Research Square

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A school-integrated physical exercise program improves motor performance of children and adolescents

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Abstract

Purpose: Children's sedentary time has increased in recent years, especially during school, while daily physical activity has decreased. The lack of physical activity can contribute to a deterioration in motor performance, which is key to a healthy development. We implemented a comprehensive exercise program in the school setting. Our study aimed to evaluate this program by assessing changes in motor skills after one year and to compare these changes to children who did not participate.

Methods: A total of 357 children from 5 schools were included in this observational longitudinal cohort study. Motor skills were assessed using the German Motor Test 6-18. Children were either assigned to the exercise group (EG) or waiting group (WG). The EG participated in the physical activity program for one year. Of those, a total of 303 children (EG n=183; WG n=120) completed motor tests at baseline and follow-up one year later, and comprise the study population. Linear mixed modeling was used to calculate corrected means and analyze for inter-group differences of change in motor skills after one year between the groups, and to determine the effect of sex, age group and weight category on the change in motor skills.

Results: After one year of additional physical activity, the EG improved significantly more strongly in 6 out of 8 motor skill tests than the WG. After the adjustment for sex, age, and BMI the improvement is still significantly stronger in the EG in 4 of 8 motor skill tests (sprint, side jumps, both p=0.017; stand and reach, p=0.012; ergometry, p=<0.001), when compared to the WG. Girls improved more strongly in the sit-ups than boys, 2nd graders more than 5th graders in the backwards balance and the ergometry, non-overweight pupils more in the standing long jump than overweight children.

Conclusions: Participating in the exercise program for one year positively influenced motor skill development in schoolchildren. Our data suggest that girls were not disadvantaged, and even improved more than boys in the sit-ups, and that overweight pupils profited as much as their non-overweight peers in all categories but one. The exercise program, simple and easily implemented into the school routine, is effective in increasing motor skills and physical fitness.

What Is Known

- Children and adolescents do not exercise sufficiently, which negatively affects overall health and physical capability
- Between 1975 and 2002, motor performance of German children and adolescents decreased by 10% until the turn of the century and seem to have stabilized for Germany as well as internationally.

What is new:

- We present an exercise program tailored to children and adolescents, integrated into the school setting that effectively increases daily physical activity.
- Participating in this program for a year significantly improves motor skills.

Introduction

Children and adolescents do not exercise sufficiently. The target level of 60min physical activity per day, recommended by the World Health Organization (WHO) [42], is only reached by 13.1% of the girls and 17.4% of the boys aged 3–17 years in Germany. This goal is less likely to be reached with increasing age [27].

Lack of physical activity negatively affects overall health and physical capability in children [11, 26, 29, 51, 73]. Overweight children and adolescents exercise less than normal-weight children, which can be both cause and consequence of overweight [13, 20, 60, 63].

Sedentary time is associated with poorer motor coordination [35] and has increased for children and adolescents, especially during school [3, 24]. In parallel, motor performance is low [21]. Between 1975 and 2002, motor performance of German children and adolescents decreased by 10% [9]. This decrease was shown to be more pronounced in the 12- to 17-year-olds with 12.5% when compared to the 6- to 11-year-olds with 5.5% [8]. This downward trend persisted until the turn of the century and seems to have stabilized for Germany [1] as well as internationally [66].

It is vital to boost this development in order to achieve an increase in children's motor skills and physical fitness, as these are key to healthy and appropriate development [5, 21, 32, 62] and are associated with an higher health-related quality of life [52]. Motor performance is inversely correlated with overweight and obesity and positively correlated with bone density and bone mass in childhood and adolescents [10, 61, 67]. Low motor performance in childhood is associated with an increased risk of cardiovascular disease in adulthood [2, 30].

Since health in adulthood depends on health in childhood and adolescence [15–17], health interventions are most meaningful at an early age. Sixty percent of European children, who are overweight before puberty, become overweight in early adulthood and likely develop a non-communicable disease (diabetes or cardiovascular disease) at a younger age [46]. In addition, social disadvantage is associated with poorer motor performance [28, 39, 43, 48]. A school-based program represents an especially suitable inclusive framework to target children regardless of socioeconomic factors or their affinity to sport.

The aim of our study was to develop and implement a comprehensive exercise program tailored to children and adolescents that can be easily integrated into the school setting which promotes physical activity and improves motor skills. We further aimed to evaluate this program with children from two different age groups by assessing changes in motor skills after one year and to compare these changes to children who did not participate.

Methods

Study design

The 2nd grade classes of three elementary and the 5th grade classes of two secondary schools which had been randomly chosen, were investigated in this observational longitudinal cohort study. The baseline examination was performed between April and June 2017 (v0), the follow-up examination one year afterwards (v1). After completing v0, classes were assigned to the exercise program (i.e., the exercise group, EG) or to wait for one year before starting with the exercise program (i.e., the waiting group, WG).

Motor tests

The German Motor Test 6–18 (Deutscher Motorik-Test 6–18, DMT 6–18) was chosen to comprehensively assess motor skills. It is an established tool to assess motor skills in children, recommended by the German Society of Sport Science [7]. Action-speed was assessed through a 20m sprint, Coordination in precision-tasks by backwards balancing, Coordination under time pressure with side jumps, Flexibility of the trunk and sciatocrural muscle group through the stand and reach test, Endurance-strength of the upper extremities and trunk muscles with push-ups, Endurance-strength of the torso with sit-ups, and Lower extremity jumping power with Standing long jump Maximum endurance capacity via bicycle ergometry according to a modified Godfrey protocol [18], with maximum Watt per kg bodyweight (W/kg) as the endpoint. The workload was increased in 15 Watt steps at 1-min intervals. All subjects were encouraged to exercise

until exhaustion (breathlessness and leg muscle pain and/or a heart rate ≥ 85% of maximum (calculated 220 – age in years) [31].

