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The German national cohort study on the development of motor performance, physical activity and health in children and adolescents: the MoMo 2.0-Study protocol

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ABSTRACT

Introduction Regular physical activity (PA) and good motor performance are essential for children's physical and mental health. However, historical trends suggest that levels of PA and motor performance in children and adolescents are at a low point. The relationships between PA, motor performance, health and their respective determinants, as well as their individual development throughout childhood and adolescence, are not yet fully understood. Therefore, continuous monitoring of PA, motor performance and health is needed to identify vulnerable subpopulations and provide data for policy-makers and health promotion professionals. The Motorik Monitoring 2.0-Study aims to analyse the developmental, historical and periodic trends in motor performance and PA, as well as the underlying determinants, in children and adolescents in Germany.

Methods and analysis A representative sample of children and adolescents aged 4–17 years is drawn across 195 sample points in Germany. The assessment, carried out by test instructors, includes (1) a PA questionnaire covering different settings, including determinants, (2) anthropometric measures, (3) fine and gross motor performance tests focusing on coordination, flexibility, strength and endurance, (4) 24 hours device-based measured physical behaviour by accelerometry for 1 week and (5) a health interview focusing on health behaviour, physical and mental health as well as socioeconomic status. In addition, external data may be linked to the study using geographical information systems (eg, area deprivation, access to sports facilities). Analyses will be conducted using mixed-effects models to account for the nationwide structure of the study.

Ethics and dissemination Ethical approval was obtained from the Ethics Committee of the Karlsruhe Institute of Technology. Results will be published in open-access scientific journals and disseminated at congresses for scientists, policy-makers and stakeholders.

Trial registration number The study was registered in the NFDI4health database (https://csh.nfdi4health.de/resource/1034). The NFDI4health database is a central platform of the National Research Data Infrastructure for Personal Health Data. It is used to collect, manage and provide health data for scientific research and facilitates access to high-quality data for epidemiological and clinical studies.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Expansion of a unique longitudinal database with a new representative cohort for Germany, comparable with measurements from over 20 years.
⇒ Key components include an objective assessment of motor performance and body composition, 24-hour device-based measured physical behaviour using accelerometry over 1 week, a questionnaire on physical activity and its determinants, and a bio-psychosocial health interview.
⇒ The Motorik Monitoring 2.0-Study balances the introduction of new measures and technologies while retaining the core measures to ensure comparability with previous cohorts.
⇒ Geospatial data, for example, at the municipality or neighbourhood level, can be linked to add contextual information about the living environment.

INTRODUCTION

Regular physical activity (PA) and low levels of sedentary time are beneficial for children's physical and mental health.[1–3] Childhood and adolescence are important life stages where health-related behaviour, such as regular PA, is established early in life and often maintained into (late) adulthood.[4] For example, motor performance can predict future health benefits in children and adolescents,[5 6] highlighting the importance of being physically active. Continuous monitoring is needed to provide an overview of the current health status of a population and to identify historical trends in PA and motor performance and health. In this way, health promotion efforts

can be efficiently coordinated by identifying vulnerable (sub)populations.[7]

Despite this evidence, most adolescents worldwide do not meet the WHO guidelines for PA, and despite increasing efforts to promote PA, PA levels have not improved substantially over the past decades.[8] Additionally, the COVID-19 pandemic impacted the PA of children and adolescents.[9 10] Cardiovascular fitness, an important health indicator in children and adolescents, has declined globally between 1981 and 2000 and has remained low since then.[11] Mixed historical trends are found for strength, where handgrip strength has increased in recent decades, whereas standing long jump performance increased until 2000 and has declined since.[12 13] Declines in PA and motor performance may be related to the global increase in childhood and adolescent obesity reported by the NCD Risk Factor Collaboration.[14]

In Germany, the Motorik-Module (MoMo) monitored PA and motor performance in children and adolescents in four representative cross-sectional cohorts and a large longitudinal sample between 2003 and 2021.[15 16] The main findings show that sports activity levels have remained stable over almost two decades, but there is a shift from non-club sport to club sport,[17] while motor performance in children and adolescents has remained at a low level over the same period.[18] Increased efforts to promote PA in children and adolescents have not yet led to improvements at the national level.[19]

MoMo was an in-depth study of the German Health Interview and Examination Survey for Children and Adolescents (KiGGS).[20] By linking MoMo with the health data from KiGGS, it provided unique insights into the relationship between PA, motor performance and health. The MoMo 2.0-Study (renamed as MoMo 2.0=Motorik Monitoring 2.0-Study) is a new independent cohort study providing representative data on PA, motor performance and biopsychosocial health in children and adolescents in Germany. While key measures from MoMo and KiGGS are retained to ensure comparability with previous cohorts, new procedures and measures are added based on technological advances, current societal trends and scientific developments.

The main objective of the MoMo 2.0-Study is to analyse the developmental, historical and periodic trends in motor performance and PA as well as the underlying determinants and correlates with health in children and adolescents in Germany.

METHODS AND ANALYSIS

The MoMo 2.0-Study is a joint project of four universities: The research group at the Karlsruhe Institute of Technology (KIT) is responsible for PA (questionnaire) and physical behaviour (accelerometry) and subjective health measures, the Karlsruhe University of Education focuses on the motor performance and anthropometric assessment, the University of Konstanz focuses on socio-structural determinants and social inequality, and the Humboldt-Universität zu Berlin focuses on the development of statistical methods to analyse the data. The study is funded by the Federal Ministry of Health based on a resolution of the 'German Bundestag', the federal parliament of Germany.

MoMo 2.0-Study design and main aims

The MoMo 2.0-Study aims to (1) describe PA and motor performance levels of children and adolescents aged 4–17 years in Germany, (2) compare changes/cohort trends in motor performance, PA and health with the MoMo data over the last 21 years, (3) assess the influence of societal changes and major significant developments has on motor performance, PA and health of children and adolescents, (4) analyse the socioeconomic and socio-spatial gradients regarding motor performance, PA and health and (5) analyse the relationships between motor performance, PA and biopsychosocial health.

