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INCREASED CAROTID INTIMA-MEDIA THICKNESS AND IMPAIRED SPORT MOTOR FITNESS IN OBESE ADOLESCENTS: WHAT ARE THE EFFECTS OF A SHORT-TERM MULTIDISCIPLINARY INTERVENTION?

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Abstract

Introduction: Early risk screening is important in cardiovascular (CV) atherosclerosis prevention. In overweight and obese children we assessed carotid intima-media thickness (IMT) and sport motor fitness and evaluated the CV effects of a 4-weeks hospitalized intervention program.

Methods: N=212 adolescents, thereof n=89 obese, age 11–15 years, were examined at baseline. The obese patients were re-tested at discharge of the intervention.

The examination integrated anthropometric data, BMI, body fat, blood pressure, resting heart rate and a sonography of IMT. The fitness test battery included the assessment of endurance capacity, strength, coordination and flexibility.

Results: In overweight and obese patients IMT was significantly ($p=0.023$) increased (0.584 ± 0.045 mm) compared to controls (0.532 ± 0.045 mm). IMT was associated with age ($r=0.213$, $p=0.041$), weight ($r=0.225$, $p=0.032$) and BMI ($r=0.263$, $p=0.015$). BMI was shown to be the only predictor for variable (ß=0.263, $p=0.030$) for IMT ($F\ [1.66] = 4.899$, $p=0.030$), adjusted $R^2 = 5.5\%$. However, after IMT was adjusted for sex and age the statistical significance reduced to a level that did not reach the formal level of significance ($r=0.185$, $p=0.065$). BMI, body composition, systolic and diastolic blood pressure could be significantly reduced by the intervention. However, there was no change in IMT. Skill-related physical fitness in overweight and obese adolescents was impaired in all tested components, but could be significantly improved by the intervention.

Conclusion: Increased IMT is present in obese patients. The multidisciplinary intervention enhanced CV factors and fitness. However, pathological vascular wall changes need longer time for their re-adaptation.

Keywords: intima-media thickness, sport motor fitness, intervention, obesity, paediatrics.

INTRODUCTION

Overweight and obesity prevalence are increasing in children worldwide[1-4]. The World Health Organization has declared obesity as a global epidemic. Using international definitions, at least 10% of the school children worldwide are overweight or obese, whereas the Americans are leading (32%), followed by Europe (20%) and after that the Middle East (16%)[3]. In Germany 8.7% of the children and adolescents between 3 and 17 years of age are overweight, 6.3% are obese. One of the main concerns of the rise in paediatric obesity is the possible impact that this will have on adult atherosclerotic disease rates in the future[5].

The main approach to decrease obesity-related cardiovascular risk is to reduce body weight. Previous studies in adults describe that a reduction of BMI of at least 1, over a period of one year leads to a lower rate of morbidity[6]. However in children, the interpretation of studies focusing on the result of reducing BMI is difficult, since BMI increases in healthy normal weight children with increasing age[7,8].

In childhood and adolescents there are only few studies showing that weight reduction leads to improvement of the atherogenetic risk factor profile[9].

Intervention strategies in obese children: The importance of exercise and the role of sport motor fitness in cardiovascular prevention of overweight and obese children

It is now widely accepted that atherosclerosis is a chronic disease, having its origin in childhood. Since the atherosclerotic progression takes a long time before the development of measurable plaques are manifested[10]. It is important to evaluate the arterial health status, by measuring the carotid intima-media thickness (IMT) and further to analyze the role of physical exercise and over all physical fitness in this process. Studies in adults revealed controversial results. Moreau and co-workers[11] found out that training does not typically have an impact on IMT. Contradictory a recent study in elite athletes examined consistently lower carotid wall thickness in athletes versus control subjects[12]. Findings of the Amsterdam Growth and Health Longitudinal Study described that cardiovascular fitness was an independent determinant of arterial stiffness, independently from obesity and the metabolic syndrome[13].

In obese children it has generally been stated that levels of physical activity in childhood have protective effects on body composition and cardiovascular disease[14]. However, overweight and obese children prefer a sedentary lifestyle, which leads to less sport motor ability and physical fitness[15]. Modules in intervention programs are multi-factorial and multi-disciplinary and include both dietary and physical exercise and activity pattern.

Currently it remains unclear, if sport motor fitness components such as cardiorespiratory endurance, muscular strength and muscular endurance, speed, coordination and reaction time have a positive effect on IMT in overweight and obese adolescents.

Furthermore, little is known about the impact of multidisciplinary interventions on these parameters.

OBJECTIVES

The present study aimed to assess the vascular status (IMT) and sport motor fitness in overweight and obese children and adolescents compared to normal weight peers. Secondly, correlations between traditional cardiovascular risk factors (BMI, total percentage of body fat, systolic and diastolic blood pressure), surrogate markers and physical fitness components in overweight and obese adolescents are calculated.

Thirdly, a short-term stationary rehabilitation program was evaluated to examine whether it has an effect on cardiovascular risk factors, including vascular structural changes and sport motor fitness.