Exercise Program

The exercise program was comprised of several modules. These were designed to be primarily conducted by teachers, and were accompanied by sports scientists who visited every class on two days every week.

The main module were the exercise impulses, where pupils performed a 5-minute exercise in every lesson, coordinated by the teachers. Exercises were adapted from literature [6, 41, 44], and were specifically designed to be suitable and fun for children, to take a maximum of 5 minutes and to be easily performed in the classroom. They represent four different categories (strength, endurance, coordination and relaxation), with at least 15 different exercises for every category. Since speed and flexibility were an aspect in almost all exercises, they were not assigned separate groups. Most of the exercises was related to a school subject to facilitate integration into the classroom (e.g., “math jogging” where pupils jump and squat depending on the result of the calculation). EG classes were provided with a box of index cards (see Fig. S1 for examples) describing every exercise. Teachers received detailed instructions by uniformly trained sports scientists on how to perform these exercises correctly and to use all four categories evenly. Teachers were asked to document each exercise impulse, representing five minutes of activity.

In addition, the following modules were provided once per week, under instructions from a sports scientist. A 15–20 minute early morning exercise module was offered before the first lesson. Additionally, a 15 minute exercise module was provided during the great break and a 45 minute module after school, or before afternoon classes for the secondary school. Once per week, an afternoon module of 45 minutes was organized for every class.

Lastly, teachers and pupils from the EG received general information on the benefits of daily physical activity before the start of the program.

Anthropometric Measurements

Body height and body weight were measured according to Dippelhofer et al. [14] and used to calculate the body mass index (BMI). BMI was normalized for age and sex, using WHO normative data [69] and expressed as z-scores, with a z-score of 0.0 representing the 50th percentile. Pupils were grouped according to BMI into non-overweight (defined as BMI < 85th percentile, i.e. z-score < 1.036) or overweight (defined as BMI ≥ 85th percentile, i.e. z-score ≥ 1.036) [4].

Statistical analysis

All calculations were performed using Statistical Analysis Software Enterprise Guide 7.1 (Cary, North Carolina, USA). Categorical variables are given as frequencies and percentage, continuous variables as mean and standard deviation. The change in motor test results (calculated as the Delta (Δ) of the result of v1 – v0) were the primary endpoints. For the univariate analyses at baseline, the two-sided t-test was used for continuous variables, and the χ^2-test for categorical variables. For the univariate analysis of the change in the motor tests, paired t-test was used within-group comparisons, and the non-paired two-sided t-test for the between-group comparison. Then, linear regression modeling was utilized to calculate corrected means for the primary endpoint adjusted (for age, sex and BMI), differentiated by the WG and EG group category. For the analysis of interdependent factors, we calculated a separate linear regression model for every endpoint, with the group category and interaction terms between (i) the group category and sex, (ii) the group category and age group, and (iii) the group category and BMI category, as covariates. A p-value of < 0.05 was considered significant.

Results

Study population

Out of a total of 598 pupils that were invited, 357 children (n = 205 for 2nd grade, n = 152 for 5th grade) agreed to participate and were included in the study. The whole cohort of 357 pupils is described in detail [40]. Out of these, 303 pupils completed one or more of the motor skill tests at both time points v0 and v1 and comprise the study population for this study (EG n = 183; WG n = 120; Fig. S2). Baseline characteristics are given in Table 1. At baseline, there were no significant differences between the EG and the WG in terms of gender, age, weight, height, or BMI.

Table 1
Baseline characteristics of the Exercise Group and Waiting Group

	WG		EG		p
	Mean ± SD or number (%)	n	Mean ± SD or number (%)	n	
Sex (m/f)	68/52	120	94/89	183	0.366
Age (years)	9.7 ± 1.7	120	9.4 ± 1.6	183	0.141
Height (cm)	140.4 ± 12.1	119	138.8 ± 10.9	183	0.223
Weight (kg)	37.4 ± 12.4	119	35.3 ± 11.5	183	0.129
BMI z-score	0.40 ± 1.07	119	0.22 ± 1.15	183	0.178
Overweight pupils	32 (27%)	119	48 (26%)	183	0.899
Sprint (sec)	4.5 ± 0.5	109	4.6 ± 0.5	173	0.196
Backwards Balance (steps)	29.4 ± 9.5	102	28.9 ± 10.4	159	0.709
Side Jumps (repetitions)	26.9 ± 5.7	108	25.3 ± 7.8	164	0.056
Stand and reach (cm)	-1.1 ± 6.3	97	-0.5 ± 7.5	144	0.472
Push-ups (repetitions)	12.1 ± 3.3	103	13.2 ± 3.9	152	**0.026**
Sit-ups (repetitions)	19.3 ± 6.0	112	18.6 ± 6.2	169	0.405
Standing long jump (cm)	128.1 ± 21.9	112	127.7 ± 26.0	170	0.895
Ergometry (W/kg)	3.1 ± 0.7	117	3.1 ± 0.7	178	0.671

Abbreviations: EG, exercise group; SD, standard deviation; WG, waiting group. P-values < 0.05 are bolded.

