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Effect of lifestyle interventions on cognitive function, physical fitness and activity over 2 years in primary school children: results from the fit4future intervention programme

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ABSTRACT

Objectives Physical activity is associated with positive health effects and improved cognitive function in children. However, these data are primarily based on cross-sectional studies. We investigated changes in cognitive function, physical fitness and physical activity in children following a school-based intervention.

Methods The 'fit4future' study is a prospective, interventional, long-term study conducted in Germany to evaluate the impact of a comprehensive school-based health promotion programme in children. The aims of the programme have been to increase the amount of physical activity, to support a healthy diet and to improve attention and concentration performance as well as coping strategies. Schools received equipment to support physical activity, for example, action cards, brochures as well as online materials containing information regarding physical activity, nutrition, cognitive function and stress management. Teachers were trained in six workshops to enable them to promote a systematic health promotion process at schools. Parents received brochures about healthy lifestyles with practical advice for everyday family life. Additional information was provided on the programme's homepage. At the beginning of the second and the end of the third grade, children completed a differential performance test (Concentrated Task) for the assessment of concentration and attention in which they had to cross predetermined pictorial symbols on preprinted test sheets (average marked signs). Changes in the average marked signs were investigated and compared with age-specific and sex-specific norms. Physical fitness and activity were assessed using a six-item fitness test and questionnaire.

Results A total of 839 children (mean age 7.5±0.6 years, 48% girls) from 32 schools participated in this study. Over 2 years, average marked signs increased from 91.6±20.7 to 138.0±27.6 ($p<0.001$) (n=553 children, mean age 7.5±0.6 years, 51% girls). This improvement was greater than expected compared with the age-specific and sex-specific norms. The children showed significant improvements in all fitness test items and a significant increase in physical activity ($p<0.001$). Age, baseline average marked signs and changes in the jump-and-reach test were associated with changes in cognitive function (regression coefficient $\beta=0.95$, SE=0.23, $p<0.001$).

Conclusion A school-based health promotion programme improved cognitive function, physical activity and physical fitness beyond the age-related improvements expected over 2 years in a large cohort of primary school children.

Trial registration number German Clinical Trials Register (DRKS-ID: DRKS00020894, Date of registration: 2020-02-26).

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Physical activity has positive effects on children's health and cognitive function.
⇒ Longitudinal data assessing changes in cognitive function, physical fitness and physical activity in primary school children following school-based interventions are scarce.

WHAT THIS STUDY ADDS

⇒ This study demonstrated improvements in cognitive function, physical fitness and physical activity in primary school children using a school-based intervention.
⇒ Improvements in cognitive performance were greater than the expected age-specific and sex-specific norms.
⇒ Age, baseline cognitive function and changes in jump-and-reach test scores were associated with changes in cognitive function.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Physical activity is associated with positive health effects and improved cognitive function in children. Strategies to promote physical activity, fitness and cognitive function that can be easily integrated into school are crucial for children's health and can positively impact their cognitive performance.

BACKGROUND

Physical activity is effective in reducing the risk of chronic diseases in children and adolescents, with positive effects on the cardiovascular system,[1] muscular-skeletal development[2] and obesity.[3] Therefore, the current guidelines of the WHO recommend that children and adolescents aged 5–17 years should engage in moderate-to-vigorous intensity physical activity for ≥60 min per day.[4]

In addition to its health benefits, physical activity has been associated with improved cognitive and academic performance in children and adolescents aged 5–18 years. Systematic reviews, such as those by Singh *et al* and Donnelly *et al*, highlight positive associations between physical activity, fitness levels and academic outcomes. Singh *et al* observed in both observational and interventional studies involving over 12 000 children (6–18 years) that physical activity enhances academic performance.[5] Similarly, Donnelly *et al* reviewed more than 60 studies on students aged 5–13 years, reporting that higher physical fitness and regular physical activity were associated with better cognitive function and academic achievements compared with peers who did not achieve comparable fitness levels or engage in regular physical activity.[6] In recent years, numerous educational institutions have implemented interventions to enhance children's physical activity levels and maximise associated health and cognitive advantages. For example, the Fitness Improves Thinking in Kids (FIT Kids) programme uses structured after-school activities to investigate the effect of a physical activity intervention on brain and behavioural indices of executive control in children and indicates an improvement in executive control which supports the important role of physical activity for children's cognition.[7] However, its exclusion from standard academic curricula limits its accessibility, scalability and potential for widespread adoption. To reach more children and achieve greater scalability, such programmes must be integrated into everyday school life wherever possible. Overall, it was found that most studies on the relationship between physical activity, fitness and cognition are cross-sectional and that the results of school-based interventions are inconsistent due to significant variations in the content and duration of these interventions.[6] Therefore, this study aimed to investigate changes in cognitive function, physical fitness and physical activity over 2 years in children during a school-based intervention.