Study hypotheses

1. IMT is significantly enlarged in overweight and obese children and adolescents in comparison to normal weight peers.
1. IMT is associated to non-invasively measured traditional cardiovascular risk factors in overweight and obese adolescents.
2. Obese and overweight adolescents have significantly impaired sport motor fitness compared to non-obese peers.
3. IMT and traditional non-invasive cardiovascular risk factors are significantly associated to components of sport motor fitness (speed of limb movements, reactive strengths, coordination and speed, coordination and reaction time, cardiorespiratory fitness, upper trunk muscular endurance strength, abdominal muscular endurance strength).
4. A 4-week hospitalized multidisciplinary intervention reduces cardiovascular risk factors and increases performance in sport motor skills.

METHODS

A total of 212 children and adolescents were examined. Thereof 89 study participants attended a hospitalized intervention at the Rehabilitation Centre/Clinic Gaissach, Bad Tölz/Germany, and were consecutively examined in the first week after admission (baseline). To analyze the effects of the hospitalized intervention program, 85 obese adolescents were measured at baseline and 4-weeks later. The inclusion criteria for participation in the trial were: age 11 to 15 years, no history of cardiovascular disease and no personal history of diabetes mellitus or impaired fastening glucose. Obesity was defined as a BMI > 97th percentile, using population specific data[8]. All patients participated in the intervention according to the National guidelines[16]. The program was multidisciplinary and based on physical exercise, nutrition education (high carbohydrate, fat reduced diet) and behaviour therapy including individual psychological care of the child. An interdisciplinary team of paediatricians, diet

assistants, psychologists and sport scientists were responsible for the interventional training.

The control group consisted of children and adolescents from Munich secondary schools.

The same medical doctors and sport scientists performed the investigation.

The assessment included sonography of the A. carotis communis, distal of the carotid artery bifurcation on a segment ≥ 1 cm length (GE Loqiq Book XP. 10 Mhz linear probe). Further anthropometric data height, weight, BMI, body composition (FUTREX 6100 AL) and resting (15 min.) blood pressure were taken. Both sonography and anthropometric data collection were performed in the mornings before the sport motor fitness tests following a standardized protocol as previously described[17].

Description of the sport motor fitness test

Further a self-assessed health and skill related physical fitness test was conducted by sport scientists and qualified staff. The tests were performed in the sport gymnasium of the Clinic in Gaissach for all hospitalized patients. For the control group the tests were performed on two afternoons in the sport laboratory of the Faculty of Sport and Health Sciences, Technische Universität München.

Both the laboratory and sports gymnasium of the clinic were provided with standardized gymnastic facilities and were complementally equipped with the computer-based test system[18]. Due to a lack of a wall bar in the laboratory the bent-arm hang could not be tested in the control group.

The physical fitness tests were performed in the afternoons starting off with a 10-minute warm-up program, followed by a 9-minute run on the first afternoon. On the next day, the same warm-up program was performed, followed by a pre-set test order (tapping, drop jump, complex coordination and reaction time test, a 10 m coordination run, sit-ups and bent-arm hang).

Tapping – assessment of speed of limb movement

The aim of the test was to perform as many contacts on the force plate as possible with the right and left foot. This tapping frequency was measured 4 times during a time of 3 seconds. The tapping frequency is measured in Hertz [contacts per minute]. From the four test trails a mean value of the two best trails was calculated and used for further analysis[19,20].

Drop jump – assessment of reactive strength

The aim of the test was to jump down from a platform onto a force plate and immediately up on a second landing platform. The contact time on the force platform was measured in milliseconds [msec]. Each subject performed five jumps. In between the

5 jumps a recovery time of at least 10 seconds was integrated in the test. The best jump with the shortest contact time was taken for further analysis[21].

Coordination run – assessment of coordination and speed

Light barriers were set up at the start line and finishing line within a distance of 10 meters. 5 meters in front of the start line was the preparation point for the test person. The coordination run consisted of 6 squares (total lengths 3.30 meters), which were set up in a row, pair wise (one for the left foot and one for the right foot). A second set of 6 squares was set up with an interspace of 2 meters.

The objective of the coordination run was to run through squares as fast as possible without making a step mistake, e. g right foot steps in right square, left foot steps in left square. The subject had three trials; the best trial (run time in seconds) was counted for statistical analysis[18,22].

Complex reaction test – assessment of coordination and reaction time

The computer screen was divided into 4 sections, two sections for the hands (left and right side) and two sections for the feet (left and right side). The hardware consisted of two hand plates and a force plate with two sections for the right and left foot. The hand sensor plates were set up on the table in front of the test person, the force plate was under the table. Similar to the hardware the computer screen was divided. Two white fields on the screen marked for the hand plates and two blue fields marked for the contact area´s for the feet. After the test start, different black signals appeared on the screen in random order. The aim was to touch the hand and feet plates exactly as their combinations appear on the screen. A following image only appears after the correct repetition of the showed combination. 30 different combinations were shown. The time was counted in seconds. Each test person had three trials. The best trial was counted for further analysis[18].