Motor skills at baseline

At baseline there were no significant differences in the motor skills between the WG and the EG with the exception of the push-ups, where the EG achieved more repetitions (WG 12.1 ± 3.3 repetitions, EG 13.2 ± 3.9 repetitions, p = 0.026; Table 1). Boys performed better in the sprint, stand and reach, sit-ups, standing long jumps and ergometry than girls,

with no difference for the backwards balance, side jumps, and push-ups (Table S1). Fifth graders were better in the sprint, side jumps, and standing long jump, 2nd graders were better in the stand and reach test (Table S2). When compared to the overweight, non-overweight pupils performed better in all tests except for the stand and reach test, where no significant difference could be seen between the two groups (Table S3).

Physical activity due to the exercise program

Participation in the movement impulses during lessons was documented by the teachers. Based on these documentations, an average of 24 minutes and 34 minutes of additional exercise per day due to participation in the total exercise program could be achieved for the 2nd and 5th graders, respectively. Regular curricular physical education classes that were available to both EG and WG alike were not included in this calculation.

Within-group change in motor skills after one year

When looking at within-group changes after one year, the EG showed significant improvements in all motor skill test items. The WG revealed significant improvement for the sprint, backwards balance, side jumps, push-ups, and the standing long jump, but not in the stand and reach, sit-ups or ergometry (Table 2).

Between-group change in motor skills after one year

The unadjusted between-group analysis of the change after one year showed that EG pupils improved significantly more strongly in the sprint, backwards balance, side jumps, stand and reach, sit-ups, and ergometry, than the WG pupils (Table 2).

After adjusting for sex, age, and BMI, the EG still exhibited a significantly stronger improvement in the sprint, side jumps (both $p = 0.017$), stand and reach ($p = 0.012$) and ergometry ($p < 0.001$); with a tendency for backwards balance and sit-ups ($p = 0.056$ and $p = 0.053$, respectively; Fig. 1).

Interdependent factors associated with the change in motor skills

In order to analyze whether the exercise program affected pupils differently according to their sex, age group, or BMI category, separate linear regression models were calculated for each endpoint, with the change in the motor skill test item as the dependent variable, and interaction terms between group category and sex, group category and age group, or group category and BMI category, as covariates. The complete models are given in Table S4 a-h. Table 3 summarizes the results of these separate models. WG boys increased the number of push-ups more than WG girls, EG girls expanded the number of sit-ups more greatly than EG boys. Second grade WG pupils improved significantly more strongly than 5th grade WG pupils in the sprint and push-ups, 2nd grade EG pupils significantly more strongly than EG 5th graders in the backwards balance, push-ups and ergometry. When considering the BMI category, non-overweight EG children improved the standing long jump more robustly than overweight EG children.

Table 2
Within- and between-group analysis of change in motor skills after one year

	WG			EG			
	Change from baseline (v1-v0)			Change from baseline (v1-v0)			p *
	Mean ± SD	n	p	Mean ± SD	n	p	
Sprint (sec)	-0.2 ± 0.5	104	**< 0.001**	-0.3 ± 0.4	169	**< 0.001**	**0.023**
Backwards Balance (steps)	3.4 ± 8.5	96	**< 0.001**	5.9 ± 9.0	155	**< 0.001**	**0.031**
Side Jumps (repetitions)	3.5 ± 6.0	102	**< 0.001**	5.3 ± 5.7	155	**< 0.001**	**0.016**
Stand and reach (cm)	-0.6 ± 5.1	93	0.268	1.2 ± 5.3	138	**0.008**	**0.012**
Push-ups (repetitions)	2.6 ± 3.9	97	**< 0.001**	3.1 ± 4.0	143	**< 0.001**	0.277
Sit-ups (repetitions)	0.6 ± 5.2	105	0.217	2.0 ± 5.4	160	**< 0.001**	**0.047**
Standing long jump (cm)	9.4 ± 15.2	106	**< 0.001**	9.2 ± 17.9	164	**< 0.001**	0.909
Ergometry (W/kg)	-0.1 ± 0.4	112	0.099	0.2 ± 0.4	173	**< 0.001**	**< 0.001**

* p for between-group comparison

Abbreviations: EG, exercise group; SD, standard deviation; v0, baseline visit; v1, follow-up visit; WG, waiting group. P-values < 0.05 are bolded.

Table 3 Summary of interaction analyses on the effect of sex, age group and BMI category on the change of motor skills

	Sex		Age group		BMI category	
	WG	EG	WG	EG	WG	EG
Sprint (Δ s)	ns	ns	**2nd > 5th**	ns	ns	ns
Backwards Balance (Δ steps)	ns	ns	ns	**2nd > 5th**	ns	ns
Side Jumps (Δ repetitions)	ns	ns	ns	ns	ns	ns
Stand and reach (Δ cm)	ns	ns	ns	ns	ns	ns
Push-ups (Δ repetitions)	**m > f**	ns	**2nd > 5th**	**2nd > 5th**	ns	ns
Sit-ups (Δ repetitions)	ns	**f > m**	ns	ns	ns	ns
Standing long jump (Δ cm)	ns	ns	ns	ns	ns	**NW > OW**
Ergometry (Δ W/kg)	ns	ns	ns	**2nd > 5th**	ns	ns

A separate model was calculated for every endpoint. The dependent variable is the change in the respective motor skill after one year. The complete models are shown in Table S4 a-h.

Abbreviations: BMI, body-mass index; EG, exercise group; f, female; m, male; NW, non-overweight; OW, overweight WG, waiting group. P-values < 0.05 are bolded.

