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Predictive value of physical fitness on self-rated health: A longitudinal study

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Background: The self-rated health of adolescents and young adults is important for estimating future morbidities and mortality. Little is known about how physical fitness in younger populations predicts self-rated health. This longitudinal study (2003-2017) aims to explore the effects of physical fitness on self-rated health on the basis of the German population–based study KiGGS and its in-depth study, MoMo.

Methods: Self-rated health was assessed using a one-item scale, and physical fitness was measured with seven test items covering the dimensions of coordination, muscular fitness, and cardiorespiratory fitness. Longitudinal analyses were conducted using the structural equation modeling approach in Mplus 8.0 using the maximum likelihood estimator.

Results: The longitudinal samples of the KiGGS/MoMo study (T1, n = 2376; T2, n = 2821; and T3, n = 2047) had a mean age of 8.5, 14.8, and 20.0 years at T1, T2, and T3, respectively. All measurement and structural models had excellent model fits. While the results of the latent regression analysis indicated moderate-to-high stability for the coordination and muscular fitness dimensions, only low-to-moderate stability coefficients were found for cardiorespiratory fitness and self-rated health. Furthermore, small significant cross-lagged regression coefficients revealed that coordination and muscular fitness predicted self-rated health at later measurement points.

Conclusion: To the best of our knowledge, this is the first longitudinal study to demonstrate the positive predictive value of two dimensions of physical fitness, co-ordination and muscular fitness, on self-rated health at a later stage. The public health implications are highlighted.

KEYWORDS
cardiorespiratory endurance, coordination, generic, longitudinal, motor performance, muscular fitness, physical activity, well-being

1 | INTRODUCTION

In the literature, physical fitness is recognized as an integrated measure of nearly all body functions that are needed to perform physical activity in everyday situations as well as in sports.[1] An age-appropriate state of physical fitness is a necessary condition for children and adolescents to acquire basic motor competencies and a wide variety of gross and fine motor skills.[2,3] From a developmental perspective, these basic and specific competencies promote a healthy physically active lifestyle across childhood and adolescence.[4]

Caspersen and colleagues described physical fitness as "a set of attributes that people have or achieve" consisting of different motor dimensions.[5] There exist slightly different approaches regarding the main components of physical fitness and dimensionality of the construct.[5-9] The systematization by Bös overlaps with the concepts of physical fitness by Caspersen et al[5] and Bouchard and Shephard[9] with five distinguishable main dimensions: (cardiorespiratory) endurance, (muscular) strength, speed, coordination, and flexibility.[10]

Physical fitness, as described in the aforementioned concepts, can be understood as a marker of health.[4,11-13] The World Health Organization (WHO) stated in the Ottawa Charta in 1986[14] that health is a positive concept, emphasizing social and personal resources. Assessing health from a resource-oriented perspective has gained importance in the literature over the last few decades, as it adds valuable information. One of the most common measures to describe the overall health status is asking individuals to self-rate their health by one single question, "How is your health in general?" Self-reported health incorporates physical, social, and psychological dimensions that are not available to external observers as well as providing the dynamics, by integrating changes throughout the past.[15]

There is great consensus in the literature that self-rated health is an indicator of overall health status.[16,17] Even in young populations, self-rated health is linked to mortality and used to estimate the risks of future morbidities.[18,19] Evidence regarding the influence of self-rated health is rare and deserves more attention.[15] The predominant cross-sectional results suggest an association between self-rated health and physical fitness. There is a lack of longitudinal studies regarding whether an individual's physical fitness predicts the self-rated health at a later stage. This could contribute to policy decisions to improve the health of children and adolescents.

Based on the longitudinal data (2003-2017) of the German population–based KiGGS and MoMo studies, this paper seeks to examine whether physical fitness, including the dimensions of cardiovascular endurance, muscular fitness, and coordination, predicts self-rated health in adolescents and young adults.