Sit-and-reach test – assessment of hamstring, gluteal and lower back muscle flexibility

One of the most commonly used field tests for hamstring, gluteal and lower back musculature flexibility in children is the sit-and-reach test. It has one of the highest test-retest reliabilities (r=0.89 to 0.97) for measures of flexibility[23]. With legs fully extended and no shoes, the children were asked to reach forward three times and hold position on maximal reach along a ruler which was placed on the top of the box. Research assistance recorded farthest reach to the nearest cm. The differences between the feet and the tip of the longest finger was measured in cm[24,25].

9-minute run – assessment of cardiorespiratory endurance capacity

Cardiorespiratory endurance capacity was assessed in all students using a group administered timed 9-minute run. Standards of performance for youth are well established, and test-retest reliability in third grade students was 0.90. Correlations with more complex measures of fitness were estimated in the pilot phase of the CATCH study[26,27].

Bent-arm hang – assessment of upper trunk muscular endurance strength

The bent-arm hang was tested and instructed as previously described in the Handbook for Eurofit Tests of Physical Fitness[24,25]. The child maintained a bent-arm position while hanging on a bar with a forward grip at shoulder width. The time in tenth of a second was the score.

Sit-ups – assessment of abdominal and endurance strength

The children were instructed to keep arms folded across the chest, place feet about 38 cm from the buttocks, touch the elbows to thighs on the upward position, and touch mid-back to mat on the downward position. For testing purposes the participants' feet were held down by another participant and floor mats were provided for comfort. The test measures abdominal muscular endurance. The maximum number of achieved sit-ups in 30 seconds was counted[24,25,28].

Statistical analysis

All data were analysed in SPSS 16.0. Weight groups were determined by BMI reference values for German children as standardized by the German Obesity Association[8], defining BMI >90th percentile as overweight, >97th percentile as obese.

Normal distribution was tested using Kolmogorov-Smirnov-Test. Since the data show a Gaussian distribution, data are presented as mean and SD for continuous variables. Univariate, unadjusted analyses between obese and control subjects were performed with the independent samples t-test. ANCOVA was used to evaluate the presence of confounding variables in relationship between obesity status and vascular parameters. Models were adjusted for several confounding variables, including sex, age, height, systolic and diastolic blood pressure. Adjusted IMT means and 95% confidence interval (CI) were estimated with the use of Bonferroni method.

For comparisons between baseline and post examination 4-weeks later, the paired sample t-test for paired samples was used.

Unadjusted relationships were assessed with Pearson's correlation analysis. To evaluate the independence of correlates of risk factors and to assess the main predictor for increased IMT, stepwise multiple linear regression analysis was used. IMT

adjusted by sex and age was integrated in the model as dependent variable and BMI, the total percentage of body fat, systolic and diastolic blood pressure values were included as independent variables.

To evaluate the independence of correlations of IMT, cardiovascular risk factors and health- and skill-related physical fitness, and to assess main predictors for increased IMT and cardiovascular risk factors, multiple linear regression analysis (enter method) was used. IMT, BMI, body fat, systolic and diastolic blood pressure (all adjusted by sex and age) were integrated as independent variables and the test components for sport motor fitness were also adjusted by age and sex and integrated in the model as dependent variables.

In all regression analysis it was thoroughly checked for non-collinearity to avoid violations of model assumptions. Residuals were tested and the distribution was normal. All covariates included in the model were tested for interactions with each other. Because the variance inflation factor (VIF) was <5 and condition indices were <15, no correction for collinearity of the data was necessary[29]. A *P* value of less than 0.05 indicated statistical significance.

RESULTS

Table 1 displays an overview of the anthropometric data and IMT of the A. carotis communis in overweight and obese patients compared to normal weight peers.

Table 1. Descriptive data of the studied obese patients compared to normal weight control subjects

	Group	N	Mean	SD	P value
Age [years]	Normal weight	123	12,97	1,33	0,047
	Overweight/ obese	89	13,39	1,68	
Height [m]	Normal weight	123	1,61	0,1	0,019
	Overweight/ obese	89	1,64	0,09	
Weight [kg]	Normal weight	121	51,03	9,94	<0.001
	Overweight/ obese	89	86,93	24,32	
BMI [kg/m^2]	Normal weight	123	19,31	2,03	<0.001
	Overweight/ obese	89	31,76	6,96	
Body fat [%]	Normal weight	116	20,79	7,36	<0.001
	Overweight/ obese	85	37,91	7,47	

Systolic blood pressure [mmHg]	Normal weight	122	111,87	11,08	<0.001
	Overweight/ obese	85	122,56	14,37	
Diastolic blood pressure [mmHg]	Normal weight	122	67,38	9,06	0,002
	Overweight/ obese	85	63,36	8,51	
IMT [mm]	Normal weight	91	0,532	0,045	0,023
	Overweight/obese	74	0,548	0,045	

Values are presented as means +/- SD. Independent sample t-test was performed to investigate group differences. The level of significance vas $P < 0.05$.

In total, the obese and overweight patients were older (p=0.047). They were also significantly taller than their lean peers. Unquestionably the obese and overweight children and adolescents had significantly higher weight, showed a higher BMI and a higher percentage of total body fat compared to the control group (all p<0.001). Systolic blood pressure was significantly (p<0.001) higher in overweight and obese children as well as diastolic blood pressure (p<0.001). The IMT was significantly (p=0.023) thicker in overweight and obese children compared to normal weight children.

