Handgrip strength	6–17	3,386
PWC170	6–17	1,922
Stand and reach	4–17	3,942
Jumping sideways	4–17	3,950
Balancing backwards	4–17	3,925
Static stand	4–17	3,941

N denotes the unweighted number of participants aged 4–17 years with valid test data, including the diverse sex category. Test-specific age eligibility was applied. Age- and sex-specific estimates and sample sizes are provided in Supplementary Table S1.

The unweighted analytical sample comprised 3,973 participants aged 4–17 years, including 2,079 boys (52.3%), 1,892 girls (47.6%), and two participants recorded in the diverse sex category (0.1%). Socioeconomic status was classified using parental or main-earner education, occupation, and income, with imputed values according to Lampert et al. (2018).

Table 2. Characteristics of the MoMo 2.0 analytical sample by age group

Characteristic	Category / statistic	4–5 years	6–10 years	11–13 years	14–17 years
Sample size	n	578	1,678	914	803
Height (cm)	Mean (± SD)	111.27 (± 5.86)	133.21 (± 10.46)	156.85 (± 9.25)	170.73 (± 9.04)
Body weight (kg)	Mean (± SD)	19.63 (± 2.98)	30.21 (± 7.94)	47.93 (± 11.80)	62.77 (± 12.68)
WHO 2010 physical activity recommendation (usual week)	Not met (%)	68.0	79.6	89.5	92.3
	Met (%)	32.0	20.4	10.5	7.7
Socioeconomic status	Low (%)	15.4	16.9	20.6	26.7
	Medium (%)	63.2	63.0	58.6	56.8
	High (%)	21.4	20.2	20.8	16.6

M = mean; SD = standard deviation; SES = socioeconomic status. Percentages are based on valid responses. Height and weight: n = 3,968; physical activity: n = 3,842; SES: n = 3,815. Overall anthropometric statistics were calculated from sex-specific summary statistics, including the “diverse” sex category.

2.2 Data collection procedures

Participants were invited to temporary examination centres located within or close to their municipality of residence. Before participation, children and adolescents as well as their parents or legal guardians received comprehensive information about the aims and procedures of the study and about data protection. Written informed consent was obtained prior to the assessments in accordance with the applicable ethical and data protection requirements.

All examinations were conducted individually under standardised conditions. Trained and qualified test instructors accompanied participants throughout the assessment procedure, explained each task using standardised instructions, and recorded the results digitally on a tablet. The sequence of assessments was predefined to ensure comparability across participants and study locations.

2.3 Motor performance assessment

Motor performance was assessed using the standardised MoMo 2.0 profile (Worth et al., 2025). The present analysis includes nine of eleven test tasks, excluding the two fine motor tasks. Five of these tasks were administered at ages 4–5 years and all nine at ages 6–17 years (Table 3). Maximum attained cycle ergometry workload complements PWC170 by describing the highest workload reached, whereas PWC170 expresses workload at a standardised heart rate. Both outcomes are reported in absolute watts.

For each task, the test instructor first provided a standardised verbal explanation and, where applicable, demonstrated the required movement. Participants subsequently completed the respective test according to the predefined protocol, and test results were entered directly into the digital data collection system.

Anthropometry, physical activity, and biopsychosocial health were assessed within the broader study, but associations between these measures and motor performance were outside the scope of this analysis.

Table 3. Motor performance assessments included in the present analysis

Domain	Test	Age (years)	Assessment
Explosive strength	Standing long jump	4–17	Distance of a double-legged standing jump; two trials.
Strength endurance	Push-ups	6–17	Completed push-ups in 40 s using the specified MoMo sequence.
Strength endurance	Sit-ups	6–17	Completed sit-ups with elbows touching knees within 40 s.
Maximal strength	Handgrip strength	6–17	Maximum force with a Saehan SH5010 dynamometer; preferred hand, best of two trials.
Endurance	Cycle ergometry	6–17	ERG 911S Ergosana; WHO protocol. Ages 6–10: start/increment 15 W; ages 11–17: start/increment 25 W; two-minute stages. PWC170 and maximum attained workload reported.
Dynamic balance	Balancing backwards	4–17	Sum of steps of 2 attempts on 3-, 4.5-, and 6-cm-wide, 3-m-long beams; two trials per beam, maximum eight steps per trial.
Coordination under time pressure	Jumping sideways	4–17	Mean number of sideways jumps across a line on a nonslip mat in two 15-s trials.
Static balance	Static stand	4–17	Number of floor contacts during 1 minute on a 3-cm beam, single attempt, dominant leg, eyes open.
Flexibility	Stand and reach	4–17	Best of two downward reaches from a wooden box with knees extended; zero at sole level, positive below and negative above sole level.

PWC170, physical working capacity at a heart rate of 170 beats/min. Motor performance assessments included in the present analysis: nine of the eleven MoMo 2.0 test tasks, excluding the two fine motor tasks.

2.4 Statistical analysis

Weighted means and 95% confidence intervals were calculated by age group and sex using the Complex Samples module in IBM SPSS Statistics. Variance estimation used a simplified single-stage cluster

design incorporating sampling weights and clustering by test-site municipality (primary sampling unit, PSU), with with-replacement (WR) estimation. Stratification was not incorporated into the variance estimation. Unweighted sample sizes are reported for each measure.

Secondary historical comparisons used the available sex-specific means, standard deviations, confidence intervals, and sample sizes for Baseline, Wave 1, Wave 2, and MoMo 2.0. Detailed comparisons are presented in Supplementary Tables S2 and S3. Percentage differences were calculated as 100 × (MoMo 2.0 mean − historical mean) / historical mean. They are approximate because historical means were available only as rounded published values. Visual inspection of confidence intervals informed descriptive comparisons (Cumming, 2009); no formal between-wave tests were performed. Weighted violin densities were trimmed to observed ranges and scaled to equal maximum width within each plot.

2.5 Ethics and informed consent

The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. Ethical approval was obtained from the Ethics Committee of the Karlsruhe Institute of Technology on 6 November 2023 (application A2023-077). Informed consent was provided by legal guardians or by participants aged over 15 years (Woll et al., 2025).