2 | METHODS

2.1 | Background of the study

The MoMo study (MoMo, standing for Motorik-Modul) is a long-term study providing nationwide representative data of physical fitness and activity in children and adolescents in Germany. MoMo is an in-depth study of the German Health Interview and Examination Survey for Children and Adolescents ("KiGGS study"), the first nationwide health survey conducted by the Robert Koch-Institute in Berlin,[20] which focuses on health monitoring.

The KiGGS study started in 2003 and included a core survey, with MoMo as one of five modular in-depth studies with KiGGS subsamples. The KiGGS/MoMo participants were randomly selected from local population registries in 167 sample points all over Germany, using a stratified multistage probability sampling strategy.[20] The sample points adequately represent the structure of federal states and municipalities of the Federal Republic of Germany. The children and adolescents first participated in KiGGS and afterward in the MoMo study. Three measurement waves have already been completed (MoMo T1: 2003-2006; MoMo T2: 2009-2012; MoMo T3: 2014-2017). MoMo has a cohort-sequence study design with a cross-sectional and longitudinal study arm. The MoMo participants, parents, and custodians were contacted individually, and were invited to examination rooms near their homes at one of the 167 sample points. Qualified test leaders accompanied the participants individually throughout the tests. Further details of the MoMo study have been described elsewhere.[21]

This study focuses only on longitudinal results. Within the longitudinal study arm, the same participants from T1 and subsequent measurements were tested repeatedly.

2.2 | Self-rated health (SRH)

As mentioned above, self-rated health was assessed using a one-item scale ("How is your health in general?") offered with a 5-point response scale (1 = "very good", 2 = "good", 3 = "fair", 4 = "poor", or 5 = "very poor"). The children, adolescents, or young adults filled out the question themselves, which was part of a health questionnaire. The question wording met the recommendations of the WHO.[22] Since low numbers on the self-rated health scale indicate good health, we expected negative correlations and regression parameters between indicators of physical fitness and self-rated health. In this study, no parent proxy versions were analyzed. The self-rated health within our study was available from the age of 11 years onwards.

2.3 | Physical fitness (PF)

The construct of physical fitness in this study was measured using tests of the MoMo test profile,[21] which were based on the systematization by Bös.[8,10] MoMo tests originated from common validated test batteries. These test items were pre-tested, discussed with experts, optimized, and documented in a detailed test manual.[23] In the discussions with experts and the validation study, the MoMo test profile demonstrated to be valid, objective, and sufficiently informative. Results of different test leaders correlated highly ($r = .98$-$.99$). The overall test-retest reliability with a time period of four days in between the tests was good ($r = .97$) and no statistical difference was found between T1 and T2. In the present study, we included all available tests for the dimensions "coordination," "muscular fitness," and "cardiovascular endurance." This means we selected seven of the original twelve tests[23] because of the relevance for health and because they could be transmitted into percentiles. "Coordination" was assessed by a sideways jumping test under time constraints as well as under precision pressure by assessing the ability to balance backwards, with balance measured by means of a static stand. "Muscular fitness" was determined by standing long jumps, pushups, and sit-ups. "Cardiorespiratory endurance" was measured by an ergometric test assessing the physical working capacity 170 (PWC170, attained watts at 170 beats/min) with the test protocol of the WHO.[23] For each of these seven physical fitness tests, age- and gender-specific percentile curves were calculated using the LMS transformation method.[24] Therefore, a comparison, independent of age and gender, was possible within the longitudinal study over the period of 2003-2017. A percentile value refers to the percentage of persons in the age- and gender-specific reference population with the same or lower performance. Thus, a percentile value of 1 represents the lowest performance, whereas a percentile value of 99 reflects the best performance.[24]

2.4 | Study sample

The analyzed longitudinal MoMo samples consisted of 2376 children and adolescents at T1, 2821 at T2, and 2047 at T3. There were some missing data, which can be attributed either to the study design or particularities of the variables as described hereafter. The measurement of self-rated health requires the capability to reflect one's own health status. The variable was available in individuals $\geq$ 11 years old, because children younger than 11 years are not capable of answering this question in a reliable manner due to their current status of self-perception. This explains the unfavorable coverage of this variable at T1 (23%). However, the coverage of all other variables at all three measurement points was considered good with 63%-99% at T1, 76%-95% at T2, and 73%-97% at T3. Due to developmental reasons, the test items of pushups, sit-ups, and PWC170 were available in individuals $\geq$ 11 years old. Sit-ups were introduced in T2, which explains the missing data at T1.