Differences between boys and girls are presented in Table 2 and 3 for overweight and obese children compared to normal weight children. The overweight and obese boys were significantly taller (p=0.003), heavier, had a higher BMI and higher percentage of body fat and a higher systolic and diastolic blood pressure (p=0.049). Also the IMT was significantly increased (p=0.033) compared to the control group. There was no significant difference in age (p=0.075) in boys.

Table 2 Descriptive data of the studied obese patients compared to normal weight control subjects for boys

Sex		Group	N	Mean	SD	*P* value
Boys	Age [years]	Normal weight	67	13,01	1,38	0,075
		Overweight/ obese	45	13,51	1,53	
	Height [m]	Normal weight	67	1,62	0,11	0,003
		Overweight/ obese	45	1,68	0,09	

Boys	Weight [kg]	Normal weight	67	51,85	11,13	<0.001
		Overweight/ obese	45	90,81	25,26	
	BMI [kg/m^2]	Normal weight	67	19,46	2,08	<0.001
		Overweight/ obese	45	31,67	6,22	
	Body fat [%]	Normal weight	62	17,48	8,14	<0.001
		Overweight/ obese	43	36,56	8,06	
	Systolic blood pressure [mmHg]	Normal weight	67	113,48	11,15	<0.001
		Overweight/ obese	45	124	15,58	
	Diastolic blood pressure [mmHg]	Normal weight	67	67,91	9,59	0,049
		Overweight/ obese	45	64,31	9,04	
	IMT [mm]	Normal weight	53	0,535	0,045	0,033
		Overweight/obese	32	0,555	0,037	

Values are presented as means +/– SD. Independent sample t-test was performed to investigate group differences. The level of significance vas $P < 0.05$.

Table 3 Descriptive data of the studied obese patients compared to normal weight control subjects for girls

Sex		Group	N	Mean	SD	*P* value
Girls	Age [years]	Normal weight	56	12,92	1,29	0,289
		Overweight / obese	44	13,26	1,83	
	Height [m]	Normal weight	56	1,61	0,08	0,889
		Overweight/ obese	44	1,61	0,08	
	Weight [kg]	Normal weight	56	50,05	8,27	<0.001
		Overweight/ obese	44	82,97	22,92	
	BMI [kg/m^2]	Normal weight	56	19,14	1,96	<0.001
		Overweight/ obese	44	31,86	7,7	

Girls	Body fat [%]	Normal weight	54	24,59	3,72	<0.001
		Overweight/ obese	42	39,3	6,61	
	Systolic blood pressure [mmHg]	Normal weight	56	109,91	10,78	<0.001
		Overweight/ obese	40	120,95	12,87	
	Diastolic blood pressure [mmHg]	Normal weight	56	66,73	8,42	0,011
		Overweight/ obese	40	62,3	7,85	
	IMT [mm]	Normal weight	38	0,528	0,046	0,174
		Overweight/ obese	42	0,543	0,05	
		Overweight/ obese	42	0,543	0,05	

Values are presented as means +/– SD. Independent sample t-test was performed to investigate group differences. The level of significance vas $P < 0.05$.

Overweight and obese girls were heavier, showed a higher BMI, as well as a higher total percentage of body fat (all p<0.001). Further, systolic blood pressure (p<0.001) and diastolic blood pressure (p=0.011) were increased compared to the healthy control group in girls.

Concerning IMT in girls, no significant difference was found in overweight and obese subjects compared to the non-obese controls.

The analysis of carotid IMT in the total study population revealed that, when adjusted for sex, age and height, there was still evidence of statistically significant differences between obese children and adolescents and control subjects. IMT in overweight and obese patients was 0.549 mm (95% CI 0.538 – 0.559) and in healthy control subjects it was 0.532 mm (95% CI 0.523 – 0.542, p=0.022). Adding diastolic blood pressure as a covariate reduced the p-value, but the statistical significance was retained (p=0.037). However, when systolic blood pressure was substituted the statistical significance was further reduced to a level that did not reach the formal level of statistical significance. IMT in obese patients was then 0.547 mm (95% CI 0.536 – 0.558), and IMT in healthy control subjects was 0.533 mm (95% CI 0.524 – 0.543, p=0.076).

Relationships between IMT and traditional cardiovascular risk factors in overweight and obese children and adolescents

The results of the unadjusted correlation analysis of anthropometric parameters, traditional cardiovascular risk factors (BMI, the total percentage of body fat, systolic

and diastolic blood pressure) and IMT are presented in Table 4. Age was found positively correlated to IMT (r=0.213, p=0.041) as well as weight (r=0.225, p=0.032) and BMI (r=0.263, p=0.015).

