HUMAN BiOLOGY AND PUBLiC HEALTH
JOURNAL OF THE AUXOLOGICAL SOCIETY

ISSN 2748-9957 | Vol. 1 2024 | pp. 1–15

Health endangering overweight in preschool children – Relationship between body composition and physical fitness

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Citation:

Maintz, E./Mumm, R./Lechner, M. et al. (2024). Health endangering overweight in preschool children, Human Biology and Public Health 1.
https://doi.org/10.52905/hbph2024.1.73.

Received: 2023-08-22
Accepted: 2024-04-02
Published: 2024-07-08

Conflict of Interest:

The authors declare no conflicts of interest.

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Keywords

obesity, motor fitness, BMI, preschool children

Abstract

Background Body mass index (BMI) is the dominant diagnostic parameter for overweight and obesity, but its suitability is controversial. Low physical fitness (PF) is a risk factor for cardiovascular diseases and low PF is associated with obesity.

Objectives Aim of the study is to characterize groups of overweight children via different anthropometric parameters and their respective PF.

Sample and Methods Anthropometric measurements (BMI, waist circumference (WC), skinfold thickness (SF), mid-upper arm circumference (MUAC)) were assessed in 147 preschool children (age 4.7 ± 1.8 years) at 12 Kindergartens in Germany. Measurements were related to a field battery for PF, assessing musculoskeletal fitness and motor fitness.

Results All anthropometric measurements characterize different children as overweight, only four children are classified as overweight by all measurements. Children with elevated triceps SF alone or in combination with high subscapular SF or WC but not BMI showed lower PF compared with non-overweight children (long jump ($p < 0.001$), high jump ($p = 0.002$), shuttle run ($p = 0.032$)).

Conclusions Triceps SF measuring peripheral fat mass alone and in combination with parameters of central fat might give useful additional information to the routinely measured BMI to detect poor PF indicating health impairing overweight in 3- to 6-year-old children, while preventive examinations should not be placed exclusively on the BMI.

Take-home message for students BMI, the mainly solely used parameter for overweight in preschool children, seems insufficient to detect health endangering body compositions. Adding parameters for peripheral fat mass like triceps SF or in combination with parameters indicating central fat mass, might be more suitable to detect those children that also show lower physical fitness.

Abbreviations

ADHD Attention-Deficit/Hyperactivity Disorder
AGA German Adiposity Association
BIA Bioelectrical impedance analysis
BMI body mass index
B regression coefficient
DXA Dual energy X ray absorptiometry
ECOG European Childhood Obesity Group
Hmax maximal height
kg bw Kilogram of body weight
hmax maximal jumping height
MUAC middle upper arm circumference
NOW normal weight obese
P P-value
pP peak Power
pPrel relative peak Power
R2 coefficient of determination
SF skinfold thickness
subSF subscapular skinfold thickness
triSF triceps skinfold thickness
WC waist circumference

Introduction

The epidemic of obesity and its associated co-morbidities has become one of the mayor challenges for health care systems worldwide (Branca et al. 2007). Prevalence has been rising dramatically over the last 20 years in almost all countries. Obesity in children is increasing even faster than in adults (Afshin et al. 2017). According to the Global Burden of Disease Study, 5.02 million deaths occurring in 2019 were associated with overweight and obesity (Roth et al. 2020).

Childhood obesity is predictive for cardiovascular risk factors and comorbidities such as increased intima-media thickness, dyslipidaemia, hypertension and type 2 diabetes as well as psychological impairments such as low self-esteem, anxiety and depression (Berenson et al. 1998; Eisenmann et al. 2005; Juonala et al. 2011; Lobstein et al. 2004). Childhood obesity is associated with persisting obesity in adulthood, but encouraging data from four longitudinal cohort studies showed that obese children who became non-obese as adults had a similar cardiovascular risk profile as individuals who have never been obese, indicating some kind of reversibility of atherosclerosis in childhood (Juonala et al. 2011; Magnussen et al. 2012). However, secondary prevention is complex and often little effective. Extreme adiposity is a chronic disease, and in most cases not curable (Wabitsch et al. 2020). To achieve prevention of higher grades of obesity, early detection is crucial in childhood to reduce morbidity and mortality in adulthood and reduce costs for the health care system in the long run.

Overweight and obesity are commonly defined as an elevated portion of body fat that may impair health (Engin 2017). Anthropometric measurements such as BMI, as quotient of weight per height squared (kg/m^2), skinfold thickness (SF) or waist circumference (WC) are correlated with other diagnostic techniques measuring fat mass like dual energy X ray absorptiometry (DXA), densitometry or bioelectrical impedance analysis (BIA) (Müller et al. 2016; Bell et al. 2018; Freedman et al. 2007).