METHODS

Study design and participants

'fit4future' is a large school-based intervention programme throughout Germany with over 2000 schools aiming to improve the health behaviour of primary school children by increasing physical activity, promoting balanced eating behaviours and teaching stress management strategies. The programme was planned according to the social cognitive theory.[8] In addition, within the school-based setting, a health-promoting school framework taking into account the recommendations of the WHO[9] was established to sustainably strengthen the health of children and teachers. Around 30% of the participating schools stated that they were located in social hotspots.

In this prospective interventional long-term 'fit4future' study, the cognitive function and physical activity of primary school children from 32 schools were examined between 2017 and 2019. In addition, in 16 of these schools, the development of physical fitness in children was assessed using a six-item fitness test battery over the same period.

The study protocol was registered in the German Clinical Trials Register (DRKS-ID: DRKS00020894) and can be found online in online supplemental file 3. All children participated in the intervention; however, only data from children whose parents and/or legal guardians provided written informed consent were included in the analysis. No changes in the trial design were made after ethics approval. Participants or the public were not involved in the design, conduct, reporting or dissemination plans of our research.

Interventions

A healthy lifestyle in children was promoted in the areas: physical activity, nutrition, brain fitness and stress management. Schools received play equipment to increase children's physical activity, as well as action cards comprising information regarding topics of physical activity, healthy eating, brain fitness and coping with stress, to strengthen the health behaviour of the children. Two teachers of each participating school (fit4future-coaches) were trained in six workshops and received three brochures with background information and practical tips. This information was intended to be passed on to other teachers at their school to support children's health behaviour. The sustainability of the school-based approach was supported by a systematic health-promotion process in schools in which the fit4future coaches formed a project team with colleagues to plan and organise the various health-supporting measures at school (https://www.fit-4-future.de/). In addition, parents received three brochures with background information and practical tips to support the healthy behaviour of their children and maintain a healthy everyday life in their families. Online supplemental table 2 summarises an overview of the fit4future project intervention content.

Examinations

In Germany, children generally start school at the age of 6–7 years (first grade in primary school). In this study, the intervention started at the beginning of the second grade and all children underwent evaluations at the beginning of the second grade (visit 1) and at the end of the third grade (visit 2).

Assessment of cognitive function

To assess attention and concentration in primary school children, a Differential Performance Concentration Task Test-KG [DL-KG]) developed by Kleber[10] was used. The DL-KG is based on a figure-strikethrough or

Table 1 Changes in cognitive function over 2 years

		All			Boys			Girls		
	N (boys/girls)	**Visit 1**	**Visit 2**	**P value**	**Visit 1**	**Visit 2**	**P value**	**Visit 1**	**Visit 2**	**P value**
Quantitative cognitive performance parameters										
Average marked signs	553* (269/283)	91.6±20.7	138.0±27.6	**<0.001**	90.7±20.6	135.6±26.3	**<0.001**	92.5±20.7	140.2±28.6	**<0.001**
Interval min	552* (269/282)	69.7±22.3	115.7±29.3	**<0.001**	68.6±22.9	113.3±28.2	**<0.001**	70.7±21.7	117.9±30.2	**<0.001**
Interval max	552* (269/283)	112.6±23.2	159.1±28.7	**<0.001**	111.7±23.5	157.5±27.9	**<0.001**	113.4±23.0	160.6±29.6	**<0.001**
Fluctuation rate	553* (269/283)	4.9±2.3	3.3±1.7	**<0.001**	5.0±2.3	3.4±1.7	**<0.001**	4.8±2.3	3.3±1.7	**<0.001**
Qualitative cognitive performance parameters										
Error type 1	553* (269/283)	4.2±10.5	3.0±7.3	**0.002**	4.1±10.8	3.6±8.4	0.597	4.3±10.4	2.5±6.2	**<0.001**
		2.0 (0.0–5.0)	1.0 (0.0–3.0)		2.0 (1.0–5.0)	2.0 (0.0–4.0)		2.0 (0.0–4.0)	1.0 (0.0–2.0)	
Error type 2	553* (269/283)	12.0±33.2	5.3±10.5	**<0.001**	14.6±41.2	6.7±12.9	**0.019**	9.6±23.0	4.0±7.5	**<0.001**
		2.0 (1.0–10.0)	1.0 (0.0–6.0)		3.0 (1.0–10.0)	1.0 (0.0–8.0)		2.0 (1.0–9.0)	0.0 (0.0–4.0)	