Table 4 Relationships between non-invasive cardiovascular risk factors in overweight and obese patiens (n = 68)

		IMT [mm]	Age [years]	Height [m]	Weight [kg]	BMI [kg/m^2]	Body fat [%]	SBP [mmHg]	DBP [mmHg]
IMT [mm]	r	1	0,213	0,062	0,225	0,263	0,184	0,173	–0,027
	P value	,	0,041	0,307	0,032	0,015	0,067	0,079	0,414
Age	r	0,213	1	0,513	0,514	0,388	0,335	0,13	–0,131
[years]	*P* value	0,041	,	0	0	0,001	0,003	0,146	0,143
Height [m]	r	0,062	0,513	1	0,718	0,33	0,309	0,4002	0,126
	P value	0,307	0	,	0	0,003	0,005	0	0,153
Weight [kg]	r	0,225	0,514	0,718	1	0,885	0,644	0,402	0,07
	P value	0,32	0	0	,	0	0	0	0,286
BMI	r	0,263	0,388	0,33	0,885	1	0,726	0,291	0,03
[kg/m^2]	*P* value	0,015	0,001	0,003	0	,	0	0,008	0,406
Body fat [%]	r	0,184	0,335	0,309	0,644	0,726	1	0,261	–0,116
	P value	0,067	0,003	0,005	0	0	,	0,016	0,174
SBP [mmHg]	r	0,173	0,13	0,402	0,402	0,291	0,261	1	0,256
	P value	0,079	0,146	0	0	0,008	0,016	,	0,018
DBP [mmHg]	r	–0,027	-0,131	0,126	0,07	0,03	–0,116	0,256	1
	P value	0,414	0,143	0,153	0,286	0,406	0,174	0,018	,

Pearson correlation coefficients and *P* values are describing the relationship. The level of significance was defined as $P < 0.05$.
Abbreviations: IMT – Intima-media thicknessof the A. carotis communis; BMI – Body mass index; SBP – Systolic blood pressure; DBP: Diabolic blood pressure.

In the multiple linear regression analysis BMI was shown to be the only predictor for variable (ß=0.263, p=0.030) for IMT (F [1.66] = 4.899, p=0.030), adjusted R^2 = 5.5%. However, after IMT was adjusted for sex and age the statistical significance reduced to a level that did not reach the formal level of significance (r=0.185, p=0.065).

Further, BMI was positively related to systolic blood pressure (r=0.291, p=0.008). Moreover, the total percentage of body fat was related to systolic blood pressure (r=0.261, p=0.016).

Sport motor fitness

Table 5 presents the results of the sport motor fitness tests in overweight and obese boys compared to normal weight controls.

Table 5 Sport motor fitness test results in overweight and obese boys compared to normal weight peers.

	Group	N	Mean	SD	*P* value
Tapping [Hz]	Normal weight	67	11,04	1,34	<0.001
	Overweight/obese	45	15,58	9,33	
Drop jump [msec]	Normal weight	67	145,92	19,73	<0.001
	Overweight/obese	45	219,38	62,74	
Coordination run [sec]	Normal weight	67	6,04	0,76	0,002
	Overweight/obese	45	8,99	7,34	
Complex reaction test [sec]	Normal weight	67	21,59	3,25	0,045
	Overweight/obese	45	23,66	5,26	
Sit-and-reach [cm]	Normal weight	67	–0,59	7,63	0,017
	Overweight/obese	45	–5,34	11,73	
9-minute run [m]	Normal weight	0	,	,	–
	Overweight/obese	45	1064,2	195,8	
Bent-arm hang [sec]	Normal weight	0	–,	–,	–,
	Overweight/obese	45	1,35	2,45	
Sit-ups [n]	Normal weight	67	24,13	9,65	0,01
	Overweight/obese	45	19,38	7,6	

Pearson correlation coefficients and *P* values are describing the relationship. The level of significance was defined as $P < 0.05$.

Obese and overweight boys show inferior fitness in coordination and speed in comparison to their normal weight peers. Further, coordination and visual reaction time, performed in the complex reaction test, are reduced in overweight and obese children and adolescents compared to the results of normal weight peers. Moreover, obese boys show less flexibility and less abdominal muscular endurance. They ran 1064.2 ± 195.8 m in the 9-minute run. The obese and overweight boys managed to hold themselves in a bent-arm hang for a mean time of 1.35 ± 2.45 sec.

Overweight and obese girls performed less in tapping (speed of limb movement) and drop jumps (reactive strength) compared to their normal weight peers.

Further obese girls were slower in the 10 m coordination run and also slower in the complex reaction test. The obese girls further demonstrate impaired hamstring, gluteal and lower back muscle flexibility. They ran 1062.3 ± 170.7 meters in the 9-minute run and managed to hold themselves in the bent-arm hang for 1.32 ± 2.61 seconds.

Interestingly, overweight and obese girls presented better abdominal muscular endurance compared to their lean peers (Table 6).

Table 6 Sport motor fitness test in overweight and obese girls compared to normal weight peers.

