Original Article

Development of physical fitness under consideration of talent-specific aspects

ANDREAS ROTH[1] ✉, STEFFEN CE SCHMIDT[2], SINA HARTMANN[1], SWANTJE SCHARENBERG[1], ILKA SEIDEL[1], STEFAN ALTMANN[2], DARKO JEKAUC[2], KLAUS BÖS[2]

[1]*Research Centre for School Sports and the Physical Education of Children and Young Adults, Karlsruhe Institute of Technology, Karlsruhe, Germany*
[2]*Institute of Sports and Sports Science, Karlsruhe Institute of Technology, Karlsruhe, Germany*

ABSTRACT

Purpose: To measure the initial level and development of physical fitness (PF) in pupils from grade 4 to grade 7 in sport schools with respect to the discipline, training volume and training years. Methods: A total of 1590 (1074 female, 516 male) pupils from sport schools in North Rhine-Westphalia (Germany) were tested in grade 4 and re-tested in grade 7 using the German Motor Test. Additionally, the discipline, training volume and training years were captured in grade 7 via questionnaire. Results: The initial level of PF of boys and girls lies above the German average and was influenced by discipline and training volume. The track and field athletes showed the best results compared to other sport disciplines. In relation to the normal population, boys showed a slight decrease in PF from grade 4 to 7 ($F = 8.3$; $p = 0.004$; $\eta^2 = 0.009$) whereas the PF of girls remained stable ($F = 1.1$; $p = 0.290$; $\eta^2 = 0.003$). The development of PF is influenced by sport discipline, training volume and the interaction between training volume and time. In total, the effect sizes were low. Conclusions: There is still potential to improve training and physical education at sport schools to raise the level of PF. Training years did not influence the initial level of PF or the development of PF. In further studies, more information on the type of training would be useful. **Keywords:** Motor tests; Talent identification; Training; Motor performance.

Cite this article as:
Roth, A., Schmidt, S., Hartmann, S. Scharenberg, S., Seidel, I., Altmann, S., Jekauc, D., & Bös, K. (2019). Development of physical fitness under consideration of talent-specific aspects. *Journal of Human Sport and Exercise*, *in press*. doi:https://doi.org/10.14198/jhse.2020.153.11

✉ **Corresponding author.** *Research Centre for School Sports and the Physical Education of Children and Young Adults, Karlsruhe Institute of Technology. Engler Bunte Ring 15. 76131 Karlsruhe. Germany.*
E-mail: Andreas.Roth@kit.edu
Submitted for publication June 2019
Accepted for publication July 2019
Published *in press* October 2019
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2020.153.11

INTRODUCTION

Physical fitness (PF) is vital to the performance of daily physical activity and/or physical exercise (Ortega, Ruiz, Castillo, & Sjöström, 2008). Cardiorespiratory endurance, muscular endurance, muscular strength, body composition and flexibility are often described as health-related fitness components. Agility, balance, coordination, speed, power and reaction time are characteristic skill-related components (Caspersen, Powell, & Christensen, 1985). PF is in part genetically determined, but can also be greatly influenced by environmental factors (Ortega et al., 2008).

A high PF undoubtedly has a positive impact on both physical health (Smith, et al., 2014; Ortega et al., 2008) and psychological health (Ortega et al., 2008; Smith, et al., 2014). Moreover, the measurement of PF components is widely used in talent identification (TID; Lidor, Coté, & Hackford, 2009). PF is usually measured using motor field tests, and a theoretical model for measuring motor abilities with these tests has been proposed (Bös, 1987). This model provided the basis for the German Motor Test (DMT):