2.5 | Statistical analysis

Descriptive and correlational statistical analyses were performed using SPSS 24 (IBM). The level of significance was set at 0.05. Longitudinal analyses were conducted using the structural equation modeling (SEM) approach in Mplus 8.0[25] using the maximum likelihood estimator. As model fit indices, the comparative fit index (CFI) and root mean square error of approximation (RMSEA) are reported, in addition to the χ^2 value. For the RMSEA, values ≤ 0.05 reflect a good fit, and values between 0.05 and 0.08 reflect an adequate fit. For CFI, values ≥ 0.90 are considered a satisfactory fit, whereas values > 0.95 suggest an excellent fit.[26] Missing data were taken into account during the model estimation as a default option in Mplus.

As suggested in the literature,[27] in the first step, separate measurement models for coordination and muscular fitness were established with one separate latent factor for each time stage. In the second step, separate cross-lagged SEMs were estimated for the three different dimensions of physical fitness. Using complex latent regression models, this approach allowed us to model the development of different dimensions of physical fitness over time as well as the prediction of self-rated health by the different dimensions of physical fitness. We did not include age and gender as control variables in the SEMs because of the usage of age- and gender-specific percentiles for the physical fitness tasks.

We illustrate the structure of these models using an example of coordination. Coordination at T3 is predicted by the coordination performance at T2, which in turn is explained by the coordination performance at T1. Similarly, self-rated health is explained by the previous self-rated health reported at T2, which is again predicted by the self-rated health at T1. These regression coefficients refer to the stability of a particular latent construct. Within each time stage, we postulated correlations between coordination and self-rated health. In order to model the prediction of self-rated health by coordination, we included additional cross-lagged regression coefficients from T1 coordination to T2 self-rated health and from T2 coordination to T3 self-rated health. These cross-lagged regression coefficients refer to the prediction of self-rated health by coordination performance at the previous time stage, after controlling for previously reported health. In other words, it represents the prediction of reported changes in self-rated health from T1 to T2 and T2 to T3 by the coordination performance at the previous time stage. For the sake of model completeness,

the reverse cross-lagged regression coefficients were also analyzed (the prediction of the change in coordination performance by self-rated health).

2.6 | Ethical standards and data protection

The MoMo study was performed according to the ethical standards in the Declaration of Helsinki (1964). The MoMo study was approved by the ethics committees of Konstanz University and the Karlsruhe Institute of Technology. The Federal Commissioner for the data protection and freedom of information was informed about the study and approved it.

3 | RESULTS

3.1 | Sample

Longitudinal MoMo samples (T1, n = 2376; T2, n = 2821; and T3, n = 2047) had a mean age (±standard deviation [SD]) of 8.5 ± 3.7 years at T1, 14.8 ± 3.8 years at T2, and 20.0 ± 3.9 years at T3. Obviously, the samples differed in age, and the 95% confidence intervals (CIs) did not overlap. The mean age difference between samples in T1 and T2 was 6.3 years, and T2 and T3 was 5.2 years. A description of the study sample characteristics is given in Table 1.

3.2 | Indicators of physical fitness

The descriptive statistics for the tasks that represent physical fitness in the SEMs at the three measurement points are presented in Table 2. By comparing the 95% CIs of the age- and gender-related percentile points, no differences in the physical fitness tasks between T1 and T2 and T2 and T3 were obvious. The comparisons of T1 and T3 values indicated one difference over time. Within the dimension of coordination, the age- and gender-related percentile points of the "standing long jump" at T3 were significantly lower than at T1 as the

95% CIs did not overlap, and the mean difference was assumed to be around 6.4 percentile points.