3 Results

Results are presented by motor performance domain, focusing on cross-sectional differences across age groups and between sexes. Complete age- and sex-specific weighted means, 95% confidence intervals, and unweighted sample sizes are provided in Supplementary Table S1.

Figures 1–3 display age- and sex-specific performance distributions and weighted means with 95% confidence intervals. Shaded violins show the weighted distributions, while light grey dashed lines connect the means for visual orientation only. The figures summarise cross-sectional age-group differences and do not depict individual developmental trajectories or fitted continuous age curves.

3.1 Strength

Standing long jump

Standing long jump distance was higher in older age groups in both sexes. Among children aged 4–5 years, boys achieved a mean distance of 90.6 cm (95% CI: 88.0–93.2), compared with 85.7 cm (95% CI: 83.0–88.3) in girls. Among adolescents aged 14–17 years, the corresponding means were 188.9 cm (95% CI: 185.6–192.1) and 153.7 cm (95% CI: 151.0–156.3), respectively. The observed sex difference was largest in the oldest age group, amounting to 35.2 cm. Confidence intervals overlapped only slightly in the youngest age group and did not overlap in the remaining age groups, supporting the descriptive interpretation of higher performance in boys across age groups (Cumming, 2009; Supplementary Table S1).

Push-ups

Among boys, the mean number of push-ups completed within 40 seconds was higher in successively older age groups, ranging from 11.95 (95% CI: 11.61–12.29) at 6–10 years to 14.54 (95% CI: 14.17–

14.92) at 14–17 years. Among girls, the corresponding means were 11.89 (95% CI: 11.55–12.22) at 6–10 years, 12.89 (95% CI: 12.50–13.28) at 11–13 years, and 12.34 (95% CI: 11.91–12.77) at 14–17 years. Confidence intervals for boys and girls overlapped substantially in the two younger age groups but did not overlap at 14–17 years, supporting the descriptive interpretation of higher performance in boys in the oldest age group (Cumming, 2009; Supplementary Table S1).

Sit-ups

Mean sit-up performance was higher in older age groups, with larger age-group differences in boys. Means ranged from 16.5 to 22.9 repetitions in boys and from 15.6 to 18.5 in girls between ages 6–10 and 14–17 years. Girls' means differed little between the two adolescent groups. The observed sex difference was largest in the oldest group.

Handgrip strength

Mean handgrip strength ranged from 14.4 kg at 6–10 years to 40.5 kg at 14–17 years in boys and from 13.0 to 29.9 kg in girls. Sex differences were largest in the oldest age group.

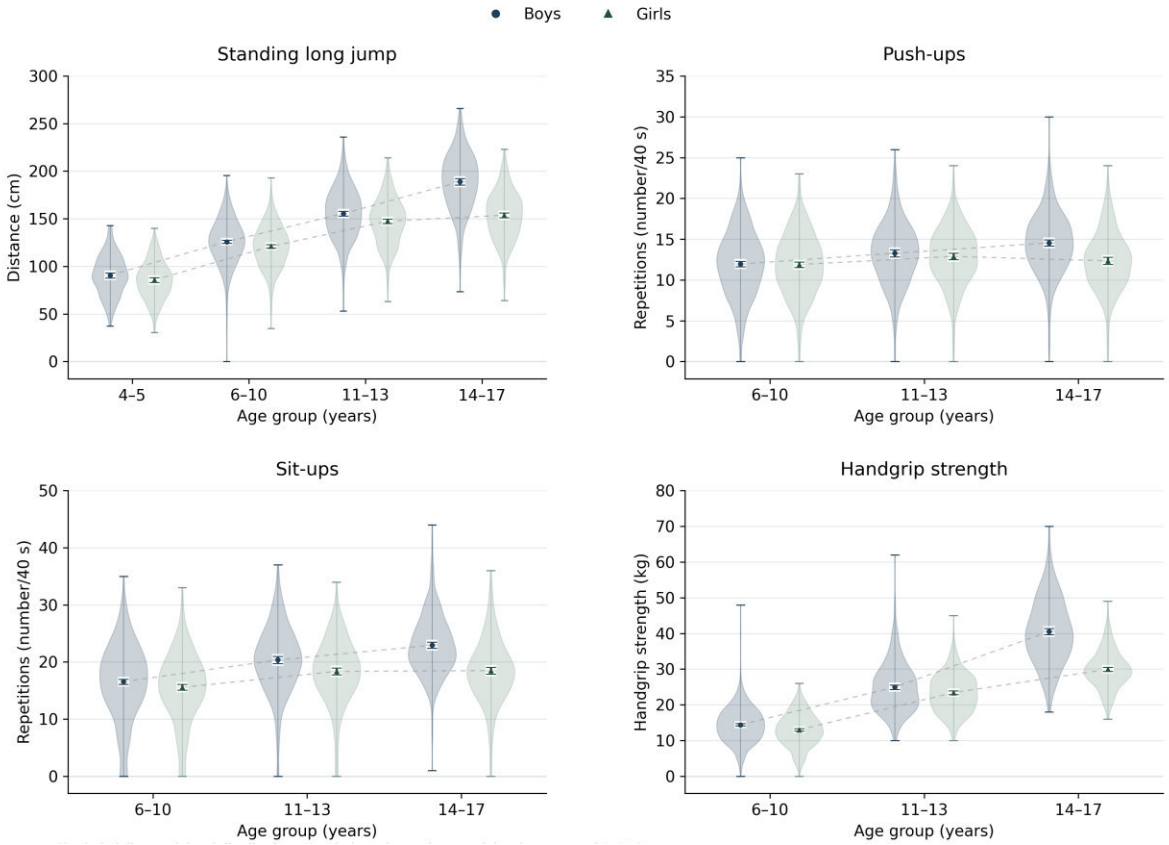


Figure 1. Strength performance by age group and sex. Shaded violins show weighted distributions, scaled to equal maximum width and trimmed to the observed minima and maxima; small caps indicate the observed range. Symbols show weighted means, with circles for boys and triangles for girls; error bars indicate 95% confidence intervals. Light grey dashed lines connect means for visual orientation only. Estimates represent cross-sectional age-group summaries rather than within-person developmental trajectories.