Discussion

This prospective, longitudinal cohort study demonstrates a novel school-based exercise program that can be easily implemented into school life and leads to a significant improvement of the pupils' motor skills when compared to peers who did not participate.

School is a socialisation institution that is a well-suited setting for programs intending to positively influence healthy behaviour [36]. It is therefore ideally suited for this inclusive and effective exercise program that is easily accessible for all pupils. The program shows particular strengths. In contrast to other programs, it does only require minimal additional equipment (i.e., the index card box) and no additional space or venues [59]. It can be effectively conducted by the teachers and does not require additional staff after the initial phase [37, 65]. Lastly, the program requires only minimal additional time and therefore does not disrupt the curriculum [37, 59, 65]. For these reasons it is easily transferable to different school settings.

By engaging in the exercise program for one year, pupils saw a clear improvement in their action-speed, coordination under time pressure and flexibility (measured by the sprint, side jumps, stand and reach tests, respectively), as well as their maximum endurance capacity (gauged bicycle ergometry). These advancements were significantly stronger in the EG than the WG, and remained significant after adjusting for age, sex, and BMI. Moreover, a tendency could be observed for coordination in precision-tasks and endurance-strength of the torso (showed by the backwards balance and sit-ups, respectively). The comparison of the change in motor skills between the EG and WG enabled us to concisely discern the impact of the exercise program from potential confounders, such as physiological development, or a potential learning effect from repeatedly performing these motor tests.

Of note, upper extremity strength and lower extremity jumping power (tested through push-ups and standing long jumps, respectively), did not show a differing development between the groups. Building additional strength like jumping power requires a long intervention period and higher intensity [33]. Upper extremity strength, and, to a lesser

degree, lower extremity jumping power, could not be targeted as intensely by the exercise impulses (which constituted the main module of the exercise program) due to limited classroom space. Therefore, it is possible that the exercise program was not intense enough to significantly boost these motor skills.

At baseline, we saw differences between the boys' and girls' results, which are in line with literature [68, 71]. However, results were similar for the side jumps and pushups, where other studies saw sex differences as well [20, 49]. When investigating the differential effect of the program between the sexes, our data showed that the increase in push-ups was less for girls than boys in the WG. Interestingly, this effect could not be observed in the EG, suggesting that the exercise program alleviated this disadvantage. With the sit-ups, EG girls profited significantly more than EG boys. It is therefore remarkable that the program seems to lift the sex differences. One possible explanation could be that the program and its exercises do not distinguish between boys and girls. It is known that there is a difference in leisure time behavior between the sexes (boys being less sedentary than girls) [19, 38, 45]. Our program can therefore contribute to counteract this effect.

The program was more effective for 2nd graders in the backwards balance and ergometry. Second graders increased the number of push-ups more strongly than 5th graders, but this was seen in both WG and EG. Taken together with the fact that WG and EG were not significantly different in this particular test item, it may be that the observed effect is due to a more pronounced physiological development in this age group [55].

It was not surprising to find that overweight children performed worse than their non-overweight peers in all tested motor skill categories (with the exception of flexibility), in line with literature [20, 23, 47, 72]. Overweight children are known to show less development in their motor skills [12]. It was, therefore surprising to see that the change in the tested motor skills in overweight children did not significantly differ from that in non-overweight children in any test item other than the standing long jump. In particular, our data showed no disadvantage for overweight children for the ergometry. This is especially important, as high physical fitness is known to alleviate the metabolic risk that is associated with overweight [16, 53, 58]. Even though we could not see a significant catch-up development (i.e., a stronger effect in overweight than non-overweight children), this finding still is very encouraging, as it suggests that overweight children can keep up with their non-overweight peers at this age. Overweight children are more likely to originate from socially disadvantaged backgrounds [34, 54, 70] which itself is associated with lack of exercise [56, 57, 64]. Furthermore, overweight children are more likely to be reluctant to engage in sports activities, because of shame or the fear of being bullied [22, 25, 50]. Placing this easily accessible exercise program into the school setting free of charge, can represent a suitable tool to reach disadvantaged groups that may not be able to engage in extracurricular sports activities, due to financial opportunities, lack of intrinsic motivation, or may be reluctant to do so.

Our study shows several strengths. It is a multi-site prospective longitudinal study on a large cohort of children from two age groups. Secondly, we employed a standardized protocol of motor tests that are suitable for children, conducted by uniformly trained sports scientists. Thirdly, by comparing the change in motor skills of pupils to that of age-matched peers from the same schools allows to precisely discern the effect of the exercise program.

The study also carries few limitations. We were not able to reach the intended goal of additional 60 minutes of daily activity. One reason is that teachers often forgot to document the exercise impulses they conducted during the lessons. It can therefore be assumed that the actual average time of exercise was higher. Notwithstanding, we could demonstrate the beneficial effect of the exercise program on the participants' motor skills and physical fitness. Our results are limited to the two age groups of 2nd grade and 5th grade pupils, therefore generalization to other age groups is limited. Further studies, involving further age groups, especially teenagers, are warranted.

In conclusion, our study presents a simple and effective in-school exercise program that increases motor skills and physical fitness, as measured by a comprehensive set of tests and can be easily implemented into the daily school routine.