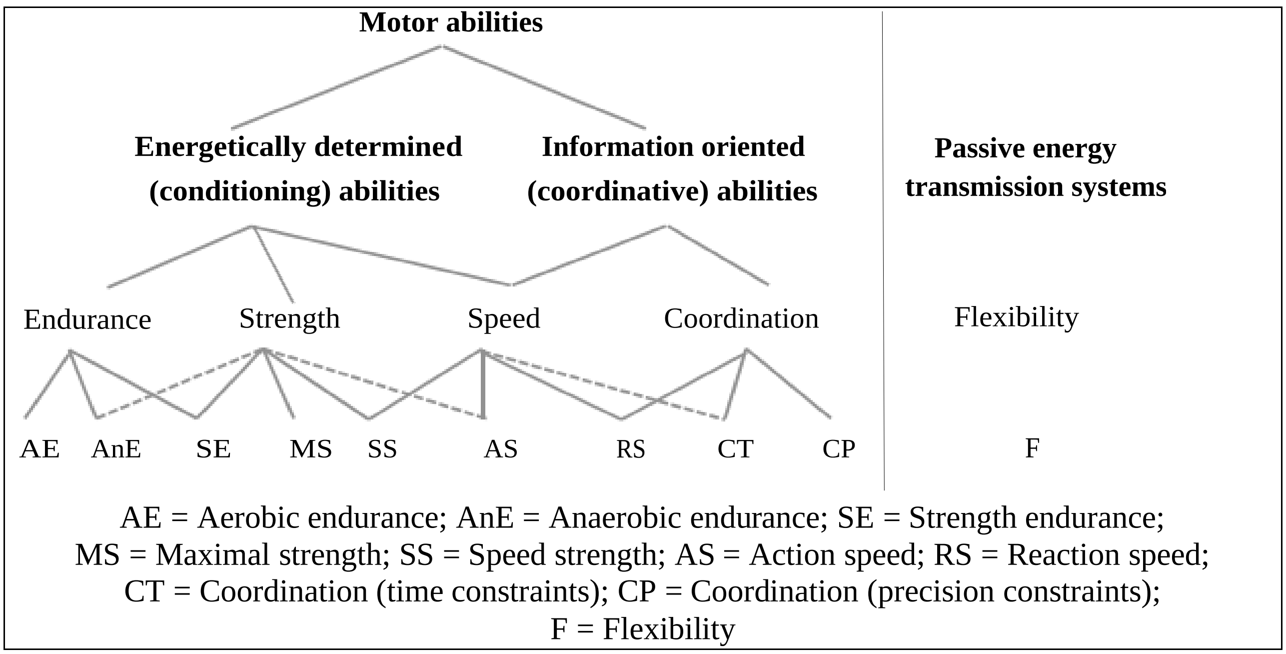

Figure 1. Differentiation of motor abilities (Bös, 1987, p. 94).

In the first level of this model, abilities are differentiated into energetically-determined (conditioning) and information-oriented (coordinative). The next level further differentiates the main abilities of endurance, strength, speed, coordination and flexibility. In this model, speed cannot be assigned to either the conditioning or coordinative abilities; and can therefore be regarded as a mixed form. Flexibility is linked to passive energy transmission systems. On the next level, 10 dimensions of general PF are listed. According to Bös (1987), there is a close interrelationship between abilities and skills. The use of the skill improves the ability, which contributes to the qualitative improvement of skills through action regulation.

Physical fitness requires an athlete to integrate many factors, some trainable (e.g. physiology, psychology and biomechanics) and some teachable (tactics); whereas others are not controllable by either the athlete or the coach (e.g. genetics and age; Smith, 2003). Because of this complexity, it is difficult to identify potential talents at a young age. Cross-sectional designs are commonly used to identify potential talents (Johnston, Wattie, Schorer, & Baker, 2018; Matthys et al., 2013). However, one-time testing is often not sufficient because there are unstable physical and anthropometric parameters during adolescence (Vayens, Lenoir, Wiliams, Philippaerts, & Renaat, 2008). Moreover, the development process is affected by maturation and training (Abbott & Collins, 2002).

Hohmann and Seidel (2003) propose four talent criteria: juvenile performance, speed of performance development, utilization of performance conditions and load tolerance. Juvenile performance can provide useful information if the discipline is only determined by a few performance components that remain largely stable during puberty (e.g. throwing technique and body height). The speed of performance development as a talent criterion is often neglected; possibly due to the methodological problem that the better an athlete performs, the smaller the residual potential to improve in the future (Hohmann & Seidel, 2003).

The aspect of utilization is linked to the assumption that young athletes should achieve their performance with economical use of resources, but in the long term full resources should be developed and used to achieve maximum performance (Hohmann, 2001). Load tolerance is another important factor. For example, countries that produce top triathletes have introduced training load, stress tolerance and mental performance as determinant factors in talent selection (Bottoni, Gianfelici, Tamburri, & Faina, 2011).

Studies in TID are based on the measurement and subsequent comparison of characteristics that contribute to sport-specific performance (Johnston et al., 2018). Longitudinal studies on the speed of performance development have been conducted in soccer (Roescher, Elferink-Gemser, Huijgen & Visscher, 2010), handball (Matthys et al., 2013), hockey (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2007), rugby (Till, Cobley, O'Hara, Chapman, & Cooke, 2013) and triathlon (Bottoni et al., 2011). A study looking at the development of general PF across several sports could not be found. However, this approach could increase knowledge of TID through a cross-disciplinary approach.

In 2006, the government of NRW decided to establish a new type of sport school, and since 2015 a total of 18 sport schools have been involved in the project (MFKJKS, 2011). Candidates must pass a selection stage before joining grades 5 and 8. In grade 4, the DMT (Bös et al., 2016) is performed to measure general PF. In grade 7, the DMT is repeated to measure the speed of performance development (Hohmann & Seidel, 2003). Additionally, semi-specific and sport-specific tests are performed; and the sport discipline, weekly training volume and training years are captured (Seidel et al., 2014).

This article focusses on the initial fitness level and the rate of performance development of pupils from different sport disciplines. The main research questions are:

- To what extent do training volume, training age and sport discipline influence the initial PF?
- To what extent do training volume, training age and sport discipline influence the development of PF from grades 4 to 7?