BMI and waist circumference have been shown to correctly identify high trunk fat in preschool children in 93% and 89% of cases respectively (Taylor et al. 2008). Correlation coefficient of SF and BMI with DXA in children 5–11 years was 0.71 -0.83 (Freedman et al. 2007). Anthropometry is a feasible tool for the evaluation of children in field settings like paediatric appointments or in schools as it does not require ionizing radiation or immobile and expensive instruments (Bell et al. 2018; Liem et al. 2009; Wells and Fewtrell 2006). Although BMI is not an ideal measurement for the estimation of body fat as it cannot distinguish between lean mass and fat mass, it has become the most widely used parameter to define overweight in adults and children (Wells 2014; Müller et al. 2016).

Although in literature concepts to describe and measure moving skills and fitness are heterogeneous using different terms, children with deficient assessed or perceived coordination skills (motor skill competence) move less in their daily routine (physical activity), and show lower (health related) physical fitness (PF) (Barros et al. 2021; Agha-Alinejad et al. 2015; Haapala et al. 2016; Barnett et al. 2016; Antunes et al. 2018; Stodden et al. 2008; Stodden et al. 2014). Poor PF is associated with poor health and shorter life (Ortega et al. 2012; Högström et al. 2016). After the model of Stodden et al. all the four competencies are interrelated and the resulting lower physical activity causes overweight and obesity (Stodden et al. 2008). In his model, motor skill competence describes locomotor skills like running and object control skills like throwing, while (health related) PF, describes muscular strength and power of endurance. According to Ortega et al. three different areas of PF can be described and measured: (1) cardiorespiratory fitness describing the ability of the cardiorespiratory system to provide oxygen during a period of moderate physical activity, (2) musculoskeletal fitness describing endurance and explosive strength (power) as well as flexibility of muscles or muscle groups, (3) motor fitness which assesses technical abilities and skills measuring speed, agility and balance (Ortega et al. 2008).

Several studies comparing PF and body composition in preschool children exist but methods especially for assessment of PF vary widely (Ortega et al. 2008; Henriksson et al. 2019; Cadenas-Sánchez et al. 2015; Kakebeeke et al. 2017; Ortega et al. 2015; Castetbon and Andreyeva 2012; Nervik et al. 2011). Tests for older children cannot easily be adapted as the preschool child has to understand the task and has to be able to technically perform the movement depending on their developmental stage.

The present study of 3- to 6-year-old children is therefore piloting a field PF battery in combination with the assessment of different anthropometric measurements to detect indicators for unhealthy body composition. Additionally, the usage of a force plate (Leonardo Mechanograph®) to measure PF with a single test (jumping) is evaluated, comparing results with the field battery. This would give examinators a time efficient alternative to the field test battery.

We hypothesize:

1. Elevated anthropometric measurements (BMI, WC, MUAC or SF) do not characterize the same individuals as overweight or obese.
2. Certain anthropometric measurements or their combinations characterizing overweight exist that are associated with lower scores for PF.
3. Jumping test on a force plate indicates low PF in similar body composition groups as the field test battery.

Sample and methods

Participants

Out of a list of all 159 kindergartens in the city of Freiburg, 12 kindergartens were randomly selected and contacted. Institutions took part in the study if the head of the facility agreed to participate. At these kindergartens, information leaflets were distributed to the parents and parents were informed and invited during parent’s evenings. Children between the ages of 3 to 6 years were included after written informed consent from parents or legal representatives was obtained. Children with chronic diseases (e.g., asthma,