3.2 Endurance

PWC170 and maximum workload

Mean absolute PWC170 was higher in older age groups in both sexes. Boys achieved higher means than girls in each age group, ranging from 64.2 W at 6–10 years to 135.1 W at 14–17 years; corresponding means in girls were 54.4 and 98.2 W. The observed sex difference in absolute workload was largest in the oldest group.

Maximum workload attained during cycle ergometry was higher in older age groups in both sexes. Among boys, mean workload ranged from 81.4 W (95% CI: 78.6–84.2) at 6–10 years to 167.6 W (95% CI: 163.6–171.5) at 14–17 years. Among girls, the corresponding means were 72.6 W (95% CI: 70.0–75.2) and 124.3 W (95% CI: 120.5–128.1). Boys had higher mean workloads than girls in all age groups, with no overlap between the corresponding confidence intervals. The observed sex difference was largest at 14–17 years (Supplementary Table S1).

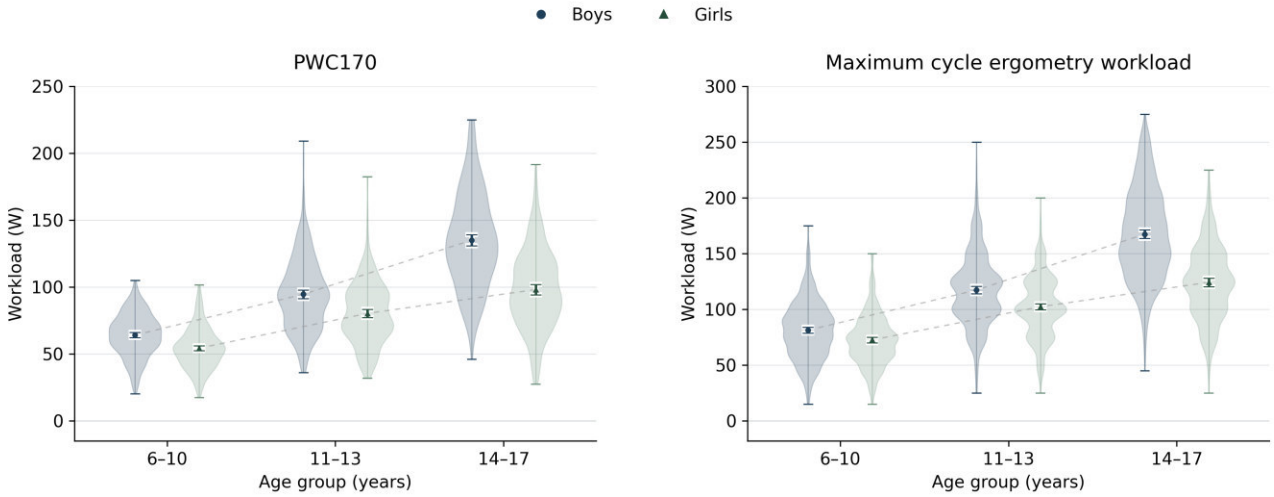


Figure 2. Cycle ergometry performance by age group and sex. Shaded violins show weighted distributions, scaled to equal maximum width and trimmed to the observed minima and maxima; small caps indicate the observed range. Symbols show weighted means, with circles for boys and triangles for girls; error bars indicate 95% confidence intervals. Light grey dashed lines connect means for visual orientation only. Estimates represent cross-sectional age-group summaries rather than within-person developmental trajectories.

3.3 Coordination

Balancing backwards

Girls achieved higher mean balancing backwards scores than boys in every age group. Boys' means ranged from 14.03 steps at 4–5 years to 35.12 steps at 14–17 years. Girls' corresponding means were 17.25 and 37.77 steps, with the highest mean at 11–13 years (38.06 steps). The difference between the two adolescent groups was small in both sexes (Figure 3; Supplementary Table S1).

Jumping sideways

Mean sideways jumping performance was higher in older age groups. At 4–5 years, boys and girls achieved 12.91 and 12.96 jumps, respectively. Sex differences remained small in the middle age groups; at 14–17 years, boys achieved 39.23 jumps compared with 36.83 in girls.

Static stand

Fewer errors indicate better static stand performance. Boys' means ranged from 20.5 errors at 4–5 years to 3.7 at 14–17 years; girls' corresponding means were 18.2 and 3.6 errors. Girls had lower mean error counts in the younger groups, whereas means were close in the oldest group.

3.4 Flexibility

Stand and reach showed distinct age-group patterns in boys and girls. Boys had weighted means of 1.05 cm at 4–5 years, −1.14 cm at 6–10 years, −4.49 cm at 11–13 years, and −1.98 cm at 14–17 years. Girls had higher mean values in every age group, with corresponding means of 2.20, 3.25, 3.02, and 5.90 cm. Among boys, the lowest mean was observed at 11–13 years, whereas girls achieved their highest mean at 14–17 years. Positive values indicate reaching below sole level, and negative values indicate reaching above sole level (Supplementary Table S1).