MATERIAL AND METHODS

Study Sample and Design

The project started in the 2007/2008 school year. In the beginning, five sport schools were selected (MFKJKS, 2011) and more were recruited to the study as they joined the general scheme. Since 2015, a total of 18 sport schools have been involved (Düsseldorf, Minden, Solingen, Dortmund, Cologne, Münster, Paderborn, Essen, Leverkusen, Mönchengladbach, Dormagen, Gelsenkirchen, Bochum, Winterberg, Duisburg, Bonn, Mülheim, and Bielefeld/Herford; MFKJKS, 2011). Each school differs in terms of content and main sport disciplines. The contracting authority was the Ministry of family, children, youth, culture and sport of the state of NRW. Motor tests were organized and performed by trained instructors from the sport schools and the Research Centre of School Sports and the Physical Education of Children and Young Adults (FoSS). The study was approved by the review board of the Institute of Sports and Sport Science, Karlsruhe Institute of Technology.

Since the 2007/2008 school year, candidates were measured annually: first in grade 4 between October and April, and again three years later in grade 7 between February and May. This took place over a decade until the 2017/2018 school year, giving a total of 13,368 (4673f, 8695m) candidates measured in grade 4 and 3585 in grade 7 (1385f, 2200m).

The number of pupils who participated in both tests and regularly participate in sport-specific training is 1590 (1074f, 516m). These pupils are spread over the following sports: badminton: 43, basketball: 26, fencing: 54, gymnastics: 3, handball: 270, hockey: 8, judo: 12, rowing: 52, soccer: 622, swimming: 77, tennis: 35, table tennis: 10, track and field: 317, volleyball: 56 and wrestling: 5.

Measures

Physical Fitness

The DMT is based on the differentiation of motor abilities (Bös, 1987, p. 94) and is used to measure the PF of boys and girls in grade 4 and grade 7. The DMT is a valid test battery that includes eight test tasks. The 1-week reliability of tests performed by a comparable team of trained instructors is on average r = 0.82 (Bös et al., 2016). For six of the eight tests (standing long jump, sideways jump, backward balancing, stand-and-reach test, push-ups, sit-ups) there are representative standard values for Germany (Bös, Worth, Opper, Oberger, & Woll, 2009). For the other two tasks (20m sprint and 6-minute run), standard values were obtained from different samples (Bös et al., 2016).

Aerobic endurance was measured by the 6-minute run (see Figure 1). Test participants had to run for 6 minutes around the volleyball field and the total distance run was obtained. In the first two rounds, test participants were escorted by an instructor to avoid running too fast at the beginning. The strength endurance of the torso muscles was examined by the number of sit-ups performed within 40 seconds. The test person lies in the prone position on the back. During execution, the feet are fixed by the test instructor and the knee joints are bent to about 80 degrees. The test person must then straighten the body out of the lying position and touch the knees with both elbows and then return to the lying position with the shoulders touching the mat. The strength endurance of the upper extremities was measured by the number of push-ups performed within 40 seconds. The test subject lies in a prone position on the stomach and the hands grasp one another on the buttocks. The hands move from behind the back to beside the shoulders. Then the test person pushes himself up evenly. Subsequently, one hand is released from the ground and claps onto the other hand. After that, the test person performs a controlled descent to resume the prone position (Lämmle, Tittlbach, Oberger, Worth, & Bös, 2010; Bös et al., 2016).

The speed strength of the lower extremities was assessed by the distance achieved by standing long jump, where the take-off and landing were carried out using both legs together. The distance from the starting line to the heel of the foot closest back after landing was measured (cm). Action speed was recorded over a 20m sprint timed using a Brower light timing system or a stopwatch. Times measured by the light-barrier system were converted into hand stop times using a correction factor, and the best time of two attempts was used for evaluation. Backward balancing allows assessment of gross motor coordination during dynamic precision tasks. Test participants must walk backward and keep their balance on beams 300 cm long and of width 3, 4.5 and 6 cm. Each test began on a platform and the numbers of steps on each beam were added. Cross motor coordination under time constraint was measured by sideways jump. The aim is to jump sideways over the centre line of a marked field (50 x 100 cm) with both legs at the same time. The number of jumps performed in 15 seconds was used for evaluation. The stand-and-reach test was used to assess the flexibility of the trunk and sciatic crural muscle group. The test person stands on a long bench and slowly bends the upper body forward. The hands are led parallel along a centimetre scale as far down as possible and the distance reached was measured (Bös et al., 2016; Lämmle et al., 2010).

Body Mass Index

Height was measured without shoes to the nearest 0.1 cm using a fixed tape. Weight was assessed standardized to the nearest 0.1 kg using a Korona Alva digital metric scale (Sundern, North-Rhine Westphalia, Germany). Body mass index was calculated as: BMI (kg/m^2) = weight (kg) / $height^2$ (m^2).

Talent-specific aspects

Additionally, information about the athletic career was captured. For this purpose, a questionnaire was completed by parents and children prior to the tests in grade 7 to capture sport discipline, training volume per week and training years in the main sport disciplines.

Statistical Analysis

Statistical analysis was performed using SPSS Statistics version 25. Test performances were converted into Z-scores: Z = 100 + 10 x (individual value-mean of the norm sample) / standard deviation of the norm sample. The mean of the Z-scores of the eight different tests was calculated. Based on the Z-scores, comparisons can be made to the national average in Germany (Bös et al., 2009).