	Group	N	Mean	SD	*P* value
Tapping [Hz]	Normal weight	56	10,41	1,81	0,002
	Overweight/obese	44	14,4	8,91	
Drop jump [msec]	Normal weight	56	150,41	24,8	<0.001
	Overweight/obese	44	207,97	52,88	
Coordination run [sec]	Normal weight	56	6,36	1,11	0,001
	Overweight/obese	44	7,1	0,92	
Complex reaction test [sec]	Normal weight	56	22,09	3,11	0,019
	Overweight/obese	44	24,76	5,82	
Sit-and-reach [cm]	Normal weight	56	6,87	8,58	0,001
	Overweight/obese	44	–0,34	10,45	
9-minute run [m]	Normal weight	0	,	,	-
	Overweight/obese	44	1062,3	170,7	
Bent-arm hang [sec]	Normal weight	0	,	,	–,
	Overweight/obese	44	1,32	2,61	
Sit-ups [n]	Normal weight	56	19,37	6,16	0,121
	Overweight/obese	44	21,98	8,37	

Relationships between IMT and sport motor fitness in overweight and obese children

In the multiple linear regression analysis all sport motor fitness test results were adjusted by age and sex and put into the model (enter) for predictor analysis of IMT, which was also adjusted for age and sex. The regression model did not reach the formal level of significance for IMT_{adj} (F [1.44] = 0.219, p=0.952), adjusted R^2 = 0.2%. No significant relationships were found between IMT_{adj} and the health- and skill-related physical fitness tests (all adjusted for age and sex): $tapping_{adj}$ (r=0.038,

p=0.751); drop $jumps_{adj}$ (r=0.010, p=0.938); coordination run_{adj} (r=0.067, p=0.583); complex reaction $test_{adj}$ (r=0.276, p=0.173); sit-and-$reach_{adj}$ (r=–0.14, p=0.251); 9-minute-run_{adj} (r=–0.056, p=0.716); bent-arm $hang_{adj}$ r=–0.107, p=0.417); sit ups_{adj} (r=–0.42, p=0.730).

However, the results of the physical fitness tests correlate with body composition. A positive relationship revealed between the performed ground contact time in drop $jumps_{adj}$ and BMI (r=0.340, p=0.004). Further a positive relation could be assessed between the reaction time in the complex coordination and reaction $test_{adj}$ and BMI (r=0.313, p=0.03). Further a negative relation revealed between the component of flexibility (sit-and-reach $test_{adj}$) and BMI (r=–0.225, p=0.04). Furthermore the achieved running performance in the 9-minute-run_{adj} negatively correlated to systolic blood $pressure_{adj}$ (r=–0.275, p=0.04).

Effects of the hospitalized intervention for obese adolescents

Table 7 presents an overview of the medical data at baseline and 4 weeks later. Anthropometric measurements revealed significant decrease in weight, BMI, and the total percentage of body fat. After the intervention the systolic blood pressure and diastolic blood pressure were significantly decreased. Further the heart rate decreased significantly. After 4 weeks the IMT did not change significantly.

Table 7 Changes in weight, BMI body composition, blood pressure heart rate and carotid IMT at baseline and 4 weeks after the hospitalized intervention

	N	Baseline	SD	4-weeks later	SD	*P* value
Weight [kg]	85	91,44	22,93	82,52	20,65	<0.001
BMI [kg/m^2]	85	33,52	6,99	30,25	6,35	<0.001
Body fat [%]	85	40,18	5,49	36,17	6,34	<0.001
Systolic blood pressure [mmHg]	85	123,55	14,1	115,09	11,73	<0.001
Diastolic blood pressure [mmHg]	85	64,51	8,61	61,69	7,58	0,037
Heart rate [beats/min]	85	85,43	12,37	70,68	12,08	<0.001
IMT [mm]	85	0,549	0,041	0,543	0,05	0,44

Data presented as mean +/– SD. A *P* value ≤ 0.05 was considered to be significant.

Results in physical fitness revealed in most tests an increase in performance (Table 8). The tapping frequency significantly improved after 4 weeks. The ground contact time assessed by drop jumps also reduced significantly. The complex reaction test revealed a significant better overall coordination, resulting in a faster reaction time. Hamstring, gluteal and lower back muscle flexibility and cardiorespiratory

endurance increased significantly after the 4-week intervention. The running coordination and speed assessed by the coordination run, upper body muscular endurance assessed by bent-arm hang and the abdominal muscular endurance assessed by sit-ups did not improve significantly.

Table 8 Changes in sport motor fitness at baseline and 4 weeks after the hospitalized intervention in obese adolescents

	N	Baseline	SD	4-weeks later	SD	*P* value
Tapping [Hz]	85	16,41	9,89	9,67	1,45	<0.001
Drop Jump [msec]	85	229,31	60,33	205,18	50,76	0,011
Coordination run [sec]	85	8,64	6,71	7,04	1,37	0,121
Complex reaction test [sec]	85	27,67	5,6	21,26	2,77	<0.001
Sit-and-reach [cm]	85	–4,11	12,61	–1,4	8,65	0,048
9-minute run [m]	85	1084,5	150,7	1240,2	195,8	<0.001
Bent-arm hang [sec]	85	1,46	2,42	1,74	4,11	0,519
Sit-ups [n]	85	37,6	8,16	38	8,28	0,781

Data presented as mean +/– SD. A *P* value ≤ 0.05 was considered to be significant.

DISCUSSION

Vascular risk of overweight and obesity in children and adolescents

Although the most severe complications of overweight and obesity do not manifest until later in life, cardiovascular health consequences may already be evident at a young age[30]. Furthermore the period of adolescence has been described as a critical period for the development and expression of obesity-related comorbidities in boys and in girls[31].