Abbreviations

BMI, body mass index

EG, exercise group

v0, baseline examination

v1, follow-up examination

WG, waiting group

WHO, World Health Organisation

Declarations

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Conflicts of interest/Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

Denise Homeyer, Nima Memaran-Dagdar, Axel Haverich, Momme Kück, Meike Stiesch, Anette Melk, and Uwe Tegtbur contributed to study conception and design. Denise Homeyer, Nima Memaran-Dagdar, Lena Grams, Jeannine von der Born, Martina Schwalba, Arno Kerling, Nadine von Maltzahn and Alexander Albrecht aided in recruitment and inclusion. Axel Haverich, Nima Memaran-Dagdar, Lena Grams, Jeannine von der Born, Elena Bauer, Martina Schwalba, Arno Kerling, Nadine von Maltzahn and Alexander Albrecht performed study measurements as well as data aquisition and collection. Denise Homeyer, Nima Memaran-Dagdar, Momme Kück and Anette Melk analyzed the data. Denise Homeyer and Nima Memaran-Dagdar drafted the manuscript. Axel Haverich, Meike Stiesch, Anette Melk and Uwe Tegtbur provided substantial professional expertise. All authors critically revised and contributed substantially to the manuscript. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors read and approved the final manuscript.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the medical school Hannover (12.01.2017, No. 7290)

Consent to participate

Written informed consent by the parents or caregiver was obtained from all individual participants included in the study.

Consent for publication

N/A

References

1. Metcalf BS, Voss LD, Hosking J, Jeffery AN, Wilkin TJ (2008) Physical activity at the government-recommended level and obesity-related health outcomes: a longitudinal study (Early Bird 37). Arch Dis Child 93:772–777
2. Jekauc D, Reimers AK, Wagner MO, Woll A (2012) Prevalence and socio-demographic correlates of the compliance with the physical activity guidelines in children and adolescents in Germany. BMC Public Health 12:1–9
3. World Health Organization (2019) Global action plan on physical activity 2018–2030: more active people for a healthier world. World Health Organization
4. Janssen I, LeBlanc AG (2010) Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. International journal of behavioral nutrition and physical activity 7:1–16
5. Rauner A, Jekauc D, Mess F, Schmidt S, Woll A (2015) Tracking physical activity in different settings from late childhood to early adulthood in Germany: the MoMo longitudinal study. BMC Public Health 15:391
6. Carnethon MR, Gulati M, Greenland P (2005) Prevalence and cardiovascular disease correlates of low cardiorespiratory fitness in adolescents and adults. JAMA 294:2981–2988
7. Königstein K, Büschges JC, Sarganas G, Krug S, Neuhauser H, Schmidt-Trucksäss A (2021) Exercise and Carotid Properties in the Young–The KiGGS-2 Study. Frontiers in cardiovascular medicine 8
8. Graf C, Jouck S, Koch B, Staudenmaier K, Von Schlenk D, Predel H, Tokarski W, Dordel S (2007) Motorische Defizite–wie schwer wiegen sie?. Monatsschrift Kinderheilkunde 155:631–637
9. Dencker M, Thorsson O, Karlsson M, Lindén C, Eiberg S, Wollmer P, Andersen L (2006) Daily physical activity related to body fat in children aged 8–11 years. J Pediatr 149:38–42
10. Shore SM, Sachs ML, Lidicker JR, Brett SN, Wright AR, Libonati JR (2008) Decreased scholastic achievement in overweight middle school students. Obesity 16:1535–1538
11. Spengler S, Mess F, Schmocker E, Woll A (2014) Longitudinal associations of health-related behavior patterns in adolescence with change of weight status and self-rated health over a period of 6 years: results of the MoMo longitudinal study. BMC pediatrics 14:1–11
12. Lopes L, Santos R, Pereira B, Lopes VP (2012) Associations between sedentary behavior and motor coordination in children. Am J Hum Biol 24:746–752
13. Huber G, Köppel M (2017) Analyse der Sitzzeiten von Kindern und Jugendlichen zwischen 4 und 20 Jahren. Deutsche Zeitschrift für Sportmedizin 68:101–106
14. Arundell L, Salmon J, Koorts H, Ayala AMC, Timperio A (2019) Exploring when and how adolescents sit: cross-sectional analysis of activPAL-measured patterns of daily sitting time, bouts and breaks. BMC Public Health 19:1–9
15. Hardy LL, Reinten-Reynolds T, Espinel P, Zask A, Okely AD (2012) Prevalence and correlates of low fundamental movement skill competency in children. Pediatrics 130:e390-e398