The influence of sport discipline, training volume and training years on the initial fitness level was analysed using ANCOVAs. The influence of sport discipline, training volume and training years on the development of PF was analysed via repeated measurement ANCOVAs (rmANCOVA). The analyses were calculated for each gender. The significance level for all statistical tests was set at the 5% level.

RESULTS

Descriptive Results

Due to relatively small sample sizes in some disciplines, soccer (57f, 565m), track and field (182f, 135m) and handball (103f, 167m) were analysed separately. The other 12 sport disciplines are summed (173f, 208m). Descriptive statistics of participants are shown in Table 1.

In boys, soccer was the most common sport discipline, with 565 (52.6%) participants, followed by handball and track and field with 167 (15.5%) and 135 (12.6%) participants, respectively. On average, boys of grade 4 were 9.90 years old, 1.42 meters tall and weighed 34.1 kilos. Three years later, boys of grade 7 were on average 13.05 years old, 1.68 meters tall and weighed 48.3 kilos. The boys trained on average for 290.6 minutes per week and had 6.4 training years in grade 7.

In girls, track and field was the most common sport discipline, with 182 (35.3%) participants, followed by handball and soccer with 103 (20.0%) and 57 (11.0%) participants, respectively. On average, girls of grade 4 were 8.85 years old, 1.41 meters tall and weighed 33.5 kilos. Three years later, girls of grade 7 were 13.03

years old, 1.61 meters tall and weighed 49.2 kilos. The girls trained on average for 298.5 minutes per week and had 5.0 training years in grade 7.

Table 1. Descriptive statistics of tests participants of different sport disciplines in grades 4 and 7.

Sport discipline	Sex	N	Age (years)	Height (m)	Weight kg)	Age (years)	Height (m)	Weight (kg)	Training Volume/week (min)	Training age (years)
			Grade 4	Grade 4	Grade 4	Grade 7	Grade 7	Grade 7	Grade 7	Grade 7
			Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Soccer	m	565	9.97 ± 0.49	1.41 ± 0.06	33.9 ± 5.7	13.05 ± 0.44	1.60 ± 0.08	47.8 ± 9.4	265.5 ± 87.5	7.4 ± 2.2
	f	57	10.00 ± 0.60	1.40 ± 0.07	33.3 ± 5.5	13.08 ± 0.40	1.59 ± 0.06	48.6 ± 6.6	251.3 ± 98.9	5.5 ± 2.9
Track and field	m	135	9.82 ± 0.41	1.42 ± 0.06	32.7 ± 4.7	13.08 ± 0.43	1.61 ± 0.09	47.1 ± 8.4	285.1 ± 136.5	5.5 ± 2.5
	f	182	9.77 ± 0.44	1.40 ± 0.06	31.9 ± 4.9	13.00 ± 0.40	1.60 ± 0.07	47.7 ± 6.9	270.5 ± 124.9	4.7 ± 2.2
Handball	m	167	9.78 ± 0.51	1.43 ± 0.06	34.7 ± 4.9	13.01 ± 0.50	1.62 ± 0.08	49.8 ± 9.2	281.7 ± 78.2	6.3 ± 2.4
	f	103	9.86 ± 0.39	1.41 ± 0.06	34.1 ± 5.9	13.11 ± 0.37	1.61 ± 0.06	51.2 ± 8.2	280.9 ± 94.1	5.9 ± 2.3
Other sports (12)	m	208	9.89 ± 0.53	1.43 ± 0.07	34.9 ± 6.4	13.06 ± 0.50	1.63 ± 0.09	49.4 ± 9.2	379.5 ± 211.1	4.4 ± 2.3
	f	173	9.88 ± 0.51	1.43 ± 0.07	34.8 ± 6.4	13.00 ± 0.39	1.63 ± 0.07	49.9 ± 7.9	354.0 ± 231.6	4.6 ± 2.3
Badminton	m	32	9.63 ± 0.35	1.39 ± 0.05	31.5 ± 4.3	12.94 ± 0.36	1.58 ± 0.08	44.7 ± 7.4	313.1 ± 182.8	3.8 ± 2.4
	f	11	9.51 ± 0.33	1.38 ± 0.06	31.6 ± 4.9	12.80 ± 0.32	1.59 ± 0.06	46.4 ± 7.8	263.3 ± 149.1	3.5 ± 2.0
Basketball	m	23	10.29 ± 0.88	1.48 ± 0.08	38.1 ± 7.8	13.26 ± 0.67	1.68 ± 0.10	54.1 ± 9.9	321.1 ± 157.4	4.1 ± 1.8
	f	3	9.37 ± 0.58	1.42 ± 0.05	33.1 ± 4.6	12.50 ± 0.52	1.64 ± 0.08	47.6 ± 2.3	360.0 ± 254.6	3.7 ± 0.4
Fencing	m	25	9.92 ± 0.50	1.40 ± 0.05	32.5 ± 4.5	13.17 ± 0.61	1.58 ± 0.06	45.8 ± 7.9	371.7 ± 90.4	3.8 ± 1.9
	f	29	9.64 ± 0.34	1.41 ± 0.07	33.8 ± 5.7	12.95 ± 0.35	1.62 ± 0.08	50.6 ± 8.4	379.1 ± 98.1	4.0 ± 1.8
Gymnastics	m	--								
	f	3	9.73 ± 0.2	1.33 ± 0.06	27.7 ± 1.48	12.83 ± 0.17	153.0 ± 6.0	40.6 ± 1.8	600.0 ± 415.7	7.8 ± 2.6
Hockey	m	6	9.89 ± 0.38	1.40 ± 0.05	32.5 ± 6.3	13.08 ± 0.40	1.60 ± 0.07	45.8 ± 8.9	306.3 ± 98.4	7.6 ± 3.4
	f	2	11.04 ± 1.51	1.55 ± 0.11	44.3 ± 6.9	13.21 ± 0.59	1.67 ± 0.04	55.6 ± 5.0	300.0 ± 84.9	8.2 ± 2.8
Judo	m	8	9.75 ± 0.49	1.39 ± 0.07	37.7 ± 12.2	12.92 ± 0.47	1.58 ± 0.08	51.5 ± 13.4	212.1 ± 88.9	4.7 ± 1.9
	f	4	10.0 ± 0.51	1.32 ± 0.04	30.1 ± 3.1	13.21 ± 0.06	1.53 ± 0.07	55.6 ± 5.0	300.0 ± 84.9	8.2 ± 2.8
Rowing	m	37	10.00 ± 0.40	1.48 ± 0.06	38.4 ± 4.1	13.21 ± 0.36	1.70 ± 0.07	54.9 ± 8.5	438.3 ± 153.1	3.3 ± 1.5
	f	15	10.06 ± 0.61	1.46 ± 0.06	37.6 ± 6.6	13.22 ± 0.46	1.66 ± 0.07	52.8 ± 8.0	457.8 ± 137.3	2.7 ± 0.5
Swimming	m	34	9.71 ± 0.44	1.42 ± 0.06	34.1 ± 4.1	12.79 ± 0.42	1.60 ± 0.10	48.0 ± 7.7	534.9 ± 314.6	6.0 ± 1.9
	f	43	9.85 ± 0.39	1.42 ± 0.08	34.7 ± 6.2	12.95 ± 0.43	1.61 ± 0.08	49.0 ± 8.6	397.1 ± 390.2	6.6 ± 2.3
Table tennis	m	10	9.80 ± 0.39	1.42 ± 0.07	34.1 ± 4.1	12.99 ± 0.40	1.62 ± 0.10	49.3 ± 10.8	301.7 ± 141.6	2.9 ± 1.8
	f	--								
Tennis	m	20	9.73 ± 0.42	1.42 ± 0.06	33.5 ± 4.5	12.91 ± 0.49	1.60 ± 0.09	46.2 ± 7.6	302.0 ± 208.4	5.6 ± 2.7
	f	15	9.95 ± 0.82	1.44 ± 0.07	34.5 ± 7.2	12.99 ± 0.26	1.63 ± 0.07	50.3 ± 7.1	248.8 ± 122.8	5.5 ± 2.4