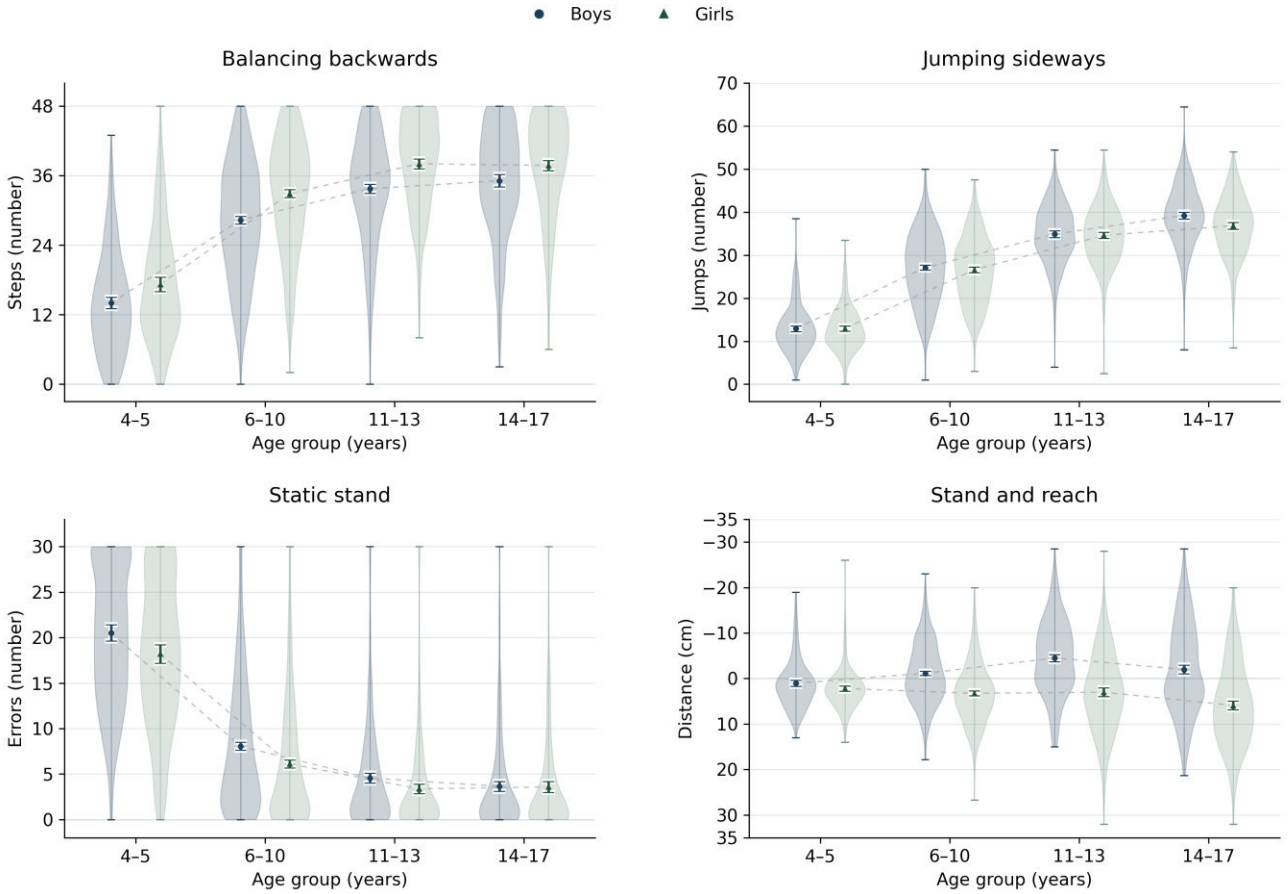


Figure 3. Coordination and flexibility by age group and sex. Shaded violins show weighted distributions, scaled to equal maximum width and trimmed to the observed minima and maxima; small caps indicate the observed range. Symbols show weighted means, with circles for boys and triangles for girls; error bars indicate 95% confidence intervals. Light grey dashed

lines connect means for visual orientation only. Estimates represent cross-sectional age-group summaries rather than within-person trajectories. Fewer errors indicate better static stand performance. For stand and reach, zero denotes foot sole level; positive values indicate reaching below and negative values above this level. The stand-and-reach y-axis is inverted.

3.5 Secondary historical comparison

Mean PWC170 values were lower in MoMo 2.0 than in the earlier waves in both sexes. Compared with Baseline (2003–2006), mean PWC170 values were approximately 11.2% lower in boys and 9.1% lower in girls. Standing long jump means were also lower than at Baseline, by 7.9% in boys and 3.2% in girls. Compared with Wave 2, boys showed lower standing long jump values, whereas girls showed a similar mean. Compared with Baseline, both sexes achieved higher mean push-up and sideways jumping performance and made fewer static balance errors. Compared with Baseline, girls also showed higher mean balancing backwards and stand-and-reach performance. Compared with Wave 2, most other test means were similar, although boys achieved fewer steps in balancing backwards. Complete numerical comparisons are reported in Supplementary Tables S2 and S3 and contextualised in the Discussion. These comparisons draw on weighted means and their 95% confidence intervals, providing information on the direction and magnitude of historical differences and the precision of the estimates.

4 Discussion

4.1 Principal findings

MoMo 2.0 provides an updated population-based description of physical fitness among children and adolescents in Germany following the COVID-19 pandemic. Its primary contribution is a contemporary account of age- and sex-specific performance across multiple motor domains, providing a reference for national and international comparisons and an evidence base to inform population monitoring, prevention planning, and policy decisions.

The findings demonstrate distinct profiles across age groups and sexes. Older age groups generally achieved higher strength performance and absolute cycle ergometry workloads and made fewer static balance errors. Sex differences favouring boys were most pronounced in adolescent strength performance and absolute ergometry outcomes, whereas girls generally performed better in balancing backwards and the stand-and-reach test. Several of these patterns, particularly those observed in strength and coordination, broadly correspond to the age- and sex-specific profiles reported in earlier MoMo assessments (Hanssen-Doose et al., 2021; Niessner et al., 2020) and in European studies (Ortega et al., 2023). Flexibility showed contrasting age-group patterns between sexes, further highlighting the importance of considering individual motor domains separately. This differentiated interpretation is consistent with the lifespan perspective, which conceptualises development as multidimensional and multidirectional (Baltes, 1987; Niessner et al., 2026). However, the present cross-sectional differences describe age-group profiles and do not establish within-person developmental trajectories.