The focus of the MoMo 2.0-Study is to carry out a nationwide data collection of a representative cross-sectional cohort (September 2023–December 2024). The data collection is designed to monitor PA, motor performance and health of children and adolescents in Germany in the light of societal changes, in particular, recent crises and megatrends (eg, COVID-19 pandemic, climate crisis, migration due to war, connectivity and sustainability) and growing social inequalities. This new cohort is a successor to the four MoMo measurement points conducted between 2003 and 2022 (see figure 1).

Following a cohort-sequence design, a longitudinal sample from MoMo was followed up. During the COVID-19 pandemic, MoMo participants were invited to participate in two online surveys to assess PA and health in such unique circumstances in April 2020 as well as February–March 2021.[10 21 22] As part of the MoMo 2.0-Study, two further online surveys (February 2023 and February–March 2024) were conducted to follow up on these longitudinal participants in addition to the main data collection at the on-site study centres.[23]

Theoretical framework

The health-related fitness model of Bouchard *et al*[24] (see figure 2) defines the relationship between PA, health-related fitness (defined as motor performance within the MoMo 2.0-Study and throughout the rest of the manuscript) and health status, taking into account influencing factors such as genetic and other factors. More specifically, the basic assumptions of the model are that PA, motor performance and health have bidirectional associations and that motor performance mediates the influence of PA on health. These main components of the model are additionally influenced by other lifestyle behaviours, physical and social environmental conditions, personal characteristics and genetic factors. Based on an adapted version of the Bouchard model, the MoMo 2.0-Study integrates many of these assumptions, allowing for a theory-based approach to answering the research questions. The study expands on the PA component (using

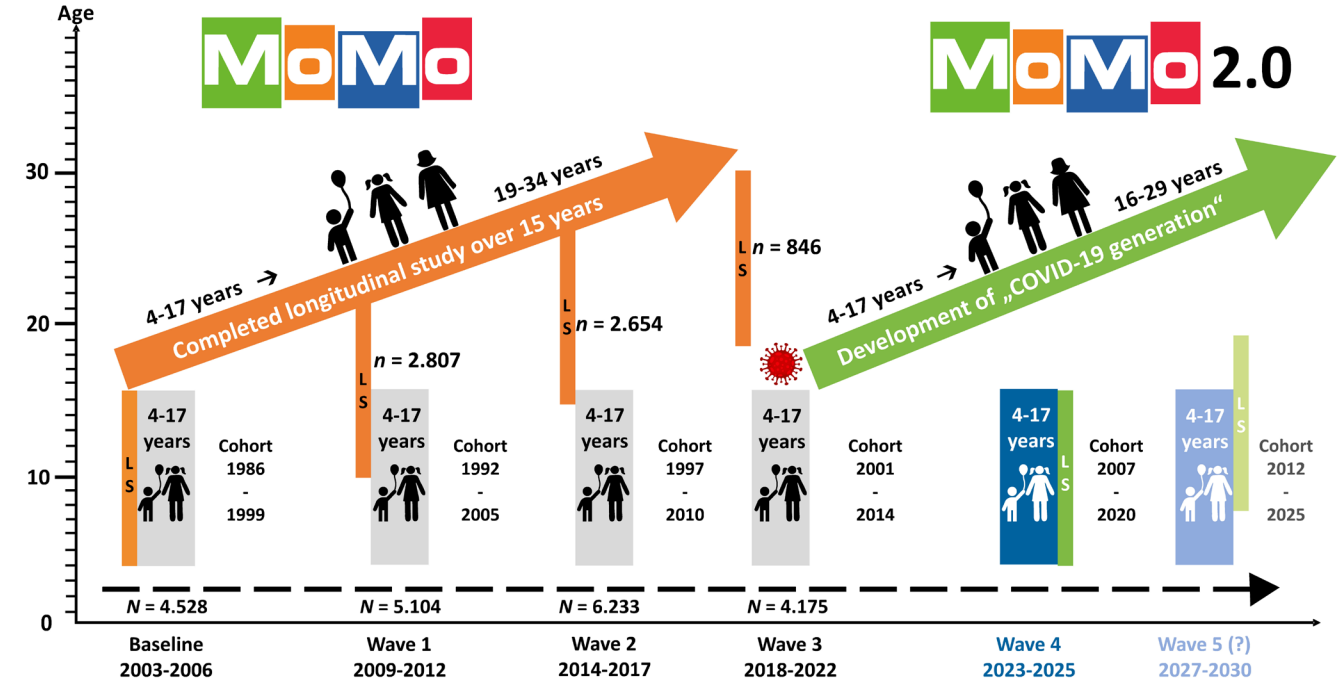

Figure 1 Study design of MoMo and the MoMo 2.0-Study.

the term 'physical behaviour') by including not only PA but also sedentary behaviour and sleep within the 24-hour activity cycle, a recently introduced paradigm.[25 26] Motor performance is represented in the MoMo 2.0-Study by the cardiovascular, morphological, muscular and motor subdomains, as shown in figure 2. Other factors such as the physical and social environment, personal characteristics and lifestyle behaviours are also considered as important determinants.

Sampling strategy

The sampling strategy for the new cross-sectional cohort follows a two-stage randomisation process in cooperation with GESIS—Leibnitz Institute for the Social Sciences. In the first step, 185 municipalities are randomly selected from the inventory of the National Register of Municipalities in Germany. The probability of selection is proportional to the number of inhabitants in the relevant age group (4–17 years). Due to the delay between contacting the municipalities and confirming the test dates, children aged 3 years at the reference date are also selected by the municipalities to ensure enough 4-year-olds may participate. In the second step, the local registration offices of the selected municipalities are asked to provide the contact details of 140 randomly selected inhabitants of the relevant age group. These people receive an invitation by mail to participate in the study with a personal login to the online registration page and are asked to make an appointment 4–6 weeks before the test period in their municipality. Invited individuals receive up to two reminder letters.