Volleyball	m f	12 44	10.20 ± 0.41 10.08 ± 0.34	1.45 ± 0.06 1.45 ± 0.06	36.6 ± 6.9 36.4 ± 6.8	13.34 ± 0.36 13.09 ± 0.37	1.65 ± 0.05 1.65 ± 0.06	53.1 ± 8.0 51.8 ± 6.8	334.1 ± 129.1 307.7 ± 93.8	3.1 ± 1.1 3.6 ± 1.2
Wrestling	m f	1 4	11.22 9.69 ± 0.36	1.47 1.40 ± 0.06	35.8 31.9 ± 4.9	14.58 13.04 ± 0.39	1.68 1.59 ± 0.05	50.1 44.9 ± 7.3	420 438.8 ± 67.5	7.6 3.3 ± 2.2
Total	m f	1075 515	9.90 ± 0.50 9.85 ± 0.48	1.42 ± 0.06 1.41 ± 0.07	34.1 ± 5.6 33.5 ± 5.8	13.05 ± 0.44 13.03 ± 0.40	1.61 ± 0.09 1.61 ± 0.07	48.3 ± 9.1 49.2 ± 7.6	290.6 ± 130.4 298.5 ± 167.3	6.4 ± 2.6 5.0 ± 2.4

Table 2. Mean Z-scores in grade 4 for different sports and results of ANCOVAs (differentiated by sex; Z-scores are calculated gender-specific).