The magnitude of age-group differences varied considerably between tests. Standing long jump performance was approximately twice as high in boys aged 14–17 years as in boys aged 4–5 years, whereas the corresponding difference in girls was smaller. These sex-specific age-group patterns may partly reflect differences in growth and maturation, including body size and muscle mass. As these factors were not accounted for in the present analyses, their contributions to the observed performance

differences cannot be distinguished. Similarly, absolute PWC170 values were approximately 2.1 times as high in boys aged 14–17 years as in those aged 6–10 years (135.11 vs. 64.15 W); among girls, the corresponding ratio was approximately 1.8 (98.19 vs. 54.36 W). Differences in push-up performance were substantially smaller, particularly among girls. Thus, even within strength-related performance, the age-group and sex-specific profiles were task-specific. Although previous research supports the feasibility of a composite fitness score for selected tests in children aged 6–9 years (Utesch et al., 2018), the present findings highlight the additional value of reporting individual test profiles.

The distributional plots complement the mean estimates by showing substantial within-group variability and overlap between boys and girls, including in tests with pronounced sex differences in mean performance. These patterns highlight the importance of distinguishing population-level differences from individual performance. The concentration of scores near the upper limit in balancing backwards and near zero errors in static stand also suggests possible ceiling and floor effects, respectively, which may limit differentiation among higher-performing participants.

The addition of handgrip strength extends the established MoMo profile, providing, to our knowledge, the first nationally representative estimates for children and adolescents in Germany. Handgrip strength is included in the Youth Fitness International Test (YFIT) core battery (Ortega et al., 2025). The observed age- and sex-specific patterns broadly correspond to European FitBack reference curves (Ortega et al., 2023). Absolute values require cautious comparison: FitBack uses the average of the best attempts from each hand, whereas MoMo uses the best of two attempts with the preferred hand. With comparable protocols, these data can support harmonised surveillance (Lang et al., 2023) and future assessments within the Active Healthy Kids Global Alliance's Global Matrix and German Report Card (Aubert et al., 2022; Demetriou et al., 2024).

Within each sex, the profiles were task-specific. Girls' push-up mean was highest at 11–13 years, whereas their sit-up and balancing backwards means differed little between the adolescent groups. Boys' stand-and-reach mean was lowest at 11–13 years; girls' was highest at 14–17 years. These cross-sectional patterns do not establish individual improvement or decline. Unadjusted absolute handgrip strength and ergometry workloads cannot separate the contributions of body size, maturation, physical activity, and other determinants.

4.2 Contextualisation with earlier MoMo waves

Earlier MoMo assessments provide approximately two decades of population reference data collected using comparable standardised procedures. Samples were weighted to their respective target populations using largely consistent procedures, accounting for age and sex composition. They were not standardised to a common population, so comparisons may also reflect demographic changes. Hanssen-Doose et al. (2021) described modest improvements between Baseline and Wave 1, followed by predominantly similar performance between Waves 1 and 2. MoMo 2.0 shows lower means in some motor domains and similar or higher values in others (Supplementary Tables S2 and S3).

Endurance (PWC170)

Mean absolute PWC170 values were similar across the first three included assessments, at approximately 108–109 W in boys and 82–83 W in girls (Hanssen-Doose et al., 2021). In MoMo 2.0, the corresponding

means were 95.9 W and 75.4 W, respectively. Relative to Baseline, these values were 11.2% lower in boys and 9.1% lower in girls. The current estimates therefore differ from the earlier pattern of broadly stable absolute ergometer performance. The observed differences may reflect a combination of pandemic-associated changes, pre-existing trends, and other period-related influences. However, the present comparisons cannot determine whether, or to what extent, the pandemic contributed to these differences.

The direction of the difference is consistent with international reports of declining endurance (Masanovic et al., 2020). Domingo-del-Val et al. (2026) reported a long-term European decline with a deceleration during 2015–2023. Excluding the 20-m shuttle run instead supported a continuous linear decline. Because this exclusion also changes the populations and periods represented, it does not establish a physiological explanation specific to the test. The apparent deceleration should therefore be interpreted cautiously when contextualising PWC170.

Pandemic-focused evidence provides additional context. Ludwig-Walz et al. (2026) reported lower endurance performance during and after the pandemic compared with pre-pandemic assessments, with pooled estimates remaining below baseline in 2023. Their endurance analyses were based on running tests, and the 2023 estimates specifically on the 6-min run. These findings support continued attention to endurance in post-pandemic monitoring, but do not establish direct equivalence with absolute PWC170. Differences in test demands, outcome scales, body-size dependence, and observation periods constrain comparisons of the magnitude of differences.

Explosive strength (standing long jump)

In boys, successive MoMo assessments yielded progressively lower mean standing long jump distances: 152 cm at Baseline, 149 cm in Wave 1, 146 cm in Wave 2, and 140.1 cm in MoMo 2.0. Importantly, the earlier paper did not classify the adjacent pre-pandemic comparisons as statistically significant reductions (Hanssen-Doose et al., 2021). The current mean was 7.9% lower than at Baseline and 4.1% lower than in Wave 2.

In girls, the current mean of 127.8 cm was lower than the Baseline and Wave 1 estimates of 132 cm, but similar to the Wave 2 estimate of 127 cm. Interpretation therefore depends on both sex and the historical reference period.

These findings are compatible with the European pattern of declining lower-body explosive strength following improvements up to approximately the late 1980s (Domingo-del-Val et al., 2026). However, the MoMo estimates indicate that lower mean jump performance in boys was already apparent before the pandemic. The current findings should therefore be situated within longer-term patterns without establishing a pandemic contribution.

Strength endurance (push-ups, sit-ups)

Push-up performance showed a different historical pattern from standing long jump. Boys' mean values were similar from Wave 1 onward, at approximately 12.9–13.0 repetitions. In girls, MoMo 2.0 yielded the highest mean among the four included assessments, at 12.3 repetitions. These contrasting findings underline the need to distinguish explosive strength from strength endurance.

They also illustrate why aggregate international strength trends cannot be applied uniformly to individual national test outcomes. Domingo-del-Val et al. (2026) combined different manifestations of upper-body strength, including maximal strength and muscular endurance. Ludwig-Walz et al. (2026) found a pooled strength estimate close to zero, alongside differences between individual tests and age groups. The MoMo findings contribute to this differentiated picture.

Comparable earlier-wave estimates were unavailable for sit-ups and handgrip strength in the historical comparison dataset. These tests broaden the current description of strength-related performance but do not support historical comparisons in the present analysis.