Data collection started in September 2023 and is expected to be completed by the end of 2024. The order in which the sample points are contacted is evenly distributed across states and urbanicity levels to avoid confounding regions or urbanicity status with seasonal variations (eg, due to weather or school holidays). The targeted sample size of 4500 participants was determined through power analyses and to satisfy the criteria for a representative sample across 195 sample points in Germany.

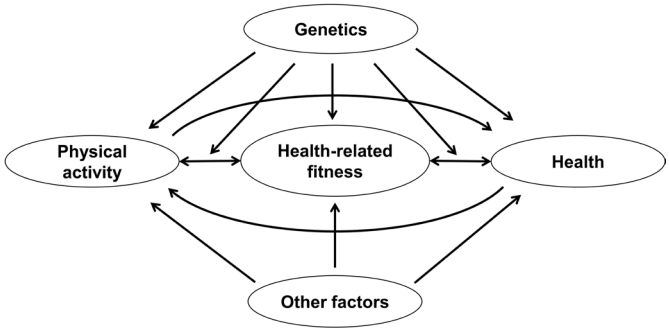

Figure 2 Theoretical framework for the MoMo 2.0Study (adapted from Bouchard and colleagues,[24] p. 47).

Data collection

There are five steps of data collection: Filling out the PA questionnaire, taking anthropometric measurements, performing motor performance tests, equipping an accelerometer and conducting a health interview (see figure 3).

Procedures marked blue are only conducted in children aged 6–17 years.

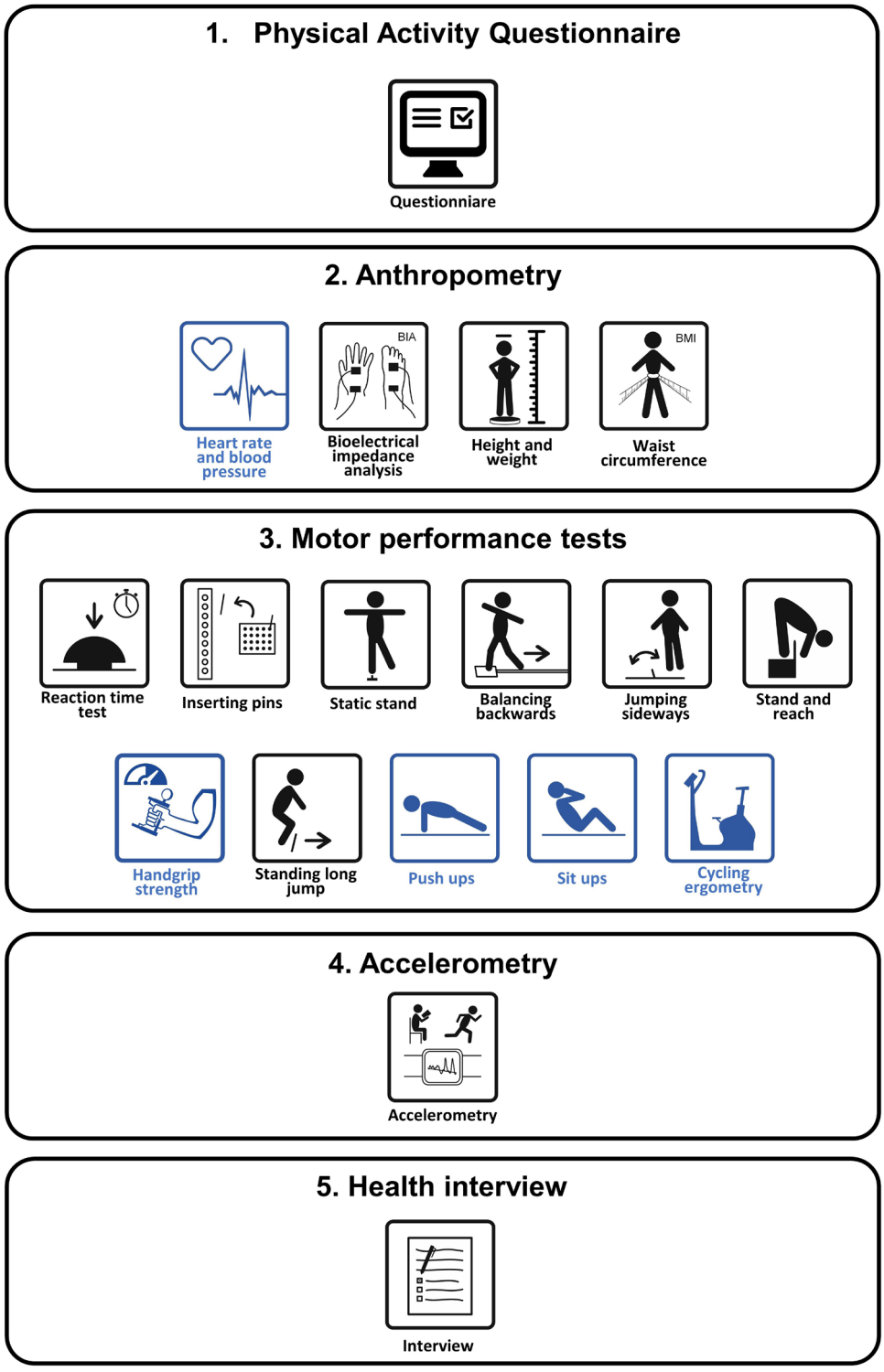

Figure 3 Five steps of data collection within the MoMo 2.0-Study. BIA, bioelectrical impedance analysis; BMI, body mass index.

PA questionnaire

Participants are given a digital questionnaire on a tablet to answer questions about their daily life PA and determinants of PA such as enjoyment, social support and neighbourhood environment. A parent or legal guardian may help the children to fill in the questionnaire. There are three versions of the questionnaire, tailored to (1) preschool children, (2) school children and (3) adolescents who have left school and are doing vocational training, a voluntary social year, or left school for other reasons. A test instructor is available to answer any questions.