	Sex = m	Soccer N = 563	Track and field N = 135	Handball N = 166	Other disciplines N = 206	
PF grade 4	Mean Z ± SD	109.9 ± 5.0	113.1 ± 3.8	111.3 ± 3.9	110.0 ± 4.8	
ANCOVA N = 895	Sum of squares	df	Mean of squares	F	p	η^2
Sport discipline	1157.1	3	385.7	17.8	< 0.001	0.057
Training volume	351.2	1	351.2	16.3	< 0.001	0.018
Training years	26.2	1	26.2	1.2	0.271	0.001
	Sex = f	Soccer N = 57	Track and field N = 181	Handball N = 102	Other disciplines N = 174	
PF grade 4	Mean Z ± SD	109.9 ± 4.0	112.6 ± 4.6	111.3 ± 4.2	110.9 ± 4.7	
ANCOVA N = 432	Sum of squares	df	Mean of squares	F	p	η^2
Sport discipline	469.7	3	156.5	8.0	< 0.001	0.054
Training volume	134.1	1	134.1	6.9	0.009	0.016
Training years	7.7	1	7.723	0.4	0.529	0.001

Table 3. Mean Z-scores of grades 4 and 7 of different sports and results of rmANCOVAs (differentiated by sex; Z-scores are calculated gender-specific).

PF grade 4-7	Sex = m	Soccer N = 549	Track and field N = 134	Handball N = 166	Other disciplines N = 202
Grade 4	Mean Z ± SD	109.9 ± 5.0	113.1 ± 3.8	111.3 ± 3.9	110.0 ± 4.8
Grade 7	Mean Z ± SD	108.8 ± 5.1	112.2 ± 4.3	110.6 ± 4.5	110.0 ± 4.9
Diff	Mean Z ± SD	-1.0 ± 4.5	-0.9 ± 4.5	-0.6 ± 4.1	-0.1 ± 4.4

ANCOVA N = 895	Sum of squares	df	Mean of squares	F	p	η^2
Time	76.3	1	76.3	8.3	0.004	0.009
Sport discipline	2009.8	3	669.9	19.1	< 0.001	0.062
Training volume	1083.8	1	1083.8	30.9	< 0.001	0.034
Training years	39.5	1	39.5	1.1	0.288	0.001
Time*sport discipline	25.0	3	25.0	0.9	0.434	0.003
Time*training volume	56.0	1	56.0	6.1	0.014	0.007
Time*training years	0.3	1	0.3	0.04	0.843	0.000

Grade 4-7	Sex = f	Soccer N = 55	Track and field N = 178	Handball N = 99	Other disciplines N = 168
Grade 4	Mean Z ± SD	109.9 ± 4.0	112.6 ± 4.6	111.3 ± 4.2	110.9 ± 4.7
Grade 7	Mean Z ± SD	110.6 ± 3.9	113.1 ± 4.2	111.4 ± 4.1	110.7 ± 4.6
Diff	Mean Z ± SD	+0.7 ± 4.4	+0.5 ± 4.3	+0.1 ± 3.8	-0.2 ± 4.1

ANCOVA N = 432	Sum of Squares	df	Mean of squares	F	p	η^2
Time	8.9	3	8.9	1.1	0.290	0.003
Sport discipline	119.3	3	373.1	12.6	< 0.001	0.083
Training volume	475.6	1	475.6	16.0	< 0.001	0.037
Training years	7.1	1	7.1	0.2	0.623	0.001
Time*sport discipline	51.8	3	17.3	2.2	0.091	0.015
Time*training volume	42.1	1	42.1	5.2	0.022	0.013
Time*training years	0.9	1	0.9	0.1	0.091	0.015

Initial Level of Physical Fitness

The PF in grade 4 was analysed in more detail. Table 2 shows the PF of different sport disciplines in grade 4 and the results of ANCOVAs for each gender. Due to missing values on the questionnaires, the ANCOVAs could only be calculated for 895 boys and 432 girls, although Z-scores could be calculated for almost all test participants (514f, 1070m).

In boys of grade 4, track and field athletes had the highest average Z-score (113.1 ± 3.8), followed by the handballers (111.3 ± 3.9) then other sport disciplines (110.0 ± 4.8) and finally soccer players (109.9 ± 5.0). The average Z-score was influenced by sport discipline ($F = 17.8$; $p < 0.001$; $\eta^2 = 0.071$) and training volume ($F = 16.3$; $p < 0.001$; $\eta^2 = 0.018$). However, there was no effect of training years ($F = 1.2$; $p = 0.271$; $\eta^2 = 0.001$).

In girls of grade 4, track and field athletes had the highest average Z-score (112.6 ± 4.6), followed by the handballers (111.3 ± 4.2), other disciplines (110.9 ± 4.7) and finally soccer players (109.9 ± 4.0). This led to a significant difference between the sport disciplines ($F = 8.0$; $p < 0.001$; $\eta^2 = 0.054$). Additionally, the Z-score was influenced by training volume ($F = 6.9$; $p = 0.009$; $\eta^2 = 0.016$), but there was no effect of training years ($F = 0.4$; $p = 0.529$; $\eta^2 = 0.001$). In total, the results of boys and girls are very similar to each other.

Development of Physical Fitness

The development of PF and the results of rmANCOVAs are shown in Table 3.