Table S1 in the electronic supplement summarizes the correlations between all analyzed variables of physical fitness and self-rated health at the three measurement points (T1, T2, and T3).

3.3 | Measurement models for coordination and muscular fitness

The model fits for coordination ($\chi^2 = 29.89$; $df = 12$; $P = .003$; CFI = 0.996; RMSEA = 0.022) and muscular fitness ($\chi^2 = 14.72$; $df = 9$; $P = .10$; CFI = 0.999; RMSEA = 0.015) were excellent. The loadings on the particular latent factors were significant and varied between 0.47 and 0.71 for coordination and 0.55-0.76 for muscular fitness. The measurement models included some theoretically meaningful residual covariances such as between the tasks of (a) "static stand" and "balancing backwards" for coordination, and (b) "pushups" and 'sit-ups' for muscular fitness. In addition, as typically done in longitudinal SEM analysis, residual correlations between the same tasks at different measurement points were part of the model.

3.4 | Longitudinal prediction of coordination, muscular fitness, cardiorespiratory fitness, and self-rated health

The model fits of all three cross-lagged SEMs were excellent; (a) coordination (Figure 1): $\chi^2 = 69.27$; $df = 34$; $P < .001$; CFI = 0.993; RMSEA = 0.019; (b) muscular fitness (Figure 2): $\chi^2 = 66.92$; $df = 28$; $P < .001$; CFI = 0.992; RMSEA = 0.022; and (c) cardiorespiratory fitness: $\chi^2 = 6.53$; $df = 3$; $P = .09$; CFI = 0.995; RMSEA = 0.020. The main results of the cross-lagged analyses are presented in a simplified manner in Figures 1, 2, 3.

While the latent dimensions of physical fitness coordination and muscular fitness seem to be relatively stable over time (regression coefficients range, 0.57-0.83), only

TABLE 1 Characteristics of the study samples (T1, T2, and T3)

Sample characteristics	Study sample T1 (2003-2006)	Study sample T2 (2009-2012)	Study sample T3 (2014-2017)
n	2,376	2,821	2,047
Age; M ± SD	8.5 ± 3.7	14.8 ± 3.8	20.0 ± 3.9
Age; Min, Max	4.0, 17.9	10.0, 25.1	14.9, 31.7
Age; 95% CI	8.3-8.7	14.6-15.0	19.9-20.2
Male (%)	Female (%)	48	52	48	52	48	52

Note: Data are either the mean values (M) ± standard deviation (SD), minimum (Min), maximum (Max), and 95% CI = confidence interval or percent (%).

Dimension of physical fitness	Study sample T1 (2003-2006)	Study sample T2 (2009-2012)	Study sample T3 (2014-2017)
Coordination			
Jumping sideways	39.5 ± 27.2 [33.5-45.6] n = 2342	48.9 ± 27.7 [42.8-55.1] n = 2685	49.4 ± 26.1 [43.6-55.2] n = 1718
Balancing backwards	41.9 ± 31.7 [34.9-48.9] n = 2364	52.5 ± 30.5 [45.8-59.3] n = 2706	51.3 ± 32.20 [44.2-58.4] n = 1719
Static stand	60.3 ± 36.7 [52.2-68.4] n = 2332	74.7 ± 30.3 [67.9-81.5] n = 2706	70.4 ± 36.0 [62.4-78.4] n = 1734
Muscular fitness			
Standing long jump	56.7 ± 27.8 [50.5-62.8] n = 2364	45.6 ± 26.3 [39.8-51.4] n = 2681	40.3 ± 29.4 [33.8-46.8] n = 1719
Pushups	52.9 ± 28.7 [46.6-59.3] n = 1713	48.4 ± 29.7 [41.8-54.9] n = 2639	47.2 ± 28.0 [41.0-53.4] n = 1705
Sit-ups	not available T1	46.8 ± 30.0 [40.1-53.4] n = 2644	43.1 ± 28.6 [36.7-49.4] n = 1720
Cardiorespiratory endurance			
PWC170	49.1 ± 28.2 [42.9-55.4] n = 1503	51.8 ± 31.0 [45.0-58.7] n = 2149	61.3 ± 29.1 [54.9-67.7] n = 1487
Self-rated health	1.8 ± 0.5 [1.7-1.9] n = 570	1.7 ± 0.6 [1.5-1.8] n = 2000	1.8 ± 0.6 [1.7-1.9] n = 1987