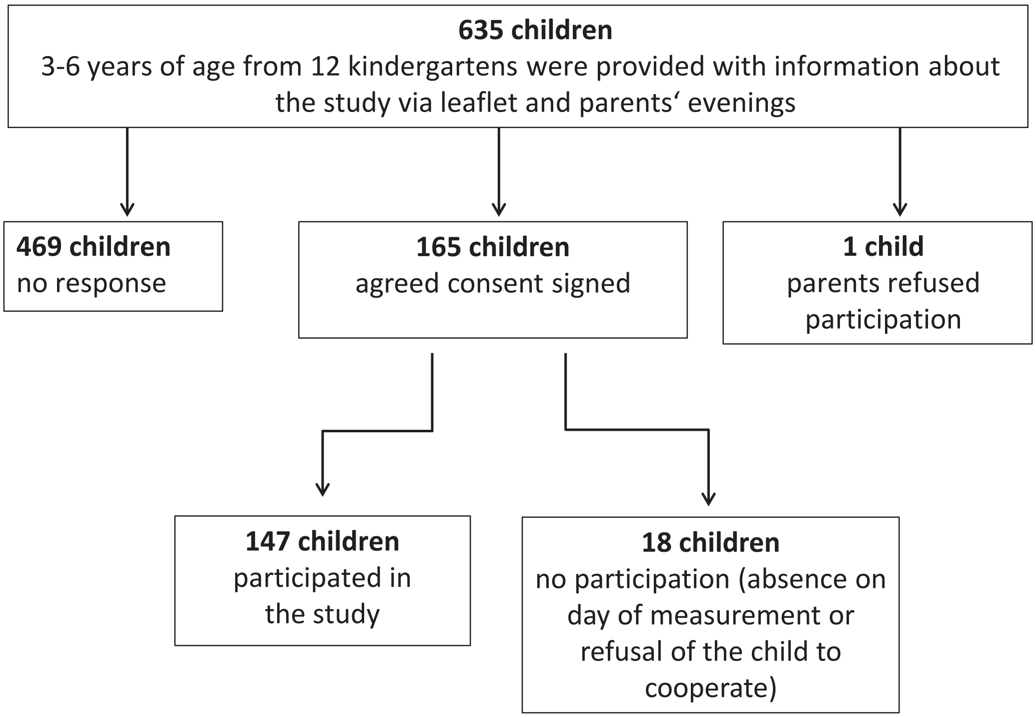

Figure 1 Recruitment of participants.

rheumatic diseases) or physical or mental disabilities were excluded from the study. Recruitment process is shown in Figure 1. The study was approved by the Ethics Committee of the University of Freiburg Medical Centre (EK-FR 276/18 to KOS).

Data collection

The field fitness battery used was an adapted protocol after a systematic review of 22 studies on reliability, validity and relation to health outcomes of PF tests for preschool children by Ortega et al. (Ortega et al. 2015). The children completed a test battery consisting of the following tests:

Motor fitness:

- 4 x 5 metre shuttle run, to test speed, agility and coordination (Przednowek et al. 2021)

Musculoskeletal fitness:

- Sit and reach test to measure flexibility of the thigh backside and the lower back (Koslow 1987; Oja and Jürimäe 1997)
- Ball throwing test using the best result of three throws with each hand for explosive strength and coordination of upper extremity (Oja and Jürimäe 1997)

Motor and musculoskeletal fitness:

- Standing long jump for explosive strength and coordination of the lower extremity (Oja and Jürimäe 1997; Castetbon and Andreyeva 2012; Nervik et al. 2011; Krombholz 2013).

To evaluate a standardized room-saving tool to evaluate musculoskeletal fitness for settings where running and jumping is not feasible, a two-leg high jump on a standardized force plate (Leonardo

Mechanograph® GRFP STD, Novotec Medical GmbH Pforzheim, Germany), which is a tool for the space-resolved registration of ground reaction forces, was performed. For examination of measurements, Leonardo Mechanography v4.4 Software Research edition was used (Rawer 2021). Parameters analysed from mechanograph were "relative maximal Power" (pPrel) calculated as maximal power (peak Power =pP) related to body mass (kilogram of body weight=kg bw) and maximal jumping height (hmax).
Further, anthropometric information was collected by standard procedures according to Knußmann et al. (Knußmann 1988). Height was measured with an anthropometer to the nearest 1mm. Weight was collected to the nearest 100g. MUAC and WC were measured with a flexible, non-elastic measurement tape to the nearest 1mm. Subscapular and triceps SF were measured with skinfold callipers (DKHS, GPM Anthropological Instruments, Zurich Switzerland) to the nearest 2mm.
The study was carried out in the respective exercise rooms of the kindergartens. During the normal daily routine, a group of 2 to 4 children was sent to the exercise room, where two trained field researchers conducted the measurements. For anthropometric measurements, sit and reach, and measurements on the force plates children were divided into two groups of 1–2 measured by one of the field researchers.
BMI cut-offs for children and adolescents are defined according to age, sex and population specific percentiles. As defined by the German Adiposity Association (AGA) and the European Childhood Obesity Group (ECOG), overweight was classified in this study as BMI above the 90th percentile and obesity above the 97th percentile (Moss and Wabitsch 2019; Poskitt 1995).
To further investigate the effect of an increase in anthropometric variables on fitness performance we (1) created groups of one anthropometric variable or a combination of several anthropometric variables (subgroups) above the 90th percentile, (2) compared fitness performance of these groups with a control group of children showing normal values (<90th percentile) in all anthropometric parameters ("all non-overweight" group). Groups with n < 10 children were excluded.
Subgroups can be summarized into two categories that are classified as follows:

1. Indicating overweight in combination with BMI:

- Group 1: All children with BMI and one other parameter above the 90th percentile;
- Group 2: All children with BMI and other possible combinations of two parameters above the 90th percentile with a subgroup size of n 10.