Data are presented as mean±SD and median (IQR); min=minimum, max=maximum, Fluctuation rate=range of variation (relative to the number of all processed intervals), error type 1=predetermined pictorial (relevant symbols) symbols that were erroneously not crossed out; error type 2=irrelevant symbols that were not marked with a dot; visit 1=at the beginning of the second grade; visit 2=at the end of the third grade.
Bold p values indicate significance (p<0.05).
*In one case, information regarding sex was missing.

symbol-strikethrough test designed to measure performance in tasks requiring sustained concentration in children aged 7–10 years. The children had to cross predetermined pictorial symbols on preprinted test sheets. Other irrelevant symbols were marked with a dot. At the end of each test interval, the test instructor gave a signal and the last symbol was circled. Tests were conducted at 10 test intervals of 90 s each.

Quantitative cognitive performance was analysed using the following parameters. The average marked signs were defined as the sum of the total signs that the children marked in the total of 10 test intervals of 90 s divided by 10 according to Kleber.[10] The maximum and minimum number of signs marked in a given time interval were measured. Subsequently, the fluctuation rate (the minimum number of signs calculated relative to the number of processed intervals subtracted from the maximum number of signs) was evaluated.

In contrast to other cognition tests, the DL-KG also assessed qualitative concentration performance using error types 1 and 2, which were defined as predetermined pictorial icons (relevant symbols) that were erroneously not crossed out and irrelevant symbols that were not marked with a dot, respectively.

Physical fitness assessment

Physical fitness was assessed using a six-item fitness test battery consisting of shuttle run, trunk bend, jump and reach, single-leg stand, target throwing and medicine ball push tests[11–14] (online supplemental table 1). The tests were conducted in sports halls at schools by trained staff (area managers) and teachers.

Assessment of physical activity

A short, non-validated, paper-based questionnaire was used to examine the children's physical activity. Physical activity in the last week and a normal week was analysed by the number of days the children were physically active for at least 60 min per day.[15]