TABLE 2 Descriptive results of physical fitness and self-rated health (T1, T2, and T3)

Note: Data are the mean values (M) of the percentiles ± standard deviation (SD) and [95% CI = confidence interval]. A percentile value of 1 indicates the worst percentile whereas a percentile value of 99 reflects the best percentile (background information in Niessner et al (2020)[24]). Self-rated health: 1 = "very good", 2 = "good", 3 = "fair", 4 = "poor", or 5 = "very poor"). PWC: physical working capacity.

low-to-moderate stability coefficients were found for both cardiorespiratory fitness (range, 0.33-0.45) and self-reported health (range, 0.23-0.27). Within the measurement points, we found small but statistically significant correlations between self-rated health and coordination and muscular fitness. As expected, these correlations were negative and ranged from −0.11 to −0.16. Unexpectedly, for cardiorespiratory fitness, significant corresponding correlations were only found at T2 ($r = -.11$). As expected, the cross-lagged regression coefficients from coordination and muscular fitness to self-rated health were statistically significant. Although the effect size was rather small (range, 0.09-0.13), these results indicate that these dimensions of physical fitness can predict the changes in self-rated health over time. Contrary to our expectations, no significant cross-lagged coefficients were shown for cardiorespiratory fitness. Finally, the reverse cross-lagged regression coefficients from self-rated health to different dimensions of physical fitness were not significant.

4 | DISCUSSION

In line with the literature,[28] most adolescents and young adults participating in this study reported a good or very good overall health status at all three measurement points. Self-rated health descriptively showed stable mean values: All analyzed 95% CIs of self-rated health in T1, T2, and T3 overlapped. Interestingly, within the structure equation model, the stability of self-rated health varied between 0.23 and 0.27 and was not very pronounced with a lot of individual change between T1, T2, and T3. This highlights the importance of analyzing the change of self-rated health at the individual level like it is done within the model and not exclusively at the group level because the changes disappeared at the group level.