Considering the development of PF from grade 4 to grade 7 among boys, the relative PF declined slightly over time in all sports ($F = 8.3$; $p = 0.004$; $\eta^2 = 0.009$). The PF of soccer players had the strongest decrease (diff.: -1.0 ± 4.5). The development of PF was influenced by sport discipline ($F = 19.1$; $p < 0.001$; $\eta^2 = 0.062$) and training volume ($F = 30.9$; $p < 0.001$; $\eta^2 = 0.034$) but not training years ($F = 1.1$; $p = 0.288$; $\eta^2 = 0.001$). An additional significant interaction between time (from grade 4 to grade 7) and training volume was found among boys ($F = 6.1$; $p = 0.014$; $\eta^2 = 0.007$). There was no significant interaction between time and sport discipline ($F = 0.9$; $p = 0.434$; $\eta^2 = 0.003$) or training years ($F = 0.04$; $p = 0.843$; $\eta^2 = 0.000$).

Regarding the relative development of PF from grade 4 to grade 7 in girls, relative PF increased slightly over time; however, there was no significant effect of time ($F = 1.1$; $p = 0.290$; $\eta^2 = 0.003$). The PF of soccer players increased the most (diff.: +0.7 ± 4.4) and there were also increases in handball and track and field; whereas the relative PF of athletes from other disciplines decreased (diff.: -0.2 ± 4.1). The development of PF was influenced by sport discipline ($F = 12.6.$; $p < 0.001$; $\eta^2 = 0.083$) and training volume ($F = 16.0$; $p < 0.001$; $\eta^2 = 0.037$). The development of PF was not influenced by training years ($F = 0.2$; $p = 0.623$; $\eta^2 = 0.001$). An additional significant interaction between time and training volume was found among girls ($F = 5.2$; $p = .022$; $\eta^2 = 0.013$). However, there was no significant interaction between time and sport discipline ($F = 2.2$; $p = 0.091$; $\eta^2 = 0.015$) or training years ($F = 0.1$; $p = 0.091$; $\eta^2 = 0.015$).

In the development of relative PF, the girls showed a stable development whereas the boys showed a small decrease in PF. Apart from that, the results of boys and girls are on the same line.

DISCUSSION

The first aim of this study was to measure how the initial level of PF is influenced by discipline, training volume and training age among pupils of sport schools of NRW. The results showed that the initial level of PF in boys and girls was influenced by sport discipline and training volume. The effect sizes are roughly the same in boys and girls and there was no effect of training years.

In the second part of the study, the relative development of PF from grade 4 to grade 7 under consideration of discipline, training volume and training years was analysed. The relative PF of boys declined slightly in the course of the study and was affected by discipline, training volume and the interaction of time and training volume. The relative PF of girls remained stable over the course of the study and was influenced by discipline, training volume and the interaction of time and training volume.

Initial Level of Physical Fitness

We note that the initial level of PF across all sport disciplines was well above the German average (Bös et al., 2009). However, we found differences between the different disciplines. Both male and female track and field athletes performed better than other sport disciplines, and soccer players performed the worst. This could be because track and field is an all-around sport containing a variety of disciplines and movement techniques (Güllich et al., 2004). Especially the tests 20m-sprint and 6-minute run show a high resemblance to the running disciplines in track and field. For soccer players, however, technical (Ali, 2011) and tactical (Kannekens, Elferink-Gemser, Post, & Visscher, 2009) skills are more important for success than motor abilities. These properties are very sport-specific and do not necessarily improve general PF.

In addition to the particular discipline, training volume in the main sport discipline has a small positive effect on the initial level of PF. At both the expert and non-expert level, there is a high correlation between training volume and performance (Baker & Horton, 2004; Baker et al., 2012). A continual increase in training volume is probably one of the highest priorities in contemporary training, especially for aerobic sports (Bomba, 1999). Youth training is a prerequisite for elite training and includes varied basic training that can improve general PF. Before puberty, coordination, speed and strength-endurance training are most important; whereas after puberty, training should include stronger loads of the anaerobic processes and comprehensive specific training (Hoffmann & Pfützner, 2014).

The variance due to training volume was low in our study. One reason could be the different training content and intensity in different sports, which are more important than volume itself (Ostojic & Ahmetovic, 2008).

The number of completed training years had no effect on the initial level of PF. This may be because this provides no information about training duration, frequency or intensity in the temporal environment of the tests; also this parameter provides no information on the type of training (club, regional or individual; Baker et al., 2012) or the type of control used.

Development of Physical Fitness

Concerning the development of relative PF in boys, the results show a small negative time effect of less than one Z-point among boys. Although it is statistically significant in this large sample, it is not of practical relevance. For example, in the standing long jump in ten years old boys (mean: 146 cm), a Z-score of one is equivalent to two cm. Among girls, relative PF remained stable.

It should be noted that the sports pupils' results are far above the German average in grades 4 and 7. The better the initial level of PF, the smaller the residual potential to improve in the future (Hohmann & Seidel, 2003). However, it also shows that the extra athletic training and extensive physical education in sport schools could not increase the difference in PF between sport pupils and the German average from grade 4 to grade 7. This does not meet the expectation that sports schools will be able to raise the average relative level of

PF of their pupils. One possible explanation is that physical and anthropometric parameters are not linear during adolescence (Vaeyens et al., 2008; Abott, Button, Pepping, & Collins, 2005). The development of endocrinology during puberty enormously increases the effects of training, especially in males (Beunen & Malina, 1988). For this reason, further performance increases are expected, especially in strength-based tests.