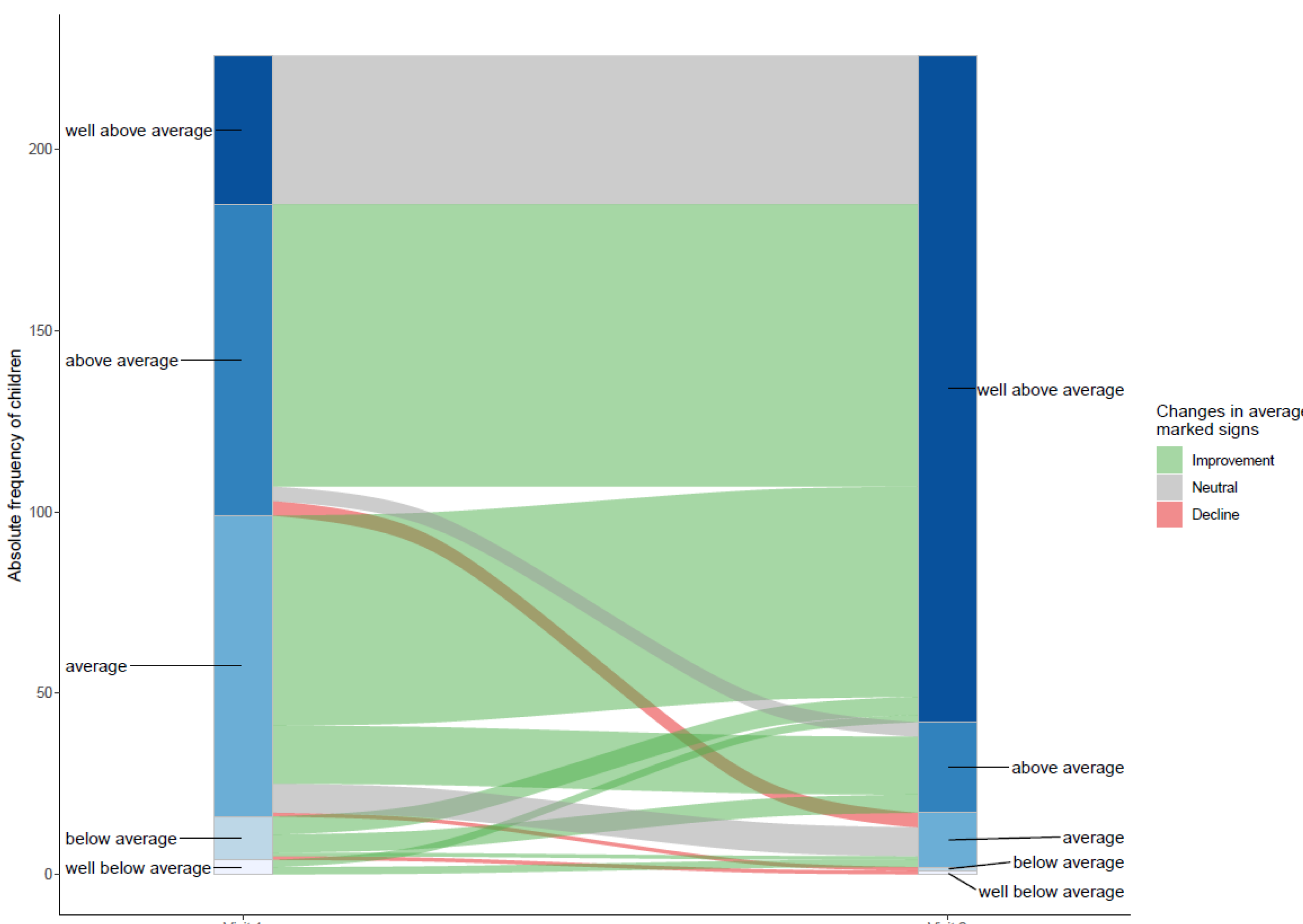

Figure 1 Changes in cognitive function in comparison to age-specific and sex-specific norms (n=482). To assess the improvement in cognitive performance, the children's achieved values were assigned to the categories from the norm values from 'well below average' to 'well above average'; between visits 1 and 2, 68% of children improved (green), 29% of children remained unchanged (grey) and 3% of children declined (red) (p<0.001); visit 1=at the beginning of the second grade; visit 2=at the end of the third grade.

Table 2 Changes in physical fitness over 2 years

	N (boys/girls)	All Visit 1	All Visit 2	All P value	Boys Visit 1	Boys Visit 2	Boys P value	Girls Visit 1	Girls Visit 2	Girls P value
Shuttle run (sec)	459* (226/231)	24.2±2.9	21.3±2.6	**<0.001**	23.5±2.9	20.8±2.8	**<0.001**	24.8±2.8	21.9±2.4	**<0.001**
		24.0 (22.2–25.7)	21.0 (19.5–23.0)		23.3 (21.2–25.0)	20.5 (19.0–22.3)		24.4 (22.8–26.3)	21.8 (20.0–23.4)	
Trunk bend (cm)	461* (228/231)	−1.2±6.6	0.0±7.1	**<0.001**	−2.5±6.1	−2.4±6.5	0.630	0.3±6.8	2.5±6.8	**<0.001**
		−1.0 (−6.0–4.0)	0.0 (−6.0–5.0)		−2.0 (−7.0–2.0)	−3.0 (−8.0–3.0)		0.0 (−5.0–5.0)	3.0 (−2.0–8.0)	
Jump and reach (cm)	460* (227/231)	21.3±4.6	23.7±5.1	**<0.001**	21.8±4.6	24.2±5.0	**<0.001**	20.8±4.6	23.1±5.2	**<0.001**
		21.0 (18.0–25.0)	24.0 (20.0–27.0)		22.0 (19.0–25.0)	24.0 (21.0–27.0)		21.0 (18.0–24.0)	23.0 (20.0–26.0)	
Single leg stand (number of contacts)	453* (223/228)	6.7±6.1	4.0±4.4	**<0.001**	7.6±6.3	4.7±4.6	**<0.001**	6.0±5.8	3.3±4.2	**<0.001**
		5.0 (2.0–11.0)	3.0 (1.0–6.0)		6.0 (2.0–11.0)	3.0 (1.0–7.0)		4.5 (1.0–9.0)	2.0 (0.0–5.0)	
Target throw (points)	461* (228/231)	8.8±4.3	12.3±4.1	**<0.001**	10.4±4.3	13.7±4.1	**<0.001**	7.3±3.6	10.8±3.6	**<0.001**
		9.0 (6.0–12.0)	12.0 (9.0–15.0)		10.0 (7.0–13.0)	14.0 (11.0–17.0)		7.0 (5.0–10.0)	11.0 (9.0–13.0)	
Medicine ball push (cm)	429* (218/209)	331.3±77.8	422.9±79.9	**<0.001**	362.8±72.7	450.3±82.1	**<0.001**	298.0±68.8	394.7±67.2	**<0.001**
		330.0 (280.0–380.0)	410.0 (370.0–470.0)		360.0 (320.0–410.0)	440.0 (390.0–500.0)		295.0 (250.0–344.3)	390.0 (340.0–430.0)	