16. Bös K (2003) Motorische leistungsfähigkeit von kindern und jugendlichen. Erster Deutscher kinder-und jugendsportbericht 3:85–107
17. Bös K, Oberger J, Lämmle L, Opper E, Romahn N, Tittlbach S, Wagner MO, Woll A, Worth A (2008) Motorische Leistungsfähigkeit von Kindern. Zweiter Deutscher Kinder- und Jugendsportbericht: Schwerpunkt: Kindheit / Schmidt, Werner (Hrsg.). - Schorndorf: Hofmann ISBN 978-3-7780-8580-6:137-158
18. Albrecht C, Hanssen-Doose A, Boes K, Schlenker L, Schmidt S, Wagner M, Will N, Worth A (2016) Motor performance of children and adolescents in Germany. A 6-year cohort study within the framework of the" Motorik-Modul"(MoMo). GERMAN JOURNAL OF EXERCISE AND SPORT RESEARCH 46:294–304
19. Tomkinson GR, Lang JJ, Tremblay MS (2019) Temporal trends in the cardiorespiratory fitness of children and adolescents representing 19 high-income and upper middle-income countries between 1981 and 2014. Br J Sports Med 53:478–486
20. Lang JJ, Larouche R, Tremblay MS (2019) The association between physical fitness and health in a nationally representative sample of Canadian children and youth aged 6 to 17 years. Health Promot Chronic Dis Prev Can 39:104–111
21. Barnett LM, Morgan PJ, van Beurden E, Beard JR (2008) Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: a longitudinal assessment. International journal of behavioral nutrition and physical activity 5:1–12
22. Southall JE, Okely AD, Steele JR (2004) Actual and perceived physical competence in overweight and nonoverweight children. Pediatric Exercise Science 16:15–24
23. Redondo-Tebar A, Fatouros IG, Martinez-Vizcaino V, Ruíz-Hermosa A, Notario-Pacheco B, Sanchez-Lopez M (2021) Association between gross motor competence and health-related quality of life in (pre) schoolchildren: the mediating role of cardiorespiratory fitness. Physical Education and Sport Pedagogy 26:51–64
24. Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR (2014) The health benefits of muscular fitness for children and adolescents: a systematic review and meta-analysis. Sports medicine 44:1209–1223
25. Brunet M, Chaput J, Tremblay A (2007) The association between low physical fitness and high body mass index or waist circumference is increasing with age in children: the 'Quebec en Forme'Project. Int J Obes 31:637–643
26. Vicente-Rodríguez G, Urzanqui A, Mesana MI, Ortega FB, Ruiz JR, Ezquerra J, Casajús JA, Blay G, Blay VA, Gonzalez-Gross M (2008) Physical fitness effect on bone mass is mediated by the independent association between lean mass and bone mass through adolescence: a cross-sectional study. J Bone Miner Metab 26:288–294
27. Kristensen PL, Wedderkopp N, Møller NC, Andersen LB, Bai CN, Froberg K (2006) Tracking and prevalence of cardiovascular disease risk factors across socio-economic classes: a longitudinal substudy of the European Youth Heart Study. BMC Public Health 6:1–9
28. Andersen LB, Hasselstrøm H, Grønfeldt V, Hansen SE, Karsten F (2004) The relationship between physical fitness and clustered risk, and tracking of clustered risk from adolescence to young adulthood: eight years follow-up in the Danish Youth and Sport Study. International Journal of Behavioral Nutrition and Physical Activity 1:1–4
29. Engeland A, Bjørge T, Tverdal A, Søgaard AJ (2004) Obesity in adolescence and adulthood and the risk of adult mortality. Epidemiology:79–85
30. Field AE, Cook NR, Gillman MW (2005) Weight status in childhood as a predictor of becoming overweight or hypertensive in early adulthood. Obes Res 13:163–169
31. Freedman DS, Khan LK, Dietz WH, Srinivasan SR, Berenson GS (2001) Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study. Pediatrics 108:712–718

32. Nittari G, Scuri S, Petrelli F, Pirillo I, Di Luca N, Grappasonni I (2019) Fighting obesity in children from European world health organization member states. Epidemiological data, medicalsocial aspects, and prevention programs. Clin Ter 170:e223-e230
33. McPhillips M, Jordan-Black J (2007) The effect of social disadvantage on motor development in young children: a comparative study. Journal of Child Psychology and Psychiatry 48:1214–1222
34. Peric T, Ruzbarsky P, Tufano JJ (2021) Relationships between Socioeconomic Indicators and Motor Performance of Schoolchildren in Slovakia. International Journal of Environmental Research and Public Health 18:13153
35. Möller S, Poulain T, Körner A, Meigen C, Jurkutat A, Vogel M, Wessela S, Hiemisch A, Grafe N, Kiess W (2021) Motor skills in relation to body-mass index, physical activity, TV-watching, and socioeconomic status in German four-to-17-year-old children. Plos one 16:e0251738
36. Kakebeeke TH, Chaouch A, Caflisch J, Knaier E, Rousson V, Jenni OG (2021) Impact of body mass index and socio-economic status on motor development in children and adolescents. Eur J Pediatr 180:1777–1787
37. Bös K, Worth A, Opper E, Oberberger J, Romahn N, Wagner M, Jekauc D, Mess F, Woll A (2009) Motorik-Modul: eine Studie zur motorischen Leistungsfähigkeit und körperlich-sportlichen Aktivität von Kindern und Jugendlichen in Deutschland; Abschlussbericht zum Forschungsprojekt
38. Godfrey S, Davies CT, Wozniak E, Barnes CA (1971) Cardio-respiratory response to exercise in normal children. Clin Sci 40:419–431
39. Kroidl R, Schwarz S, Lehnigk B, Fritsch J (2014) Kursbuch Spiroergometrie: Technik und Befundung verständlich gemacht. Georg Thieme Verlag
40. Beigel D (2012) Beweg dich, Schule!: eine" Prise Bewegung" im täglichen Unterricht der Klassen 1 bis 13. Borgmann Media
41. Mertens M (2005) Sport & Spiel mit Alltagsmaterial: 630 Trainingsideen für Gruppe, Freizeit und Schule. Verlag an der Ruhr
42. Moosmann K (2009) Das große Limpert-Buch der kleinen Spiele. Limpert, Wiebelsheim
43. Dippelhofer A, Bergmann KE, Kahl H, Lange M (2002) The physical examination within the scope of The Child and Adolescent Health Survey. Gesundheitswesen 64 Suppl 1:S12-6
44. WHO Multicentre Growth Reference Study Group, de Onis M (2006) WHO Child Growth Standards based on length/height, weight and age. Acta paediatrica 95:76–85
45. Barlow SE, Expert Committee (2007) Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. Pediatrics 120:S164-S192
46. Memaran N, Schwalba M, Borchert-Mörlins B, von der Born J, Markefke S, Bauer E, von Wick A, Epping J, von Maltzahn N, Heyn-Schmidt I (2020) Gesundheit und Fitness von deutschen Schulkindern. Monatsschrift Kinderheilkunde 168:597–607
47. MacArthur G, Caldwell DM, Redmore J, Watkins SH, Kipping R, White J, Chittleborough C, Langford R, Er V, Lingam R (2018) Individual-, family-, and school-level interventions targeting multiple risk behaviours in young people. Cochrane database of systematic reviews
48. Shore SM, Sachs ML, DuCette JP, Libonati JR (2014) Step-count promotion through a school-based intervention. Clin Nurs Res 23:402–420
49. Thivel D, Isacco L, Lazaar N, Aucouturier J, Ratel S, Doré E, Meyer M, Duché P (2011) Effect of a 6-month school-based physical activity program on body composition and physical fitness in lean and obese schoolchildren. Eur J Pediatr 170:1435–1443