Summarizing the results, the present study documented:

1. Carotid IMT was significantly increased in overweight and obese children and adolescents compared to healthy controls.
2. Significant correlations revealed between IMT and age; IMT and weight; IMT and BMI.
3. Impaired sport motor fitness in overweight and obese adolescents in most of the tested components (except abdominal endurance strength in girls, which was not impaired).
4. No significant correlations revealed between IMT and sport motor fitness components.
5. Significant correlations revealed between traditional cardiovascular risk factors and sport motor fitness components.

Effects of the multidisciplinary intervention:

1. Significant reductions of atherosclerotic cardiovascular risk factors such as weight, BMI, the total percentage of body fat, systolic and diastolic blood pressure.
2. Significant improvements in sport motor fitness.
3. Vascular structure (IMT) decreased after the intervention but not significantly.

Vascular status in overweight and obese adolescents and relationships to traditional cardiovascular risk factors

In both sexes, the measured IMT values for overweight and obese adolescents in the present study range between the 50th and 75th percentile for boys and for girls in age group 12/13 years[17]. The overweight and obese children show a significantly larger IMT than the control group.

This result could also be stated in boys, however in girls, no significant differences for IMT in overweight and obese adolescents compared to normal weight peers were found. The apparent discrepancy within the present study could be due to the small sample size in girls (42 obese versus 38 controls).

The increased IMT in overweight and obese adolescents was accompanied by significantly higher values in body weight, body fat, systolic blood pressure and diastolic blood pressure. These facts still revealed when adjusting for sex.

Further the correlation of cardiovascular risk factors such as weight and BMI with IMT as well as BMI and body fat with systolic blood pressure suggests that obesity in adolescents represents a powerful determinant of early manifestations of atherosclerosis and affects structural properties of major vessels[32]. The effect of structural changes appears to be mediated, at least in parts, by BMI and systolic blood pressure.

The results of the present study further confirm findings of several studies that documented the association of hypertension and childhood overweight as well as obesity[33-36]. Furthermore, it has been stated that obese children have a tenfold greater risk of developing hypertension as young adults compared to non-obese children. This result is of notable concern since blood pressure values tend to track from adolescence into adulthood, and especially in those who are overweight or obese[37].

Sport motor fitness in overweight and obese adolescents and the correlations to vascular structure (IMT) and cardiovascular risk factors

It is increasingly recognized that physical activity and exercise in children and adolescents is an essential component of healthy growth and development. The biological mechanisms linking exercise, physical fitness and health in children are multifactorial and of special interest due to an emerging epidemic of paediatric obesity, type 2 diabetes and the metabolic syndrome[38-40].

Some authors found differences in fitness between obese and non-obese children, while others did not[41-43]. In the present study sport motor fitness components in obese compared to normal weight adolescents were impaired. The obese adolescents had

mainly impaired performance on all tests requiring propulsion or lifting of the body mass, such as tapping, running coordination and bent-arm hang. Energy intake exceeding energy expenditure is stored in the body mainly as fat, but also in protein. Stored protein increases fat free and muscle mass[44]. Therefore, overweight and obese subjects usually have more muscle mass compared with normal weight individuals[45]. This is associated with better absolute muscle strength in adolescents[46]. But most of the functional tasks require the lifting of body weight. Relative muscle strength (muscle strength in relation to body mass) may be the key component of muscle strength to comply in daily life[44] and not the absolute muscle strength.

These poorer performances are probably due to the fact that their excess body fat is an extra load and therefore has a negative influence on relative muscle strength and muscular endurance, that needs to be moved or held during weight-bearing tasks[47]. This then leads to lower performance in many tests such as drop jumps, tapping, 10-m coordination run and bent-arm hang.

Interestingly in overweight and obese girls the numbers of performed sit-ups did not differ significantly in comparison to normal weight peers. When comparing the results of the control group to German reference values[48] the test performance in sit-ups was only sufficient on a five grading scale (very good, good, normal, moderately disturbed and severely disturbed).

Obesity[49] and overweight[50] had a strong negative effect on endurance and upper body muscular strength and muscular endurance. The present study is in agreement with the above two studies and further underlines results of Malina and co-workers[51].

Furthermore, the results of the correlation analysis reveal a positive association between anthropometric data and sport motor fitness. This can be demonstrated especially in drop jumps, testing the reactive strength of lower extremities and measuring the ground contact time. The contact time is positively associated to weight and BMI that underlines the above mentioned negative impact of body weight in weight lifting tasks[47].

The performed coordination skill was positively associated to BMI, which underlines a more impaired overall coordination and reaction in obese children. Furthermore, in the present study, the overweight and obese adolescents performed significantly slower in the complex coordination and reaction test. Wagner and co-workers[52] underlined the importance of developmental coordination in overweight and obese children in the context of human development. The authors reinforced that the data are of particular interest since developmental coordination and obesity both track with age. The results of their study made it clear that obese show higher severe risk of developmental coordination disorder in comparison to normal weight adolescents. The complex coordination test in the present study focused more on the coordination and reaction time, demonstrating less coordinative skills of overweight children.

The fact that excess body adiposity also increases the likelihood of poorer trunk fitness has been stated previously[53,54] and could also be demonstrated in this study, whereas a negative correlation between flexibility and BMI was assessed.