Data are presented as mean±SD and median (IQR); sec=seconds; cm=centimetre; visit 1=at the beginning of the second grade; visit 2=at the end of the third grade.
Bold p values indicate significance (p<0.05).
*In some cases, information regarding sex was missing.

Statistical analysis

Data were analysed using SPSS V.25 (IBM, Armonk, New York, USA), and graphs were visualised using R software V.4.1.0 (R Foundation for Statistical Computing, Vienna, Austria). Normally distributed data are presented as mean and SD, whereas data with skewed distributions are presented as median and IQR. Paired t-tests were used to evaluate mean changes in cognitive function, physical fitness and physical activity between visits 1 and 2 for normally distributed data; otherwise, Wilcoxon signed-rank tests were used. Sex-specific differences in the changes in cognitive function and physical fitness were analysed using unpaired t-tests. When information regarding sex was missing, sex-specific analyses included a slightly smaller number of children than the total cohort.

In a subsequent analysis, the results of cognitive function and physical fitness tests were compared with age-specific and sex-specific norms. The average marked signs values of the children were multiplied by a factor of 1.4 (10 instead of 14 test intervals were used in our tests), and at both visits, the resulting cognitive performance score of the children was assigned to five categories ranging from 'well above average' to 'well below average' in comparison with the age-specific and sex-specific norms reported by Kleber.[10] A sign test was used to compare the results with respect to age-specific and sex-specific norms.

The absolute results of the six fitness test items were compared with age-specific and sex-specific norms in Germany[11–14] to assess changes in physical fitness in study participants beyond the improvements expected due to development-related changes, in an exploratory manner.

To identify the predictors of cognitive function, data were fitted to a hierarchical multivariable linear regression model to analyse the association between sex, age at