Looking at the aspects of sports discipline, training volume and training years, there was a similar trend to the initial level of PF. The development of PF is influenced by sport discipline and training volume, whereas training years are not a significant predictor. Besides, the interaction between time and training volume influenced the PF development. There was no significant interaction between time and sport discipline or between time and training years.

The male soccer players lost in the course of the study, although the initial level of PF was already relatively poor compared to the other sport disciplines. This highlights that the requirements in football are specialized and not strongly related to general fitness as is the case with track and field. The PF of the other 12 sports did not decrease, but the reasons cannot be conclusively clarified in this study.

Among girls, the reverse result was seen: football players improved the most but nevertheless, the mean was below the other disciplines. The other 12 sports suffered a loss of PF. Overall, there were marginal differences relating to the development of PF, and these could have been influenced by form on the day or fatigue from the training sessions (Lidor, Coté, & Hackford, 2009).

PF was positively influenced by training volume, both on its own and in interaction with time, a result consistent with results from other studies. Empirical examinations support the relationship between training and skill development (Baker & Coté, 2006), as seen in this study. Therefore, sport-specific training in youth should always include basic training (Hofmann & Pfützner, 2014) as this can improve general PF. Especially at the beginning of the training, rapid improvements are seen. Despite the decline in learning rate over time, training volume and development rate are positively correlated and are both influential. Training amount depends on the available resources (e.g. coaches), the motivation of the athletes and optimal training stress (Baker & Coté, 2006). The effect sizes of training volume alone are therefore likely to be rather low.

Strengths & Limitations of the Study

The interdisciplinary approach in this study allows a comparison of different sport disciplines in terms of PF, training volume and training years and can expand the knowledge in the area of TID. Furthermore, the standard values (6 out of 8 tests; Bös et al., 2009) allow comparisons with the average German population.

The DMT is a quality-proven test battery that allows a standardized assessment of PF. It was employed in the current study to measure the PF of 1590 sport pupils in grades 4 and 7. At every sport school, the FoSS trained the test instructors and carried out quality control on one testing day annually. In this context, suggestions for reliable testing are given, if necessary. Consequently, high quality and comparability of the test data can be expected.

From a talent perspective, the initial level of PF and the development rate of PF were analysed in this study. Physical performance testing is only one aspect of the process of talent detection during early development in sport (Lidor, Coté, & Hackford, 2009). The aspects utilization of performance conditions and load tolerance (Hohmann & Seidel, 2003) were not included in the analysis. Another limitation of the study is that the periods of the baseline and the follow-up measurement of individual schools can differ. Therefore, small distortions concerning the development rates may have occurred. However, these deviations are unlikely to have impacted the results.

Additionally, the questionnaire could capture more details about quantitative training history, such as total training, club training, regional training and individual training (Baker et al., 2012). In this context, it should be noted that the training volume of pupils is surprisingly high, perhaps because some pupils overestimated their training volume. In the future, test instructors should capture training volume with their pupils. Another point to consider is that training years and volume were only assessed in grade 7 and not in grade 4. It would be better if this information was collected annually to get a better overview of quantitative training history. This approach could better explain the variance. In further studies, we also suggest tracking the biological age as well as calendar age to explain leaps in development or stagnations in certain individuals.

Finally, we have to state that it is difficult to classify the results of this study into the current state of research. This is because large-scale testing is very expensive and not always efficient, and is therefore often replaced by sport-specific methods (Pearson, Naughton, & Torode, 2006).

CONCLUSION

The initial level of PF of sport pupils is much higher than the German average. However, there are clear differences between sport disciplines in this study: for example, young track and field athletes receive a solid basic training, whereas soccer players carry out more sport-specific training. Consistent with the literature, PF was influenced by training volume (Baker & Horton, 2004). In both boys and girls, the effect sizes are low.

In relation to the normal population, boys showed a slight decrease in PF from the 4^{th} to the 7^{th} grade, whereas the girls' PF remained stable. It seems that there is still potential to optimize training and physical education at the 18 sports schools.

It has been shown that the development of PF is also influenced by the sport discipline. Moreover, PF is affected by training volume and the interaction between training volume and time. The results of the present study support the findings of other studies (Baker & Coté, 2006). The training years did not influence either the initial level of PF or the development of PF. In further studies, more information on the type of training should be assessed.

AUTHOR DISCLOSURE STATEMENT

The authors declare no competing or conflicting interests.

ACKNOWLEDGMENT

We acknowledge support by Deutsche Forschungsgemeinschaft and Open Access Publishing Fund of Karlsruhe Institute of Technology.

We acknowledge support by Staatskanzlei Nordrhein-Westfalen.

All participants provided informed consent about their participation. The study was approved by the review board of Institute of Sports and Sports Science, Karlsruhe Institute of Technology and performed in comply with the current laws of Germany.

ABBREVIATIONS

DMT – German Motor Test 6-18
FoSS – *Research Centre of School Sports and the Physical Education of Children and Young Adults*
NRW – North Rhine-Westphalia
PF – Physical Fitness

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