Coordination under time pressure (jumping sideways)

Boys' mean sideways jumping performance was similar from Wave 1 onward, whereas girls' current mean was higher than in Wave 2 and close to the Wave 1 estimate. Both sexes achieved higher mean values than at Baseline. These patterns contrast with the lower endurance and standing long jump values and demonstrate that historical differences are not consistent across motor domains.

International evidence on coordination remains less extensive than evidence on endurance and strength. Masanovic et al. (2020) identified only one study specifically addressing coordination, precluding a general international trend conclusion. The pandemic-focused review by Ludwig-Walz et al. (2026), which included sideways jumping and balancing backwards, reported a pooled coordination estimate close to zero. Together, these findings support retaining coordination tests in multidimensional surveillance.

Dynamic balance (balancing backwards)

Boys achieved a mean of 29.0 steps in MoMo 2.0, below the Wave 1 and Wave 2 estimates but slightly above Baseline. Girls achieved 32.8 steps, close to the Wave 1 estimate of 33.2 steps and above Baseline. These findings indicate sex-specific historical patterns rather than a consistently directed difference across assessments.

Static balance (one-leg static stand)

Both sexes made fewer errors in MoMo 2.0 than at Baseline, although current error counts were higher than the lowest values observed in Waves 1 or 2. The historical picture consequently depends on the reference assessment.

The marked age-group differences in error counts should also be interpreted in light of potential floor and ceiling effects. Earlier MoMo work identified age-related limitations in the discriminatory capacity of this test (Niessner et al., 2020). Such measurement characteristics may restrict the ability to distinguish performance among older participants, even when the same protocol is used consistently.

Flexibility (stand and reach)

Boys showed no consistently directed pattern across the included assessments. In girls, the current mean of 3.5 cm was close to the Wave 1 estimate of 3.6 cm and higher than at Baseline and in Wave 2. These findings differ from the declining European flexibility pattern reported by Domingo-del-Val et al. (2026),

while Ludwig-Walz et al. (2026) found little overall difference in flexibility between pre-pandemic and during/post-pandemic assessments.

Overall interpretation

Lower absolute PWC170 and standing long jump means relative to Baseline warrant further investigation, alongside the heterogeneous patterns in other tests. Their post-pandemic timing does not identify a cause: pandemic-associated changes, pre-existing trends, population composition, and other period effects cannot be disentangled. The health relevance of cardiorespiratory and muscular fitness and their tracking into adulthood nevertheless support attention to these components (Fraser et al., 2021; García-Hermoso et al., 2022; Guo et al., 2024).

4.3 Implications for population monitoring and prevention

The findings support differentiated fitness monitoring across motor domains, age groups, and sexes. In particular, lower absolute PWC170 values warrant continued surveillance and further investigation of their potential determinants and health implications.

The YFIT consensus recommends standardised core assessments for monitoring and surveillance, including handgrip strength and standing long jump (Ortega et al., 2025). These tests connect MoMo with an international framework. For MoMo, combining international core assessments with established national tests offers a way to improve comparability while preserving continuity in temporal monitoring.

For policymakers, MoMo 2.0 provides an updated empirical reference to inform prevention priorities and assess future population patterns. The estimates can also support comparisons with other populations when age ranges, test protocols, and outcome definitions are sufficiently comparable. They do not establish clinical thresholds or identify the effectiveness of particular interventions. Their contribution is to guide subsequent investigation and provide a reference for assessing future population-level changes in physical fitness.

4.4 Strengths and limitations

Strengths include nationwide probability sampling, standardised assessment procedures, and a broad profile covering strength, endurance, coordination, balance, and flexibility. Sampling weights and municipality-level clustering were incorporated into the estimation of means and confidence intervals. Continuity with earlier MoMo assessments enables contextualisation over approximately two decades, while the 2023–2024 assessment period provides a contemporary post-pandemic reference.

Absolute cycle ergometry workloads provide a useful description of age- and sex-specific performance. Further analyses incorporating body-mass-relative workload (W/kg) would complement these findings and help clarify the contribution of body size to the observed patterns.

The cross-sectional design precludes conclusions about within-person development. Participation may have been associated with fitness or related family characteristics, and residual nonresponse bias cannot be excluded despite weighting. Test-specific eligibility and missing data resulted in different analytical sample sizes.

Broad age-group summaries may conceal variation within groups and do not constitute continuous age-specific reference centiles. Absolute strength and ergometer workload were not adjusted for body size, and biological maturation was not incorporated into the present analyses. Potential floor and ceiling effects may additionally limit discrimination in some tests.

Historical comparisons were descriptive, with differences in weighted means and their 95% confidence intervals providing indications of potential population-level differences across assessment period. Each assessment was weighted to its respective population rather than to a common reference population. Weighted Wave 3 comparison estimates were unavailable, leaving the period immediately preceding and overlapping the pandemic unrepresented in the historical tables. Consequently, the comparisons provide long-term context but cannot isolate pandemic-associated changes. The simplified variance specification did not incorporate stratification; this may affect precision estimates relative to a fully specified sampling design.

5 Conclusion

MoMo 2.0 provides an updated population-based description of physical fitness among children and adolescents in Germany following the COVID-19 pandemic. Age- and sex-specific profiles differ across motor performance domains, supporting multidimensional assessment and interpretation. Earlier MoMo data contextualise lower absolute PWC170 values in both sexes and lower standing long jump performance relative to Baseline. In contrast, mean push-up and sideways jumping performance was higher, and static balance error counts were lower, in both sexes than at Baseline. Compared with Baseline, girls also showed higher mean performance in balancing backwards and the stand-and-reach test. These contrasting historical patterns highlight the importance of domain- and sex-specific interpretation. The study provides a contemporary reference for national and international comparisons and an evidence base to inform continued fitness monitoring and prevention policy. Considered alongside physical activity and health indicators, these findings can support a more comprehensive understanding of children's and adolescents' health and guide further investigation of social inequalities and potential determinants of fitness. This complementary perspective is particularly relevant in light of the WHO's call to reduce inequalities in adolescent physical activity and strengthen the evidence base for coordinated public health action (World Health Organization, 2026).