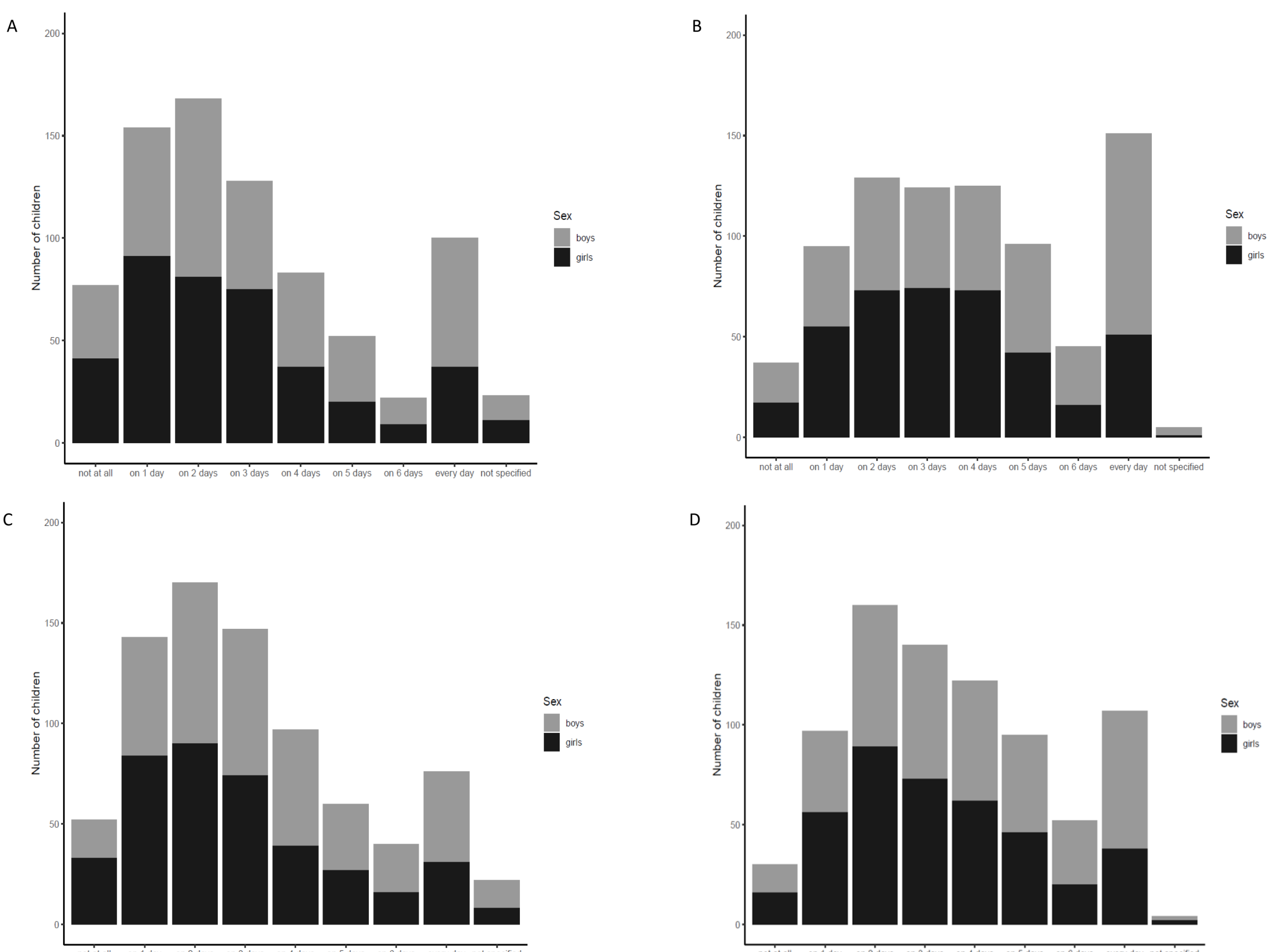

Figure 2 Changes in physical activity over 2 years. (A) The number of days with >60 min of physical activity in the last week at visit 1; (B) the number of days with >60 min of physical activity in the last week at visit 2; (C) the number of days with >60 min of physical activity in a normal week at visit 1; (D) the number of days with >60 min of physical activity in a normal week at visit 2. In some cases, information regarding sex was missing; therefore, sex-specific analyses have slightly less number of children compared with the total cohort. Data from n=807 children were analysed; visit 1=at the beginning of the second grade; visit 2=at the end of the third grade.

Table 3 Predictors of cognitive performance (n=261)

Model	Regressions coefficient β	SE	P value
Model 1 (R^2=0.053)			
Constant	93.39	15.52	<0.001
Average marked signs V1	−0.16	0.05	0.003
Sex	−0.20	2.29	0.929
Age V1	−4.43	1.99	0.027
Model 2 (R^2=0.143)			
Constant	85.58	15.24	<0.001
Average marked signs V1	−0.15	0.05	0.004
Sex	−0.76	2.29	0.739
Age V1	−3.85	1.93	0.047
Δ Shuttle run test V1 to V2	−0.23	0.38	0.543
Δ Trunk bend V1 to V2	0.25	0.21	0.225
Δ Jump and reach V1 to V2	0.95	0.23	<0.001
Δ Single leg stand V1 to V2	0.19	0.21	0.350
Δ Target throw V1 to V2	−0.04	0.22	0.860
Δ Medicine ball push V1 to V2	−0.00	−0.01	0.819

V1, visit 1; V2, visit 2. Δ=Difference between visits 2 and 1; visit 1=at the beginning of the second grade; visit 2=at the end of the third grade.

visit 1, cognitive function (average marked signs at visit 1) and changes in the six fitness test parameters over 2 years. No imputation methods were used to replace missing values. For all analyses, a significance level of p<0.05 was used.

RESULTS

Participants

At visit 1, a cognitive function assessment was conducted for 839 children (mean age 7.5±0.6 years, 48% girls) from 32 schools; at visit 2, 663 children participated in the assessment. In total, data from 553 children (mean age 7.5±0.6 years; 51% girls) over 2 years were analysed. Data from the physical fitness battery for 461 children over 2 years were analysed. The health behaviour questionnaire was completed by 813 children from 32 schools (visit 1, n=981; visit 2, n=847) over 2 years. Children who were not at school on the day of the examination or who had not completed the documents correctly were excluded from the analysis (online supplemental figure 1).

Changes in cognitive function over 2 years

Analyses of cognitive function (n=553) showed significant improvements in quantitative and qualitative cognitive performance parameters over 2 years. Regarding quantitative parameters, significant improvements between visits 1 and 2 were observed in terms of an increase in average marked signs and a reduction in the fluctuation rate (p<0.001 for both). In addition, the average number of errors of types 1 and 2 decreased significantly over the 2 years (p=0.002; p<0.001). Both boys (n=269) and girls (n=283) showed significant improvements in cognitive function between visits 1 and 2 (table 1), without sex-specific differences (p>0.05).