50. Madsen K, Linchey J, Gerstein D, Ross M, Myers E, Brown K, Crawford P (2015) Energy balance 4 kids with play: results from a two-year cluster-randomized trial. Childhood Obesity 11:375–383
51. Lesinski M, Prieske O, Granacher U (2016) Effects and dose-response relationships of resistance training on physical performance in youth athletes: a systematic review and meta-analysis. Br J Sports Med 50:781–795
52. Woll A, Kurth B, Opper E, Worth A, Bös K (2011) The 'Motorik-Modul'(MoMo): physical fitness and physical activity in German children and adolescents. Eur J Pediatr 170:1129–1142
53. Wagner MO, Bös K, Jekauc D, Karger C, Mewes N, Oberger J, Reimers AK, Schlenker L, Worth A, Woll A (2014) Cohort Profile: The Motorik-Modul Longitudinal Study: physical fitness and physical activity as determinants of health development in German children and adolescents. Int J Epidemiol 43:1410–1416
54. Petrovics P, Sandor B, Palfi A, Szekeres Z, Atlasz T, Toth K, Szabados E (2021) Association between obesity and overweight and cardiorespiratory and muscle performance in adolescents. International Journal of Environmental Research and Public Health 18:134
55. Nielsen GA, Andersen LB (2003) The association between high blood pressure, physical fitness, and body mass index in adolescents. Prev Med 36:229–234
56. Maier IB, Özel Y, Wagnerberger S, Bischoff SC, Bergheim I (2013) Dietary pattern and leisure time activity of overweight and normal weight children in Germany: sex-specific differences. Nutrition journal 12:1–8
57. Gonzalo-Almorox E, Urbanos-Garrido RM (2016) Decomposing socio-economic inequalities in leisure-time physical inactivity: the case of Spanish children. International journal for equity in health 15:1–10
58. Roth A, Schmidt SC, Seidel I, Woll A, Bös K (2018) Tracking of physical fitness of primary school children in trier: a 4-year longitudinal study. BioMed research international 2018
59. Okely AD, Booth ML, Chey T (2004) Relationships between body composition and fundamental movement skills among children and adolescents. Res Q Exerc Sport 75:238–247
60. Woll A, Worth A, Mundermann A, Holling H, Jekauc D, Bos K (2013) Age- and sex-dependent disparity in physical fitness between obese and normal weight children and adolescents. J Sports Med Phys Fitness 53:48–55
61. Hilpert M, Brockmeier K, Dordel S, Koch B, Weiss V, Ferrari N, Tokarski W, Graf C (2017) Sociocultural Influence on Obesity and Lifestyle in Children: A Study of Daily Activities, Leisure Time Behavior, Motor Skills, and Weight Status. Obes Facts 10:168–178
62. de Waal E, Pienaar AE (2021) Influences of persistent overweight on perceptual-motor proficiency of primary school children: the North-West CHILD longitudinal study. BMC pediatrics 21:1–10
63. Seo Y, Lim H, Kim Y, Ju Y, Lee H, Jang HB, Park SI, Park KH (2019) The effect of a multidisciplinary lifestyle intervention on obesity status, body composition, physical fitness, and cardiometabolic risk markers in children and adolescents with obesity. Nutrients 11:137
64. Renninger M, Hansen BH, Steene-Johannessen J, Kriemler S, Froberg K, Northstone K, Sardinha L, Anderssen SA, Andersen LB, Ekelund U (2020) Associations between accelerometry measured physical activity and sedentary time and the metabolic syndrome: A meta-analysis of more than 6000 children and adolescents. Pediatric obesity 15:e12578
65. Lissau I, Sørensen TIA, Lissau I (1994) Parental neglect during childhood and increased risk of obesity in young adulthood. The Lancet. doi: https://doi.org/10.1016/S0140-6736(94)91163-0
66. Rolland-Cachera M, Bellisle F (1986) No correlation between adiposity and food intake: why are working class children fatter?. Am J Clin Nutr 44:779–787
67. Williams AS, Ge B, Petroski G, Kruse RL, McElroy JA, Koopman RJ (2018) Socioeconomic status and other factors associated with childhood obesity. The Journal of the American Board of Family Medicine 31:514–521