Anthropometric measurements

After completing the PA questionnaire, participants have their blood pressure measured (only participants

≥6 years). Body weight, height and waist circumference measures are taken, and a bioimpedance analysis is conducted to assess the body composition. All data collected is entered into a tablet by the test instructors.

Motor performance tests

Depending on the age, 7 (<6 years) to 11 (≥6 years) motor performance tests are performed in a predetermined order (see figure 3). A test instructor explains the tests to the participants and records the results on a tablet.

Accelerometry

Participants are asked to wear an accelerometer for the following 8 days. If the participant agrees, an accelerometer is attached to the right thigh with medical adhesive tape. Instructions are given on how to complete the digital wearing protocol and how to return the accelerometer at the end of the wear period in a prepaid envelope provided.

Health interview

A face-to-face health interview is conducted with the participant (and legal guardian for children aged ≤16 years) with a test instructor, asking questions about physical and mental health, socioeconomic status and migration background. A parent or legal guardian can help the child during the interview. The interview format is designed to ensure that the questions are correctly understood and that any questions that arise can be answered immediately by the test instructor.

General procedures

After receiving the invitation letter, participants can register and book an appointment (08:00–18:00) at a study centre near their home within the specified day of examination (2 days per sample point). Written consent is obtained from each participant at the start of the appointment. Children and adolescents under the age of 16 must be accompanied by a parent or legal guardian who also complete the consent form. Participants aged 16 years and over can complete the consent form independently and take part without a parent or guardian. The whole testing process takes 90–120 min to complete. On completion of all tests and questionnaires, participants receive a €20 gift voucher and a feedback email with the results of their motor performance tests, anthropometric measurements and accelerometer-measured physical behaviour.

Test instructors and quality control

The test instructors are students of sports science or a related subject who receive a 2day-in-person training from at least two sports scientists from the Karlsruhe University of Education and the KIT. In addition, further online training materials and a test manual for the standardised procedures are available.[27]

A maximum of four participants are invited at the same time, and the motor performance testing area is separated from the others to ensure a suitable environment and to minimise external disturbance. A test instructor accompanies each participant throughout the whole testing procedure. All data are entered directly into a tablet using the questionnaire software SoSciSurvey[28] to avoid transmission errors and reduce the number of implausible entries.

While participants and the public were not involved in the design and conduct of the study, there are plans to involve the public in the dissemination of the results by organising a congress with workshops on how best to report and disseminate the results to relevant stakeholders and the public (see 'Ethics and dissemination' section).

Measures

Core measures of PA, motor performance and key determinants are retained from MoMo to ensure direct comparability with previous cohorts. In addition, key measures of biopsychosocial health and socioeconomic status, previously monitored in KiGGS are implemented in the MoMo 2.0-Study. To take account of developments in society, technology and research, new measures have been added (eg, handgrip strength, stress questionnaires) and previous methods have been adapted (eg, now using a 24-hour accelerometer to include sleep behaviour). All participants provided data on their day of birth, sex and who is assisting them (eg, father, mother) with the questionnaire and interview (if applicable).

PA and physical behaviour

The MoMo PA questionnaire[29] covers all domains of PA: PA during daily activities (eg, household chores), kindergarten or school and leisure time sports activities in and outside of sports clubs (see table 1). The MoMo PA questionnaire is comparable to other international PA questionnaires with a 1-week test–retest reliability of kappa=0.66 and an intraclass coefficient of 0.67 as well as a correlation with moderate to vigorous PA (MVPA) measured via accelerometer of r=0.29.[29]

Participants who agree to wear an accelerometer receive an ActivPAL which will assess 24-hour physical behaviour including PA, sedentary time and sleep for 8 days from the day of examination (see table 2). In addition, the participants fill out a digital wearing protocol in which they record the times when they get up, go to bed, start and end of school and physical education. At the end of the week, participants will report the amount of MVPA per day to estimate compliance with the new WHO 2020 PA guideline.[30]

In the MoMo 2.0-Study, the transition in accelerometry from the ActiGraph to the ActivPAL was motivated by the necessity to obtain a more nuanced understanding of sedentary behaviour. While the ActiGraph predominantly measures movement intensity, the ActivPAL facilitates a more precise analysis of sedentary behaviour by recording body posture (eg, sitting vs standing). A study by Ortega *et al*,[31] among others[32–35], demonstrates that the ActivPAL with adjusted epoch lengths provides estimates

Table 1 Physical activity (PA) measures in the MoMo 2.0-Study (adapted from the MoMo PA questionnaire[29])

Construct	Target group	Description
Moderate-to-vigorous PA	4–17 years	Number of days engaged in moderate to vigorous PA for at least 60 min during the past 7 days (1 item) and during a typical week (1 item).
Strengthening PA	4–17 years	Number of days engaged in muscle-strengthening activities during a typical week* (1 item).
Everyday PA	4–17 years	Frequency (days per week), duration (minutes per day) and intensity (light, moderate, vigorous) of gardening, playing outside, doing housework, cycling and using non-motorised vehicles (15 items); walking distance (km per day) and intensity (light, moderate, vigorous) (2 items).
PA in kindergarten	Children attending kindergarten	Frequency (days per week), duration (minutes per week) and intensity (light, moderate, vigorous) of physical education classes or instructed PA during a typical week in the kindergarten (3 items).
PA at school	School children	Frequency (days per week), duration (minutes per week) and intensity of physical education classes (3 items); participation in extracurricular sports activities, type, frequency (minutes per week) and intensity (light, moderate, vigorous) of extracurricular sports activities (4 items); frequency (days per week) of PA breaks during a normal week and the incorporation of PA into the delivery of academic content (2 items)*.
PA at work	Employed adolescents/school leavers	Frequency (days per week), duration (hours and minutes per day) and intensity (light, moderate, vigorous) of PA at work during a typical week (3 items); walking frequency (days per week), duration (hours and minutes per day) and intensity (light, moderate, vigorous) at work during a typical week (3 items)*.
Leisure time sports activities in a sports club	4–17 years	Sports club membership (yes/no); type, duration (minutes per week), time throughout the year (months) and intensity (light, moderate, vigorous) of up to four sports activities (up to 17 items).
Leisure time sports activities outside a sports club	4–17 years	Participation in sports activities outside a sports club (yes/no; type of organisation); type, duration (minutes per week), time throughout the year (months) and intensity (light, moderate, vigorous) of up to four different sports activities (up to 18 items).
Active transport to school/ kindergarten/work	4–17 years	Usual transport mode to kindergarten/school/work and duration (minutes) of active kindergarten/school/work trips (up to two items); distance from home to kindergarten/school/work (1 item)*.