Changes in cognitive function in comparison with age-specific and sex-specific norms

In a subsequent analysis, we compared the results of the children with age-specific and sex-specific norms.[10] We observed a significant improvement (55%) in the total number of children categorised as 'well above average' (dark blue bar) between visits 1 and 2 (p<0.001, n=482; figure 1); this trend was maintained for both girls (p<0.001, n=256) and boys (p<0.001, n=226).

Changes in physical fitness over 2 years

The physical fitness of the children (n=461) over 2 years showed significant improvements in all parameters (p<0.001) (table 2). Both boys (n=228) and girls (n=231) showed significant improvements in all six parameters (p<0.001), except for trunk bending (boys: p=0.639; girls: p<0.001) (table 2).

Changes in physical fitness in comparison with age-specific and sex-specific norms

Regarding the shuttle run test, children were significantly faster after 2 years. Comparison with age-specific and sex-specific norms was not possible because of the unavailability of relevant norms data for this age group. In trunk bending, boys showed preservation of stretching ability, in contrast to the developmentally expected decline[12]; girls were in the 'above average' category at both visits. In girls, improvements in the jump-and-reach test over the course of the project largely corresponded with the developmentally expected increase. In boys, the absolute improvement was somewhat lower than that expected owing to developmental factors.[14] In the single-leg stand test, the average number of ground contacts decreased for both girls and boys between visits 1 and 2, and the boys' balance ability changed from 'well above average' at visit 1 to 'above average' at visit 2; the girls were in the 'well above average' category at both visits.[12] In target throwing, the baseline values of boys and girls were 'below average,' and girls achieved an increase in throwing accuracy over 2 years, from 'below average' to reaching 'average' performance.[11] In medicine ball pushing, the boys achieved 'below average' values after 2 years of the project compared with the 'average' throwing distance at the beginning of the project, despite a clear improvement in their absolute throwing distance. At both visits, girls were in the 'average' category compared with the norms, despite a clear improvement in absolute performance over the course of the project.[11]

Changes in physical activity over 2 years

We observed a significant increase in physical activity over 2 years. At baseline, 22% of children reported being physically active for at least 60 min on more than 5 days/week in the last week, compared with 36% after 2 years (p<0.001). In a normal week, 22% of the children reported being physically active for more than 5 days/week at visit 1 and 32% after 2 years (p<0.001). Significant improvements in physical activity were observed in boys (n=405) and girls (n=402) in the last week and in the normal week (p<0.001 for both groups) (figure 2).

Predictors of cognitive performance

Multivariable linear regression model 1 included average marked signs at visit 1, sex and age at visit 1 (R^2=0.053, F(257)=4.758, p=0.003) and showed that between visits 1 and 2, children who were older at the baseline showed less improvement in cognitive function than those who were younger at the baseline (regression coefficient β=−4.4, SE=2.0, p=0.027). Additionally, children who had a better cognitive function at baseline showed less improvement during the intervention period than those who had a lower cognitive function at baseline (regression coefficient β=−0.15, SE=0.053, p=0.003). The model explained 5% of the variance in the outcome variables. Sex was not significantly associated with the changes in cognitive function (table 3). Model 2 included average marked signs at visit 1, sex, age at visit 1 and changes in the shuttle run, trunk bend, jump and reach, single-leg stand, target throw and medicine ball push tests (R^2=0.143, F(251)=4.639, p<0.001) and showed that age at visit 1, average marked signs at visit 1 and changes in the jump and reach test were significantly associated with changes in cognitive function (regression coefficient β=0.95, SE=0.23, p<0.001), while other variables were not significantly associated with cognitive function. The model explained 14% of the variance in the outcome variables (table 3).

DISCUSSION

This prospective long-term ‘fit4future’ study showed significant improvements in cognitive function, physical fitness and an increase in physical activity over 2 years in a large cohort of primary school children following a school-based intervention compared with expected norms.