As expected from the literature,[29] the descriptive analysis of the seven tests of the MoMo test profile over time on group level showed relatively stable physical fitness performances across the measurement points. All 95% CIs between T1, T2,
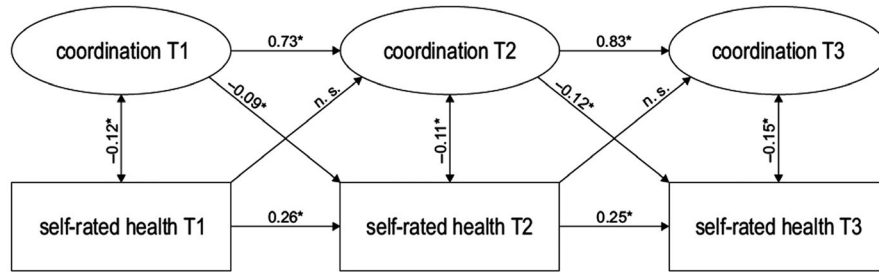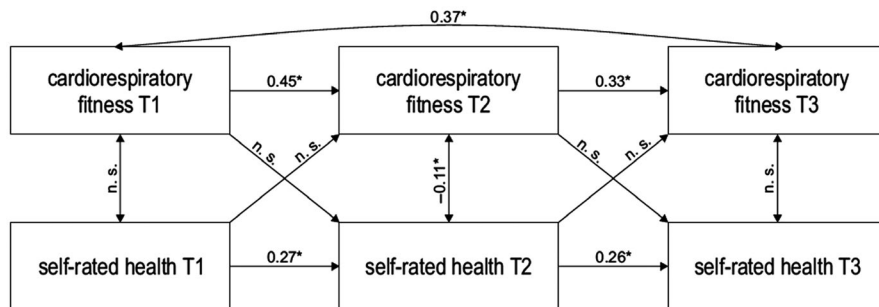
FIGURE 1 Cross-lagged structural equation modeling (SEM) for coordination ($\chi^2 = 69.27$; $df = 34$; $P < .001$; CFI = 0.993; RMSEA = 0.019). Abbreviations: T1, 2003-2006; T, 2009-2012; T3, 2014-2017. In this cross-lagged SEM, the regression coefficients between coordination at consecutive timepoints refer to the stability of the coordination performance over time. Within each time stage, we postulated correlations between coordination and self-rated health. To model the prediction of self-rated health by coordination, additional cross-lagged regression coefficients from coordination to self-rated health at consecutive timepoints were included. They represent the prediction of the reported change in self-rated health by the coordination performance at the previous time stage. For the sake of model completeness, the reverse cross-lagged regression coefficients were also analyzed, that is, the prediction of the change in coordination performance by self-rated health at the previous time stage
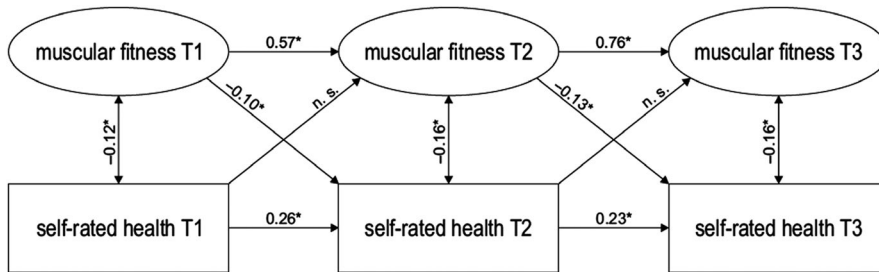
FIGURE 2 Cross-lagged structural equation modeling (SEM) for muscular fitness ($\chi^2 = 66.92$; $df = 28$; $P < .001$; CFI = 0.992; RMSEA = 0.022). Abbreviations: T1, 2003-2006; T, 2009-2012; T3, 2014-2017. In this cross-lagged SEM, the regression coefficients between muscular fitness at consecutive timepoints refer to the stability of muscular fitness over time. Within each time stage, we postulated correlations between muscular fitness and self-rated health. To model the prediction of self-rated health by muscular fitness, additional cross-lagged regression coefficients from muscular fitness to self-rated health at consecutive timepoints were included. They represent the prediction of the reported change in self-rated health by the muscular fitness at the previous time stage. For the sake of model completeness, the reverse cross-lagged regression coefficients were also analyzed, that is, the prediction of the change in muscular fitness by self-rated health at the previous time stage

FIGURE 3 Cross-lagged structural equation modeling (SEM) for cardiorespiratory fitness ($\chi^2 = 6.53$; $df = 3$; $P = .09$; CFI = 0.995; RMSEA = 0.020). Abbreviations: T1, 2003-2006; T, 2009-2012; T3, 2014-2017. In this cross-lagged SEM, the regression coefficients between cardiorespiratory fitness at consecutive timepoints refer to the stability of the cardiorespiratory fitness over time. Within each time stage, we postulated correlations between cardiorespiratory fitness and self-rated health. To model the prediction of self-rated health by cardiorespiratory fitness, additional cross-lagged regression coefficients from cardiorespiratory fitness to self-rated health at consecutive timepoints were included. They represent the prediction of the reported change in self-rated health by the cardiorespiratory fitness at the previous time stage. For the sake of model completeness, the reverse cross-lagged regression coefficients were also analyzed, that is, the prediction of the change in cardiorespiratory fitness by self-rated health at the previous time stage

and T3 overlapped with only one exception ("standing long jump" between T1 and T3) (Table 2).