*Items were developed independently and were not a part of the original MoMo PA questionnaire.
MoMo, Motorik-Module; MoMo 2.0, Motorik Monitoring 2.0.

of MVPA that are comparable to those of the ActiGraph, thereby validating its use in the MoMo 2.0Study.

Anthropometry and motor performance

Anthropometric measurements are taken after completing the PA questionnaire. Resting blood pressure and heart rate are measured three times on the right upper arm with an Omron HBP-1320, with 1 min rest in between. Participants' body height and weight are measured without shoes and light clothing using a stadiometer (Seca 213) and a digital scale (Seca 813). Waist circumference is measured in a standing position after exhalation. Bioelectrical impedance analysis is used to determine body composition. A body impedance analyser (NutriBox from Data Input with four channels, 50 Hz) measures resistance and reactance between the right wrist and ankle while the participant is in a supine position.

Depending on the age of the participants, up to 11 validated motor performance tests are performed,[27 36] which aim to measure coordination (reaction time test, inserting pins, static stand, balancing backwards, jumping sideways), flexibility (stand and reach), strength (handgrip strength, standing long jump, push ups, sit ups) and endurance (cycling ergometry) (see table 3).

Health and determinants

Health measures are mainly assessed in the health interview and range from psychological to physical health measures, also including risk factors such as alcohol consumption and smoking among adolescents (see table 4).

Several individual and sociospatial determinants are assessed by questionnaire. More sensitive questions, for example, on socioeconomic status and migration background, are asked in the face-to-face interview (see table 5).

Geospatial data, that is, information on contextual conditions, can be linked to the MoMo 2.0-Study data, for example, based on participants' municipality and neighbourhood. We have access to satellite, land use

Table 2 Accelerometer criteria (adapted from Migueles *et al*[54])

Accelerometer criteria	Description
Wearing location	Right thigh, 10 cm above the upper edge of the kneecap, orange side away from the body, torso visible from the front and upright
Attaching	3M Tegaderm 10×8 cm, wrapped in cut-off fingers of disposable nitrile gloves, size M, waterproof
Sampling frequency	40 Hz
Wearing time	24 hours per day, for 8 nights and 7 days
Wearing protocol	Daily digital entry: Getting up, going to bed, start/end of school, start/end of physical education, start/end of school sports club, early drop-off with reason, WHO-2020 PA guideline question
Data format	Raw data (x, y, z-axis), events XYZ file, steps
Epoch length	1 s with the option of converting to for example, 5 s, 10 s or 60 s
Intensity classification	Sleep, sedentary behaviour, light, moderate and vigorous PA
Determination of body position	Sleeping, lying, standing, walking, seated transport, cycling
Valid wearing time	24 hours for at least 5 days (including one weekend day)

PA, physical activity.

and point of interest data from the Federal Agency for Cartography and Geodesy and can also use open access data from Census 2022 for population data, the Robert Koch Institute for socioeconomic deprivation data, the Federal Institute for Research on Building, Urban Affairs and Spatial Development for urbanicity data and OpenStreetMap for selected purposes.

Analysis

The MoMo 2.0-Study has a combined cross-sectional and longitudinal design (ie, accelerated longitudinal design[37]), resulting in a complex data structure with temporal dependencies (multiple measurements of the same individuals), spatial dependencies (individuals in communities), a complex missing data structure and various forms of heterogeneity (interindividual differences).

The data analysis strategy aims to explore the intricate relationships between motor performance, PA/physical behaviour, biopsychosocial aspects of health and their sociodemographic moderators, as well as associated changes. We will use inferential statistical methods such as general linear mixed models[38] to explore differences, associations and risk factors. Multivariate statistical techniques will be used to account for confounding factors and to capture moderating effects through interaction terms. These methods aim to identify at-risk groups and potential targets for adaptive interventions. In addition, we will use longitudinal data to better understand the causal relationships between motor performance, PA, biopsychosocial health and sociodemographic determinants.

To address these methodological challenges and further the aims of the current study, state-of-the-art statistical methods are used, such as continuous time models,[39 40] mixed-effects models[41] and score-based procedures[42] will be employed. These methods are intended not only to improve the optimal analysis of the complex data structures in the MoMo 2.0-Study but also to contribute to the development of new statistical and methodological approaches that will benefit future projects and research groups.

ETHICS AND DISSEMINATION

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).

The legal guardians of the participants are informed of the planned scope of the examinations in the invitation letter and through a detailed information material on the website. The legal guardians are also present at the examinations at all times. At the study centre, participants and guardians are informed verbally about the aforementioned risks and asked about possible contraindications prior to the motor performance tests. To minimise the risks, a standardised health screening is conducted asking for known pre-existing conditions prior to those tests. The tests are only carried out if there are no contraindications and if the legal guardians or participants (for those over 15 years) consent to the tests. It is imperative to emphasise that all tests are voluntary and can be declined or terminated at any time by the legal guardians and participants. Based on the experience of over 20 years of using the established, standardised procedures in MoMo, there have been no significant incidents. Nevertheless, the participation is not entirely without risk, as for example, muscle soreness and minor injuries may occur as a result of the motor performance tests.