Improvement in cognitive function and physical fitness

We observed significant improvements in concentration performance compared with age-specific and sex-specific norms in Germany, consistent with the findings of previous studies. In a randomised controlled trial comprising a physical activity group performing 90 min/week of physically active academic lessons with moderate-to-vigorous intensity (n=814) and a control group without intervention (n=713), significant beneficial effects of physical activity on academic achievements were observed.[16]

Furthermore, herein, a decrease in the fluctuation rate was observed, reflecting a more uniform and concentrated performance. Qualitative cognitive performance, as revealed by a decrease in the average number of errors of types 1 and 2, improved significantly over the 2 years. Notably, the strikethrough test applied herein assessed both the quantity and quality of cognitive performance, which are important factors for educational success at school.[17]

Over 2 years, the children showed significant improvements in absolute values in all dimensions of the six-item fitness test battery. A comparison of age-specific and sex-specific norms showed improvements in certain aspects, such as trunk bending, which were higher than the developmentally-expected changes. In other tests, the children achieved significant improvements in absolute values, which were in line with the expected age-related changes or slightly lower, especially in boys. We compared the children’s absolute values with age-specific and sex-specific norms for 8-year-olds at visit 1 and 10-year-olds at visit 2. Since the actual test interval in our study was closer to 1.5 years, the children were younger than the age for which the norms were used in the second test. Thus, the actual increase in physical fitness may be higher than that observed. In a longitudinal cohort study (n=240 children, 9–12 years), changes in a six-item test battery (50 m sprint, ball push, triple-hop, stand and reach, star agility run and 9 min run) were analysed over 4 years, and an increase in all motor-related performance was observed, except for flexibility in boys.[18] In the German ‘MoMo’ study (n=4529 children, aged 4–17 years), all parameters (endurance, strength, coordination and flexibility) increased until the onset of puberty.[19] In a systematic review comprising 98 studies on children and adolescents aged 9–17 years (2 779 165 Eurofit test performance data), sex-related differences in physical performance were observed.[20] Therein, 78% of boys and 83% of girls met the healthy cardiorespiratory fitness norms, with percentages decreasing with age. Boys outperformed girls in muscular, speed-agility and cardiorespiratory fitness tests but scored lower in flexibility tests. Overall, physical fitness improved faster in boys than in girls and increased with age.

Improvements in physical activity

We observed an increase in daily physical activity of children from 22% to 36% over 2 years. The increase in the proportion of children who were physically active for more than 60 min at least 5 days per week may indicate positive changes following the school-based intervention, as other studies have reported a decrease in regular physical activity among primary school children.[21] A systematic review of 52 studies including 22 091 children and adolescents aged 3–18 years found that the average moderate-to-vigorous physical activity is often below the current WHO recommendation of 60 min per day. Moreover, the authors observed an average decline in physical activity of −3.4 min, 95% CI (−4.6 to −2.2), with a decline of −3.4% (95% CI −5.9 to −0.9) in boys and −5.3% (95% CI −7.6 to −3.1) in girls, across all age groups after 1 year.[22] These results emphasise the need for effective strategies to address the decline in physical activity among children and adolescents. In this context, promoting physical activity using a setting-based approach is essential as children spend most of their time at school.

Predictors of cognitive function

Herein, we demonstrated improvements in cognitive function, physical fitness and physical activity over 2 years. However, we did not observe a clear association between cognitive function and physical fitness in our multivariate linear regression models. Age and cognitive function at baseline and changes in jump-and-reach test scores were associated with changes in cognitive function. However, our model had low prognostic accuracy.

Clinical implication

Physical activity is associated with positive health effects and improved cognitive function in children. Strategies to promote physical activity, fitness and cognitive function that can be easily integrated into school are crucial for children's health and can positively impact their cognitive performance.

Limitations

This study has several limitations. As the main objective of the school-based initiative was the nationwide implementation of the programme in over 2000 schools, we did not include a control group. While this limits the ability to draw definitive causal conclusions, we addressed this by comparing our findings to established normative values, which provide a meaningful context for interpreting the observed changes. Furthermore, data collection was conducted by independent personnel (area managers) throughout Germany, which might have led to bias in the results based on different test teams. However, we attempted to minimise this by regularly training area managers and developing standard operating procedures.

CONCLUSION

Cognitive function, physical fitness and physical activity improved over 2 years in primary school children following a school-based intervention. Improvements in cognitive performance were greater than the expected age-specific and sex-specific norms. An increase in physical activity was also an important finding of our study, as a decline in physical activity in this age group has been reported in previous studies. These observations indicate the positive effects of the school-based intervention.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval This study involves human participants and was approved by the local ethics committee of Technical University of Munich, TUM University Hospital, Germany (approval reference number 478/16 S). The parents or legal guardians of all participating children provided written informed consent prior to the start of the study.

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