Supporting information

Supplementary Table S1 presents age- and sex-specific weighted means, 95% confidence intervals, and unweighted sample sizes. Supplementary Tables S2 and S3 provide historical comparisons for boys and girls used to contextualise the findings in the Discussion.

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Supporting information

Physical fitness of children and adolescents in Germany in 2023–2024

Current age- and sex-specific profiles from a nationwide cross-sectional study

Supplementary Table S1

Weighted motor performance estimates by age group and sex. N denotes the unweighted analytical sample size. Estimates cover ages 4–17 years, with test-specific eligibility at ages 6–17 years for strength endurance, handgrip strength and cycle ergometry. Participants aged 18 years or older and the diverse sex category were excluded from these sex-specific tables.

Standing long jump (cm)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	4–5	90.58	[87.96–93.21]	289
Boys	6–10	125.85	[124.20–127.49]	873
Boys	11–13	155.44	[152.88–158.00]	489
Boys	14–17	188.89	[185.64–192.14]	416
Girls	4–5	85.66	[83.00–88.32]	278
Girls	6–10	120.92	[119.14–122.69]	800
Girls	11–13	147.43	[145.09–149.77]	419
Girls	14–17	153.67	[151.04–156.30]	383

N denotes the unweighted analytical sample size.

Push-ups (number/40 s)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	6–10	11.95	[11.61–12.29]	861
Boys	11–13	13.27	[12.84–13.70]	483
Boys	14–17	14.54	[14.17–14.92]	412
Girls	6–10	11.89	[11.55–12.22]	793
Girls	11–13	12.89	[12.50–13.28]	419
Girls	14–17	12.34	[11.91–12.77]	382

N denotes the unweighted analytical sample size.

Sit-ups (number/40 s)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	6–10	16.54	[16.11–16.96]	863
Boys	11–13	20.35	[19.73–20.98]	489
Boys	14–17	22.93	[22.39–23.47]	416
Girls	6–10	15.56	[15.05–16.06]	792
Girls	11–13	18.34	[17.74–18.95]	421
Girls	14–17	18.48	[17.87–19.09]	385

N denotes the unweighted analytical sample size.

Handgrip strength (kg)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	6–10	14.41	[14.07–14.76]	871
Boys	11–13	24.93	[24.31–25.55]	491
Boys	14–17	40.53	[39.63–41.42]	416
Girls	6–10	12.99	[12.62–13.35]	799
Girls	11–13	23.39	[22.83–23.96]	421
Girls	14–17	29.92	[29.33–30.51]	386

N denotes the unweighted analytical sample size.

PWC170 (W)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	6–10	64.15	[62.23–66.08]	382
Boys	11–13	94.69	[91.40–97.97]	305
Boys	14–17	135.11	[131.03–139.18]	334
Girls	6–10	54.36	[52.45–56.26]	353
Girls	11–13	80.37	[77.23–83.51]	257
Girls	14–17	98.19	[94.32–102.05]	289

N denotes the unweighted analytical sample size.

Maximum cycle ergometry workload (W)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	6–10	81.40	[78.61–84.18]	609
Boys	11–13	117.37	[114.04–120.71]	480
Boys	14–17	167.57	[163.61–171.52]	404
Girls	6–10	72.64	[70.04–75.24]	542
Girls	11–13	102.41	[99.63–105.19]	408
Girls	14–17	124.33	[120.53–128.14]	361

N denotes the unweighted analytical sample size.

Stand and reach (cm)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	4–5	1.05	[0.40–1.69]	284
Boys	6–10	−1.14	[−1.59–−0.69]	872
Boys	11–13	−4.49	[−5.26–−3.72]	492
Boys	14–17	−1.98	[−2.96–−1.01]	415
Girls	4–5	2.20	[1.63–2.77]	275
Girls	6–10	3.25	[2.73–3.77]	796
Girls	11–13	3.02	[2.07–3.97]	420
Girls	14–17	5.90	[4.97–6.84]	386

N denotes the unweighted analytical sample size. Positive values indicate reaching below sole level; negative values indicate reaching above sole level.

Jumping sideways (number)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	4–5	12.91	[12.26–13.56]	290
Boys	6–10	27.10	[26.51–27.69]	873
Boys	11–13	34.89	[34.12–35.66]	490
Boys	14–17	39.23	[38.44–40.01]	415
Girls	4–5	12.96	[12.37–13.55]	279
Girls	6–10	26.59	[25.94–27.23]	798
Girls	11–13	34.62	[33.88–35.35]	420
Girls	14–17	36.83	[36.05–37.62]	383

N denotes the unweighted analytical sample size.

Balancing backwards (steps)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	4–5	14.03	[13.02–15.04]	279
Boys	6–10	28.32	[27.65–29.00]	871
Boys	11–13	33.73	[32.93–34.54]	492
Boys	14–17	35.12	[34.05–36.19]	416
Girls	4–5	17.25	[16.02–18.47]	263
Girls	6–10	32.91	[32.21–33.61]	798
Girls	11–13	38.06	[37.21–38.90]	419
Girls	14–17	37.77	[36.88–38.65]	385

N denotes the unweighted analytical sample size. Maximum possible score: 48 steps.

Static stand (errors)

Sex	Age (years)	Weighted mean	95% CI	N
Boys	4–5	20.51	[19.61–21.41]	287
Boys	6–10	8.06	[7.63–8.49]	869
Boys	11–13	4.55	[4.02–5.09]	492
Boys	14–17	3.65	[3.12–4.19]	416
Girls	4–5	18.20	[17.20–19.20]	274
Girls	6–10	6.12	[5.69–6.55]	796
Girls	11–13	3.38	[2.87–3.88]	419
Girls	14–17	3.59	[3.00–4.18]	386

N denotes the unweighted analytical sample size. Fewer errors indicate better performance.