A novelty is the accelerometer which is attached directly to the thigh. There is a possibility of skin irritation or allergic reactions, this risk is minimised by using a medial-grade adhesive. The participants are required to uncover their thighs in order to attach the sensor, which may require them to lower their pants. This is communicated in advance. To ensure the privacy of the participants, a screen is installed behind which the sensor can be applied. In the interest of safeguarding the well-being of

Table 3 Motor performance tests in the MoMo 2.0-Study

Construct	Instrument	Target group	Description	Reliability
Fine motor coordination eye-hand (reaction time)	Reaction time test	4–17 years	Pushing a button after a light signal appears on a computer screen, measured in seconds (10 trials).	Children aged 4–17[55] Test–retest reliability: ICC=0.92
Fine motor coordination	Inserting pins	4–17 years	Time to insert 25 thin pins one by one into designated holes by hand, a test of the Motorische Leistungsserie (MLS).	Children aged 4–17[55] Test–retest reliability: ICC=0.94
Coordination: Static balance	static stand	4–17 years	Counting floor contacts standing on the dominant leg on a 3 cm wide beam with eyes open for 1 min.	Children aged 4–17[55] Test–retest reliability: ICC=0.86
Coordination: dynamic balance	Balancing backwards	4–17 years	Counting steps balancing backwards on wooden beams of 3, 4.5 and 6 cm width and 3 m length (2 trials on each beam and a maximum of 8 steps per trial).	Children aged 4–17[55] Test–retest reliability: ICC=0.76
Coordination under time pressure	Jumping sideways	4–17 years	Counting the number of sideways jumps over a printed line on a nonslip mat within 15 s.	Children aged 4–17[55] Test–retest reliability: ICC=0.96
Active flexibility	Stand and reach	4–17 years	Measuring how far the fingertips can reach below sole foot level with knees extended standing on a box with a measuring tape (2 trials).	Children aged 4–17[55] Test–retest reliability: ICC=0.86
Isometric maximal strength	Handgrip strength	6–17 years	Maximum force exerted on the handgrip dynamometer Saehan SH5001 with the preferred hand (2 trials).	Children aged 6–17[56] Test–retest reliability: ICC=0.95
Explosive strength	Standing long jump	4–17 years	Distance of a double-legged jump from a standing position (2 trials).	Children aged 4–17[55] Test–retest reliability: ICC=0.96
Strength endurance (upper body)	Push ups	6–17 years	Number of completed push-ups within 40 s. The push-up must be done in 4 steps: First lying on the floor with arms on the lower back, second, moving into the push-up position, third, in the push-up position with one hand touching the other and returning to the push-up position, fourth, lying down again in first position.	Children aged 6–17[55] Test–retest reliability: ICC=0.76
Dynamic strength endurance (Core)	Sit-ups	6–17 years	Number of complete sit-ups with elbows touching the knees within 40 s.	Children aged 6–17[56] Test–retest reliability: ICC=82
Endurance	Cycling ergometry	6–17 years	Watts attained at a heart rate of 170 beats per minute (PWC170) on an ERG 911S Ergosana bike using the test protocol of the WHO (6–10 years: start: 15W, increment: 15W, duration of stage: 2 min; 11–17 years: start: 25W, increment: 25W, duration of stage: 2 min).	Children aged 6–17[56] Test–retest reliability: ICC=82

ICC, intraclass correlation coefficient; MoMo 2.0, Motorik Monitoring 2.0.

children, participants may choose a test instructor of the same sex or refuse to have the accelerometer attached.

The participants receive a €20 gift voucher and a feedback email with the results of their motor performance tests, anthropometric measurements and accelerometer-measured physical behaviour for their participation.

The results of the MoMo 2.0-Study will be published primarily in open-access scientific journals and presented at national and international scientific conferences. At the national level, the publication of the MoMo 2.0-Study data in Germany's 2022 Report Card on Physical Activity for Children and Adolescents is another example.[43] Using open access databases, the data and reference values obtained are to be made available to interested parties (eg, scientists but also teachers, coaches) in the form of 'public use files', also at national (MO|RE Data) and international level (Fitback, International Children's Accelerometry Database). The MoMo 2.0-Study will provide new reference data for the development of motor performance in children and adolescents in different educational settings.[44] Furthermore, a project website is created as a communication platform, as well as various media formats (eg, interviews, social media, press releases), which will enable the public to access information, results and recommendations of the MoMo 2.0-Study and make an important contribution to improving

Table 4 Health measures in the MoMo 2.0-Study

Construct	Instrument	Target group	Description	Reliability and validity
Health-related quality of life*	KIDSCREEN-10[57 58]	4–17 years	The 10-item version of the KIDSCREEN scale is used to assess the general health-related quality of life.	Children aged 8–17 years[58] Test–retest reliability: ICC=0.70 Internal consistency: α=0.82
Self-perceived health	MEHM[59]	4–17 years	Self-perceived health is recorded with a single item from the European Minimum Health Module.	Children and adults aged 15 years and older[59] Test–retest reliability: Kappa=0.74
Diagnosed diseases	Modified version of KiGGS[60]	4–17 years	Participants are asked whether selected physical and mental illnesses have been diagnosed by a doctor or psychologist (11–12 items) and (if the answer is yes) whether the illness has been diagnosed by a doctor or psychologist.	
Recurrent pain*	Modified version of KiGGS[61]	4–17 years	Three items are used to assess whether subjects have had abdominal pain, headaches or back pain in the last 3 months. Participants who have specified 'female' or 'other' as their biological sex and are aged 9 and over are additionally asked about menstrual pain.	
Disability	Modified version of KiGGS (developed by RKI)	4–17 years	Five items are used to assess whether participants have a non-official restriction or an officially recognised disability that makes it difficult for them to participate fully in social life and limits their physical activity.	
Dietary habits	Modified version of KiGGS[62]	4–17 years	Three items are used to assess eating habits (breakfast at home, food refusal, vegetarian or mixed diet).	
Nutritional intake	PEACHES questionnaire[63]	4–17 years	The short Food Frequency Questionnaire comprises 10 items to assess the consumption frequency of 7 indicator food groups.	
Stress*	SSKJ 3–8 R, three subscales[64]	School children	A modified 6-item scale from the Stress and Coping Questionnaire for Children and Adolescents is used to assess stressors (as well as their perceived intensity) and an 18-item scale is used to assess physical and psychological stress symptoms.	Children aged 8–14 years[64] Stress vulnerability: Test–retest reliability: ICC=0.77 Internal consistency: α=0.70 Physical symptoms scale: Test–retest reliability: ICC=0.65 Internal consistency: α=0.67 Psychological symptoms: Test–retest reliability: ICC=0.75 Internal consistency: α=0.85
Alcohol and tobacco consumption	AUDIT-C (alcohol)[65] Modified version of KiGGS (tobacco)[66]	11–17 years	Four items are used to assess whether participants drink alcohol and if so, in what quantities. Two items are used to assess whether participants smoke and, if so, in what quantities.	9th and 10th grade students[67] Alcohol consumption: Internal consistency: α=0.80
Media use*	Adapted from KiGGS media use questionnaire[68]	4–17 years	One item asking about smartphone ownership and twelve items to measure participants' media usage during weekdays and weekends, including both digital (TV, gaming, internet use, learning/working on a computer) and analogue media (learning/working without a computer, leisure time reading) on a 6-point Likert scale ranging from 0 to 6 hours/day.	