On the other hand, in the present study cardiorespiratory endurance tested by the 9-minute run was negatively associated to systolic blood pressure. This result underlines published data of intervention studies that reported an effectively reduced blood pressure in overweight and obese children after an exercise intervention[55]. Further, the present results are in line with reports of the Children and Adolescents Trial for Cardiovascular Health (CATCH) study[27]. Analysis of the CATCH trial demonstrated a greater number of cardiovascular risk factors in heavier children and a lower performance on 9-minute endurance run.

Boreham and co-workers[56] demonstrated that relationships between fatness and coronary risk factors were stronger than between fitness and cardiovascular risk factors in adolescents. Also in this study, no association between skill-related physical fitness and IMT could be stated.

Effects of the intervention program

The sedentary lifestyle, and within that the imbalance of energy intake and expenditure, contributes to the increased obesity prevalence in adolescents. Intervention strategies are multi-disciplinary, including nutritional, exercise and behavioural treatment programs.

The main finding of the study is that a 4-week hospitalized intervention already accounts for a significant reduction of atherosclerotic cardiovascular risk factors such as weight, BMI, the total percentage of body fat, systolic and diastolic blood pressure. These results are in line with previous paediatric intervention studies that demonstrated an improvement of cardiovascular risk factor profile in association with obesity[57-60].

In this context, studies of Meyer and colleagues[61] underlined that cardiovascular fitness plays an important role for the improvement of cardiovascular risk factors and further in cardiovascular health prevention to reverse any atherosclerotic damage.

However, in the present study vascular structure (IMT) did not change significantly after 4-weeks of hospitalized intervention. This result is in line with reports of Woo and co-workers[62] who did not find changes in IMT after 6 weeks of exercise and diet intervention. It is possible that pathological changes need longer time for their adaptation or in this case re-adaptation.

Studies of Wunsch and colleagues[63] described parallel to an improvement of the cardiovascular risk profile with substantial weight loss, a decrease of IMT after a 1-year outpatient intervention program.

Taking traditional non-invasively measured cardiovascular risk factors into account the intervention program revealed a significant reduction of systolic and diastolic blood pressure. Those positive effects of exercise had been previously stated after a 8-months intervention program by McMurray and colleagues[64]. Richter and co-workers[65] explained the reduction of blood pressure firstly due to the enhancement of insulin action and glucose transport by physical exercise. A second explanation could be that the increased capitalization results in increased blood flow and energy supply to muscle tissue, which results in an improved fat metabolism and decreased blood pressure[65-68].

Advances in sport motor fitness

Exercise training was a major component in the intervention, daily activity indoor and outdoor sport programs. The exercise intervention not only improved measures of cardiovascular risk factors, but also improved sport motor fitness. A significant improvement revealed in speed of lower limbs assessed by tapping, reactive strength assessed by drop jumps, complex coordination and reaction test, hamstring, gluteal and lower back muscle flexibility assessed by the sit-and-reach test and in cardiorespiratory endurance which was assessed by the 9-minute run.

Complex sport motor assessments in hospitalized intervention obese children are still rare. Results of a Belgium hospitalized intervention study[69] underlined the importance of coordination and motor skill development in overweight and obese children. Their results demonstrated impaired scores for overweight and obese children and an increase in test scores of the Körperkoordinationstest after a short-term intervention. The authors emphasized the importance of gross motor skills in obese children with regard to a possible increase in physical activity. Sola and colleagues[70] also tested a variety of different basic motor abilities and complex movements in different muscle groups before and after 6 and 12 months of intervention. They stated an improvement in physical fitness and also a reduction of BMI over the intervention time.

CONCLUSIONS

The study underlines that vascular structure changes with increased body weight. It could be proven that an increased IMT is present in overweight and obese adolescents compared to normal weight controls. Furthermore, overweight and obese children demonstrated impaired sport motor fitness in almost all tested components. Therefore the results emphasize the need of an early focus on motor abilities. A better motor fitness might encourage overweight and obese adolescents to more sport activity. This is even more important since physical fitness components are in correlation with traditional risk factors. However a correlation between vascular structure and physical fitness could not be stated in the present study. The awareness of the complex relationships emphasized with the fact that obesity in childhood and adolescence is an important risk factor for cardiovascular disease as well as morbidity

and mortality in later life [71-73] underlines the importance of early prevention. The necessity becomes even clearer with the continuing increase in overweight and obese children.

The alterations of the analyzed cardiovascular risk factors were significantly related to the loss of weight throughout the intervention program. In advantage to invasive diagnostics, the ultrasound measurement can demonstrate the effect of the intervention program on the level of the vascular system since it enables an insight into the health of the blood vessel. No significant reduction of IMT could be measured after 4-weeks of hospitalized intervention. Obviously pathological changes need longer time to be reduced.

The multidisciplinary intervention with a focus on daily physical exercise revealed an enhancement in speed of lower limbs, reactive strength, complex coordination and reaction time, hamstring, gluteal and lower back muscle flexibility and endurance capacity. These positive effects might be beneficial for long-term physical activity and sport motor skill improvement.

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