Supplementary Table S2. Descriptive motor performance comparisons across MoMo waves in boys

Test or statistic	Baseline 2003–2006	Wave 1 2009–2012	Wave 2 2014–2017	MoMo 2.0 2023–2024
PWC170 (W) – M ± SD	108 ± 50	109 ± 49	109 ± 42	95.9 ± 39.7
95% CI	[105–111]	[104–113]	[105–113]	[93.0–98.9]
N	1779	1075	801	1021
Standing long jump (cm) – M ± SD	152 ± 43	149 ± 42	146 ± 42	140.1 ± 40.2
95% CI	[150–154]	[146–152]	[143–150]	[138.1–142.0]
N	2309	1537	1351	2067
Push-ups (number/40 s) – M ± SD	12.2 ± 4.1	12.9 ± 4.3	13.0 ± 4.0	12.9 ± 4.0
95% CI	[11.9–12.5]	[12.5–13.3]	[12.6–13.4]	[12.6–13.2]
N	2013	1287	1141	1756
Sit-ups (number/40 s) – M ± SD	—	—	—	19.1 ± 6.7
95% CI	—	—	—	[18.7–19.4]
N	—	—	—	1768
Handgrip strength (kg) – M ± SD	—	—	—	23.2 ± 12.3
95% CI	—	—	—	[22.6–23.9]
N	—	—	—	1778
Jumping sideways (number) – M ± SD	26.3 ± 11.2	29.2 ± 11.1	29.2 ± 11.2	29.3 ± 11.0
95% CI	[25.7–26.9]	[28.3–30.0]	[28.3–30.1]	[28.7–29.9]
N	2296	1525	1342	2068
Balancing backwards (steps) – M ± SD	28.0 ± 11.8	30.7 ± 11.8	30.6 ± 11.3	29.0 ± 11.7
95% CI	[27.4–28.7]	[29.8–31.6]	[29.6–31.5]	[28.4–29.5]
N	2309	1532	1324	2058
Static stand (errors) – M ± SD	9.6 ± 8.8	7.7 ± 8.7	7.2 ± 7.8	8.1 ± 8.4
95% CI	[9.1–10.1]	[7.0–8.4]	[6.5–7.9]	[7.7–8.5]
N	2285	1535	1342	2064
Stand and reach (cm) – M ± SD	−2.0 ± 7.4	−1.4 ± 7.2	−2.5 ± 7.9	−1.8 ± 7.8
95% CI	[−2.5–−1.6]	[−2.0–−0.9]	[−3.2–−1.8]	[−2.1–−1.5]
N	2283	1536	1344	2063

M, weighted mean; SD, standard deviation; CI, confidence interval; N, unweighted sample size. Lower static stand error counts indicate better performance. Dashes denote unavailable historical estimates for sit-ups and handgrip strength.

MoMo 2.0 estimates exclude participants aged 18 years or older. PWC170, push-ups, sit-ups and handgrip strength cover ages 6–17; the other tests cover ages 4–17. Historical estimates are retained as supplied. MoMo 2.0 confidence intervals account for sampling weights and municipality clustering using single-stage with-replacement estimation.

Supplementary Table S3. Descriptive motor performance comparisons across MoMo waves in girls

Test or statistic	Baseline 2003–2006	Wave 1 2009–2012	Wave 2 2014–2017	MoMo 2.0 2023–2024
PWC170 (W) – M ± SD	83 ± 34	82 ± 31	83 ± 29	75.4 ± 29.3
95% CI	[80–85]	[79–85]	[80–86]	[73.2–77.7]
N	1684	982	730	899
Standing long jump (cm) – M ± SD	132 ± 31	132 ± 29	127 ± 33	127.8 ± 32.3
95% CI	[130–133]	[130–135]	[124–131]	[126.0–129.6]
N	2195	1456	1267	1880
Push-ups (number/40 s) – M ± SD	11.2 ± 3.7	11.9 ± 3.5	11.5 ± 4.0	12.3 ± 3.7
95% CI	[10.9–11.5]	[11.6–12.2]	[11.1–12.0]	[12.0–12.5]
N	1903	1231	1053	1594
Sit-ups (number/40 s) – M ± SD	—	—	—	17.0 ± 6.1
95% CI	—	—	—	[16.6–17.3]
N	—	—	—	1598
Handgrip strength (kg) – M ± SD	—	—	—	19.6 ± 8.7
95% CI	—	—	—	[19.1–20.1]
N	—	—	—	1606
Jumping sideways (number) – M ± SD	26.5 ± 10.3	28.6 ± 9.8	27.4 ± 10.4	28.3 ± 10.5
95% CI	[26.0–27.1]	[27.9–29.3]	[26.4–28.4]	[27.7–28.9]
N	2170	1457	1267	1880
Balancing backwards (steps) – M ± SD	29.8 ± 11.5	33.2 ± 11.3	31.2 ± 12.0	32.8 ± 11.4
95% CI	[29.1–30.6]	[32.3–34.1]	[30.1–32.4]	[32.1–33.4]
N	2192	1461	1246	1865
Static stand (errors) – M ± SD	8.3 ± 8.3	6.1 ± 7.5	6.5 ± 7.6	6.8 ± 8.1
95% CI	[7.8–8.7]	[5.4–6.7]	[5.7–7.3]	[6.4–7.2]
N	2173	1454	1257	1875
Stand and reach (cm) – M ± SD	1.6 ± 7.8	3.6 ± 7.1	2.5 ± 7.6	3.5 ± 7.6
95% CI	[1.1–2.1]	[3.1–4.1]	[1.8–3.2]	[3.2–3.9]
N	2177	1462	1270	1877

M, weighted mean; SD, standard deviation; CI, confidence interval; N, unweighted sample size. Lower static stand error counts indicate better performance. Dashes denote unavailable historical estimates for sit-ups and handgrip strength.

MoMo 2.0 estimates exclude participants aged 18 years or older. PWC170, push-ups, sit-ups and handgrip strength cover ages 6–17; the other tests cover ages 4–17. Historical estimates are retained as supplied. MoMo 2.0 confidence intervals account for sampling weights and municipality clustering using single-stage with-replacement estimation.