*These constructs are assessed via self-report questionnaire.
AUDIT-C, Alcohol Use Disorders Identification Test; ICC, intraclass correlation coefficient; KiGGS, German Health Interview and Examination Survey for Children and Adolescents; MEHM, European Minimum Health Module; MoMo 2.0, Motorik Monitoring 2.0; PEACHES, Programming of Enhanced Adiposity Risk in CHildhood- Early Screening; RKI, Robert-Koch Institute; SSKJ, Stress and Coping Questionnaire for Children and Adolescents.

Table 5 Determinant measures in the MoMo 2.0-Study

Construct	Instrument	Target group	Description	Reliability and validity
Physical activity (PA) enjoyment	PACES-S[69]	4–17 years	The short version of the Physical Activity Enjoyment Scale consists of 4 items on the subjective feeling component of the emotion enjoyment.	Children aged 11–17 years[69] Test–retest reliability: r=0.76 Internal consistency: α=0.82–0.88 Concurrent validity: r=0.21–0.44 Construct validity: χ^2=53.62, df=2, p<0.001, RMSEA=0.073, CFI=0.99
Physical self-concept	PSK[70]	School children and employed adolescents/school leavers	Shortened version of the Physical Self-Concept scale (3 items each for flexibility, coordination, strength, speed and endurance).	Adults aged 18–28[70] Test–retest reliability: ICC=0.73–0.87 Internal consistency: α=0.79–92
Ability to swim and cycle	Four questions*	4–17 years	Ability to swim and cycle and if so, at what age they learnt to swim or cycle (up to four items).	
Accidents in school	Adapted from KiGGS[71]	School children	Two items asking if and where an accident or injury happened at school that was treated by a physician.	
Academic achievement	Adapted from KiGGS	School children	Three items asking about the last report card grades in maths, German and physical education.	
Strengths and difficulties	SDQ-Deu[72 73]	4–10 years: parental version; 11–17 years: self-report version	The German versions of the Strengths and Difficulties Questionnaire (parent version for children aged 4–10 years; self-report for participants aged 11 and older) consist of 25 items: internalising problems (emotional and peer symptoms, 10 items), externalising problems (conduct and hyperactivity symptoms, 10 items) and the prosocial scale (5 items).	Children aged 11–17 years[72] Internal consistency: α=0.77 Test–retest reliability: ICC=0.66 Construct validity: (χ^2/df=5.12, df=265, CFI=0.82, TLI=0.79, RMSEA=0.05
Tracking of PA	Single-item question*	4–17 years	One question about the frequency of using devices/apps to track PA	
Social support	German social support scale[74]	4–17 years; different version for employed adolescents/school leavers	The two subscales from the German social support scale were used: parental support (5 items) and peer support (3 items). For employed adolescents/school leavers, the wording of the items was adjusted to fit the context: support from family (6 items) and support from acquaintances/friends (6 items).	Children aged 9–17 years[74] Parental support: Test–retest reliability: ICC=0.83 Peer support: Test–retest reliability: ICC=0.67 Construct validity: χ^2=40.50; df=19; p<0.01; RMSEA=0.05, CFI=0.98 Predictive validity: r=0.22–0.31
Home and neighbourhood environment	ALPHA environmental questionnaire (3 subscales)[75]	4–17 years	Three subscales from the German version of the European environmental questionnaire ALPHA were used: safety from crime and traffic (6 items), aesthetics (4 items) and home environment (6 items). The wording of the home environment items was adjusted to fit the context of children and adolescents.	Adults[75] Safety: Test-retest reliability: ICC=0.71 Internal consistency: α=0.72 Aesthetics: Test–retest reliability: ICC=0.44 Internal consistency: α=0.31 Home environment: Test–retest reliability: ICC=0.71 Internal consistency: α=0.13
Socioeconomic status†	KiGGS socioeconomic status[76]	4–17 years (parents preferred)	The socioeconomic status scale consists of school and vocational education (4 items) and occupation (4 items) of both parents as well as household size (3 items) and household net income (2 items).	

Continued

Table 5 Continued

Construct	Instrument	Target group	Description	Reliability and validity
Household composition†	KiGGS personal details questionnaire (developed by RKI)	4–17 years (parents preferred)	One item asking about which people are living in the household (eg, parents, grandparents, other relatives) and one specifically asking about siblings in the household (eg, older/younger brother/sisters).	
Migration background†	KiGGS migration background[77]	4–17 years (parents preferred)	Migration background of both parents, the year when they moved to Germany and what language is spoken at home (four items)	
Subjective social status†	McArthur Scale[78 79]	4–17 years	One item measure of the MacArthur Scale of Subjective Social Status scale assessing the subjective socioeconomic status based on a ladder with 10 steps.	Children aged 14.4±1.6 years[78] Test–retest reliability: ICC=0.73
Cultural capital†	Single-item question[80]	4–17 years (parents preferred)	One item asking the number of books at home as an indicator of cultural capital.	
Economic capital†	2 selected KIDSCREEN27-items[57]	4–17 years	Two items from the KIDSCREEN27 questionnaire assess having enough money to do the same things as friends and having enough money for expenses as an indicator of (socio)economic capital.	
Home ownership†	Single-item question*	4–17 years (parents preferred)	Two items about the living situation (house/flat) and owning/renting the place.	