Within the structure equation model, this stability was further confirmed in the dimensions of coordination (0.73 and 0.83) and muscular fitness (0.57 and 0.76) for T1 and T2 and T2 and T3, respectively. One hypothesis why coordination appears a little more stable over time than muscular fitness (Figures 1 and 2) is that it is stronger linked to appropriate physical fitness training within the time period before the test. Maybe coordinative performances are less time sensitive. Further research is needed to a better understanding of the effects of training and time; most of findings about the stability of physical fitness across the life span are rather old[30] and refer to single tests and not to dimensions of physical fitness. The stability of the dimension cardiorespiratory fitness in contrast to coordination and muscular fitness was not as pronounced (0.45 and 0.33, respectively). The findings on dimensions support previous findings on task-specific changes in physical fitness.[31,32]

As already stated, the relationship between physical fitness and self-rated health in a young population is rarely studied, and existing studies with objectively measured physical fitness are cross-sectional. In a cross-sectional study with male participants only, Häkkinen and colleagues[33] found differences in self-rated health between individuals with poor, satisfactory, and good physical fitness measured as an index including cardiorespiratory and muscular fitness (N = 727). In a cross-sectional study with male and female adolescents, Kantomaa et al[15] showed that high levels of cardiorespiratory fitness were associated with very good self-rated health. A cross-sectional study[34] also demonstrated associations between cardiorespiratory fitness in children and adolescents of both genders and self-rated health. Among all dimensions of physical fitness, cardiorespiratory fitness is the most intense and prominently discussed as highly health relevant. In adults, cardiorespiratory fitness is associated more strongly with all-cause mortality than physical activity.[35] Therefore, improving cardiorespiratory fitness should be encouraged in unfit individuals to reduce the risk of mortality.

In this study with a younger population, we were neither able to confirm the above-described cross-sectional associations nor detect the longitudinal effect of cardiorespiratory fitness on self-rated health. However, it cannot be ruled out that this can be explained by measurement issues. The assessment of cardiorespiratory fitness in this study was performed with a submaximal PWC 170 ergometer test. When the maximum of the respiratory and cardiovascular capacity was not reached, comparisons and predictions may not have enough informative value. During exhaustive exercise, children and adolescents easily reach a heart rate of over 200 beats per minute as observed in a study of 433 young athletes (mean age, 14 years) who showed average maximal heart rates of 197 ± 9 beats per minute.[36] Contrary to this are the findings of Kantomaa et al,[15] who also worked with a submaximal ergometer test; however, it must be noted that those participants were already 16 years old, which is 7.5 and 1.2 years older than the participants in the current study at T1 and T2, respectively. A study by Padilla-Moledo and colleagues[37] also indicated a positive association only in adolescents. However, the comparability of the few existing studies is limited. Some studies dichotomized self-rated health, which also reduces comparability. This study suggests that the self-rated health of children and adolescents can be positively influenced by coordination and muscular fitness. Targeted interventions of sufficient frequency and intensity have been demonstrated to affect coordination performance and muscular fitness.[1,13]

The major strengths of this study lie in the large population-based sample, long study period (2003-2017), and comprehensive and objective measurement of physical fitness. Because of the longitudinal design of this study, "the chicken-and-egg question" is answered as reverse causality can be excluded.

5 | PERSPECTIVE

To the best of our knowledge, this is the first longitudinal study to demonstrate the positive predictive value of two dimensions of physical fitness, coordination, and muscular fitness, on self-rated health at a later stage in a population-based all-gender study sample. From a public health perspective, it is important to increase the likelihood of all children and adolescents to become physically fit in order to improve their long-term health. Therefore, children and adolescents with reduced physical fitness should be detected early. Special programs to enhance their physical fitness levels may prevent future diseases in adulthood. This study provides longitudinal scientific evidence on the relevance of physical fitness for future health in a younger population. In this way, the findings support existing public health messages and may help public health activists, politicians, scientists, and stakeholders to justify public health action and cooperate more closely.

CONFLICT OF INTEREST
The authors declare no conflict of interest, financial, or otherwise.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.