68. Schmidt SC, Anedda B, Burchartz A, Oriwol D, Kolb S, Wäsche H, Niessner C, Woll A (2020) The physical activity of children and adolescents in Germany 2003–2017: The MoMo-study. PLoS one 15:e0236117
69. Rullestad A, Meland E, Mildestvedt T (2021) Factors predicting physical activity and sports participation in adolescence. Journal of environmental and public health 2021
70. Tandon PS, Kroshus E, Olsen K, Garrett K, Qu P, McCleery J (2021) Socioeconomic Inequities in youth participation in physical activity and sports. International Journal of Environmental Research and Public Health 18:6946
71. Rancourt D, Barker DH, Sato AF, Lloyd-Richardson EE, Hart CN, Jelalian E (2014) Longitudinal associations among change in overweight status, fear of negative evaluation, and weight-related teasing among obese adolescents. J Pediatr Psychol 39:697–707
72. Hayden-Wade HA, Stein RI, Ghaderi A, Saelens BE, Zabinski MF, Wilfley DE (2005) Prevalence, characteristics, and correlates of teasing experiences among overweight children vs. non-overweight peers. Obes Res 13:1381–1392
73. Ievers-Landis CE, Dykstra C, Uli N, O'Riordan MA (2019) Weight-related teasing of adolescents who are primarily obese: Roles of sociocultural attitudes towards appearance and physical activity self-efficacy. International Journal of Environmental Research and Public Health 16:1540

Figures

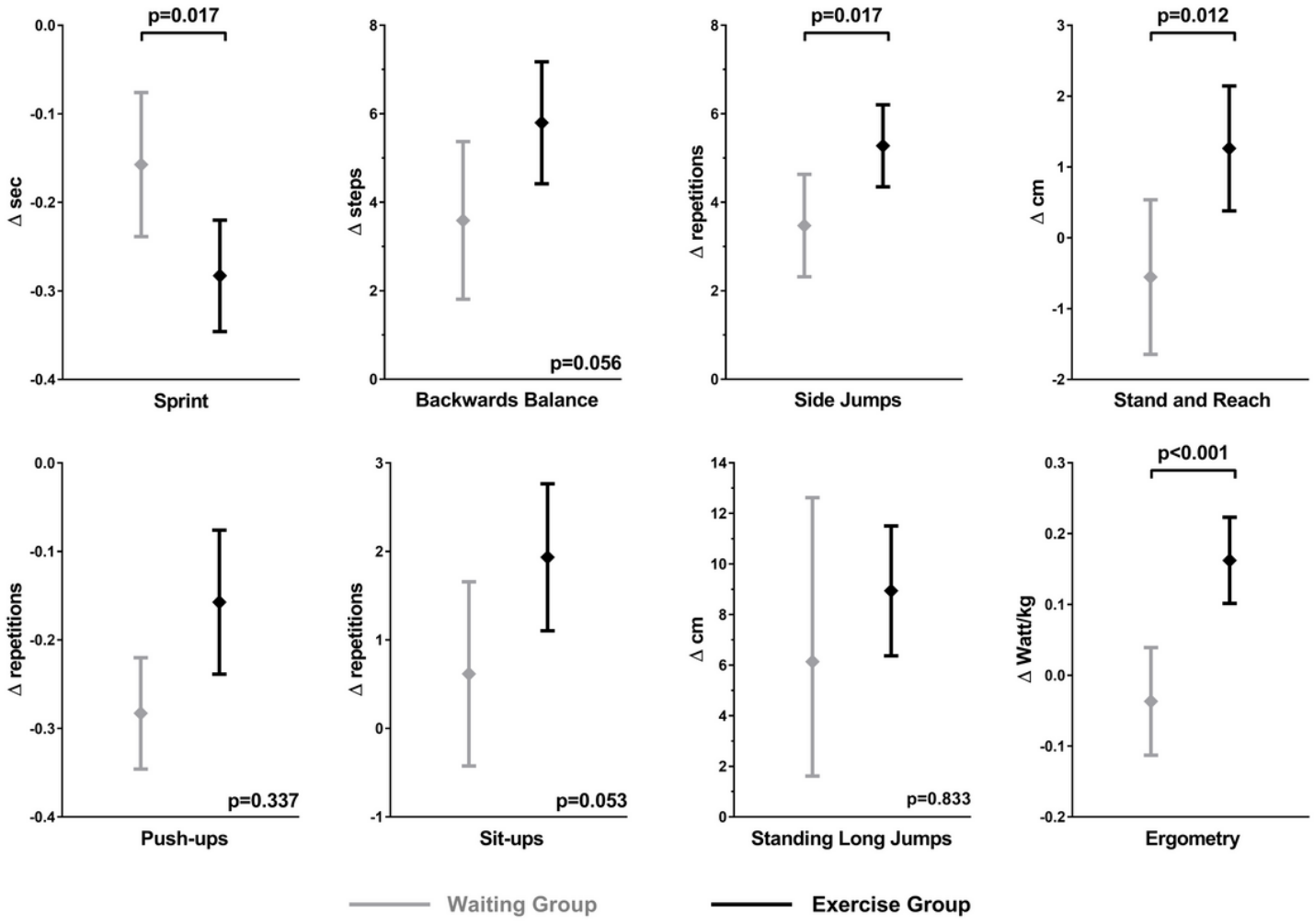

Figure 1

Comparison of the corrected means of the change in motor skills after one year between the waiting group (grey) and the exercise group (black), adjusted for age, sex, and BMI. The exercise group improved significantly more strongly than the waiting group in the sprint, side jumps, stand and reach, and ergometry test items, and showed a tendency for stronger improvement in the backwards balance and sit-ups, while no significantly different change could be observed for the standing long jumps and push-ups.

Supplementary Files

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