*Items were developed independently.
†These constructs are assessed in the health interview.
ALPHA, Instruments for Assessing Levels of Physical Activity and fitness; CFI, comparative fit index; ICC, intraclass correlation coefficient; KiGGS, German Health Interview and Examination Survey for Children and Adolescents; MoMo 2.0, Motorik Monitoring 2.0; PACES-S, Physical Activity Enjoyment Scale–short version; PSK, Physical Self-Concept; RKI, Robert-Koch Institute; RMSEA, root mean square error of approximation; SDQ-Deu, Strengths and Difficulties Questionnaire–German version; TLI, Tucker-Lewis Index.

the quality of life and health of children, adolescents and young adults in Germany.

The 'Let's move Kids–Kinder bewegen' congress in Karlsruhe is a particularly noteworthy communication format. In 2025—the last year of the MoMo 2.0 project funding—the results of the project will be presented to a large group of national and international multipliers and stakeholders (>300 participants from the fields of education, medicine/health and sport). Experts and representatives of various (professional) organisations (eg, Federal Centre for Health Education, German Gymnastics Association, Paediatric Sports Medicine, German Obesity Society) will analyse the results of the MoMo 2.0-Study and discuss further consequences. Materials such as flyers, factsheets and infographics will be used to disseminate the results of the project and the symposium through thematic networks established in previous projects as well as through schools and healthcare providers.

DISCUSSION

Physical inactivity has been described for years by the WHO (2020)[2] as the 'lifestyle pandemic of the 21st century'. The WHO (2010)[45] recommends that children and adolescents should be physically active for at least 60 min every day. However, less than one in 25 children and adolescents in Germany meet these recommendations based on accelerometer data.[46] Therefore, continuous monitoring is needed to guide policy efforts in PA and health promotion.

The MoMo 2.0-Study is an independent continuation of the four national MoMo cohorts, which started over 20 years ago. With its nationally representative sample of children and adolescents aged 4–17 years, it will provide an important database combining PA, motor performance, and physical and psychological health data for Germany, for example, to regularly grade the activity level in this age group in the German Report Card for Physical Activity within the Active Healthy Kids Alliance,[43] for international comparisons like the European fitness landscape.[31]

In the history of MoMo, there have been several historical milestones that have shaped society and the status of PA and (public) health (eg, introduction of smartphones and the refugee crisis). The medium-term to long-term impact of the COVID-19 pandemic on the motor performance of children and adolescents is widely discussed. However, current data in Germany are limited to a specific age group (eg, third graders)[47] or a single community,[48] with mixed results showing an increase in some strength tests and no change or a decrease in cardiovascular fitness,

coordination and speed. As PA is beneficial not only for the physical but also mental health it is an important health resource that should be monitored, especially since the COVID-19 pandemic led to a declining mental health status among children and adolescents.[49–51] The MoMo 2.0-Study can provide new, nationwide data across age groups with established cohorts before the COVID-19 pandemic. Especially in times of multiple crises (eg, climate crisis, war in Ukraine) and megatrends (connectivity, sustainability, etc), it is important to understand the development of PA, motor performance and health in the context of those challenges that impact this and future generations.

At the same time, advances in science and technology have led to the development of new methods for assessing physical behaviour, motor performance and health. In recent years, the use of 24-hour accelerometry to assess not only PA and sedentary behaviour but also sleep has opened up a whole new area of research.[52] Another area of research that has gained much interest recently is the linking of PA and health data with (neighbourhood) environmental data through geographic information systems.[53]

The MoMo 2.0-Study, therefore, aims on the one hand to capture these historical changes as accurately as possible by maintaining established methods, and on the other hand to incorporate technical (eg, 24 hours accelerometry), methodological (eg, digital input devices) and contextual (eg, data linking) innovations to produce novel scientific results and to guide policy.

Strengths and limitations

Comprehensive, representative and current data for children and adolescents on PA, motor performance, health and their determinants build the main strength of the MoMo 2.0-Study. In addition, longitudinal data needed to analyse individual developmental trajectories before, during and after the pandemic are provided by a continuation of the MoMo COVID-19 online surveys. However, this data set does not contain any on-site measurements—for obvious reasons.

The longitudinal participants have been participating for more than 20 years and are now between 24 and 38 years old. The size of the realised sample has diminished considerably and may be biased by selective dropout. The new cohort of an estimated 4500 children and adolescents drawn in the MoMo 2.0-Study follows a comparable strategy as the predecessor study. Thus, time trend analyses for more than 20 years will be possible.

Its on-site assessment of motor performance and body composition and health interviews, in terms of age range and range of different tests, is unique for Europe, creating a powerful dataset of health-related fitness measures. The MoMo 2.0-Study adapts new technologies and measures of PA and motor performance while retaining some core measures to be compatible with previous cohorts.

Although comprehensive cross-sectional data allow precise monitoring of age cohorts at a certain time of measurement, they are informative regarding time trends only if the time between measurements is relatively short. On the individual level, MoMo 2.0-Study is hardly able to detect causal relations; there are no experimental designs implemented (lack of control conditions, lack of interventions). Finally, the questionnaires and interviews of MoMo 2.0-Study are again conducted in German language only. Therefore, participants and/or their parents or legal guardians who do not understand German cannot be included in this study. Despite these limitations, the MoMo 2.0-Study will create a wide range of possible and reliable databases and analyses in a highly relevant health-related field of research: PA and motor performance of children and adolescents.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

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