2. Indicating overweight irrespective of BMI:

- Group 3: All children with combinations of two anthropometric parameters above the 90th percentile except BMI with subgroup size n 10.

Statistical analysis

Statistical analysis was carried out with SPSS Statistics 26 (IMB, New York, USA) and R 4.0.3 (R studio, Boston, USA).
For descriptive statistics, mean, median and standard deviation were calculated.
Anthropometric measurements were standardized using percentile z-scores, based on references for preschool children in Germany published by Hesse et al. (Hesse et al. 2016a; Hesse et al. 2016b; Hesse et al. 2017).
A Venn diagram was calculated and illustrated for a descriptive presentation of distribution and relation of different elevated anthropometric measurements. In the Venn diagram five planes are drawn, one for each anthropometric measurement.

The planes show the number of children above the 90th percentile for a specific parameter as well as the overlapping with other parameters.

Multiple regressions analysis was performed to analyze the effect of anthropometric characteristics (in z-scores) on the fitness performance. As fitness performance might depend on age and sex we corrected for these confounding variables (Busche et al. 2013; Krombholz 2011).

For comparison of fitness performance of different subgroups (see above) with a group of children showing normal values in all parameters ("all non-overweight" group) Mann-Whitney-U-Test was used due to small sample sizes and a lack of normal distribution.

To compare field battery fitness test with measurements of Leonardo Mechanograph Spearmans-correlation was calculated.

Results

A total of 147 children participated in the study. Distribution of anthropometric data by sex are shown in Table 1.

For the subgroup of WC above the 90th percentile (36 of 147 children), numbers are slightly higher than those children overweight by BMI (32 of 147 children). 12 of the children with increased WC do not show increased BMI values.

The prevalence of overweight measured as elevated SF in this study was lower for triSF (19 of 147 children) and higher for subSF (39 of 131 children) compared to the prevalence of overweight by BMI or WC. Elevated MUAC has the lowest prevalence (17 of 147 children) and all but one child of this group simultaneously show elevated BMI.

When considering the combination of BMI and SF in our study, 24 children show only BMI but no SF >90th percentile, eight children had both high BMI and triSF, 19 children both high BMI and subSF. 10 of all children showed both SF >90th percentile, five of which had also elevated BMI measurements. 26 (20% of all) children had either one SF measure increased (triSF or subSF) but no increase in BMI value.

In the multiple regression analysis of fitness performance as an outcome variable and anthropometric parameters as explanatory variable adjusted for age and sex, (borderline) significant positive association can be seen (Table 2) for MUAC and relative power of high jump on the mechanograph (pPrel) (p=0.048) and the ball throwing test (p=0.010). Negative linear association are

Table 1 Descriptive characteristics of boys and girls).

	Male (n=83)		Female (n=64)		All children (n=147)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Age (years)	4.83 (0.91)	4.91(1.38)	4.62 (0.94)	4.34 (1.51)	4.74 (0.93)	4.7(1.43)
Z-scores						
BMI	0.43 (1.36)	0.24 (1.35)	0.45 (1.08)	0.28(1.47)	0.44 (1.24)	0.25 (1.29)
WC	0.72 (1.42)	0.39 (1.42)	0.60 (1.08)	0.51(1.34)	0.67 (1.28)	0.42 (1.41)
MUAC	-0.31 (1.17)	-0.45 (1.21)	0.08 (1.16)	0.11(1.48)	-0.14 (1.18)	-0.27 (1.37)
triSF	-0.35 (1.24)	-0.42 (1.35)	0.36 (1.02)	0.49 (1.4)	-0.04 (1.2)	-0.06 (1.43)
subSF	0.85 (0.8)	0.8 (1.09)	0.75 (0.88)	0.72(1.29)	0.81 (0.84)	0.78 (1.14)

SD = standard deviation, BMI = body mass index, WC = waist circumference, MUAC = middle upper arm circumference, triSF = triceps skin fold thickness, subSF = subscapular skin fold thickness, IQR = interquartile range, SD = standard deviation

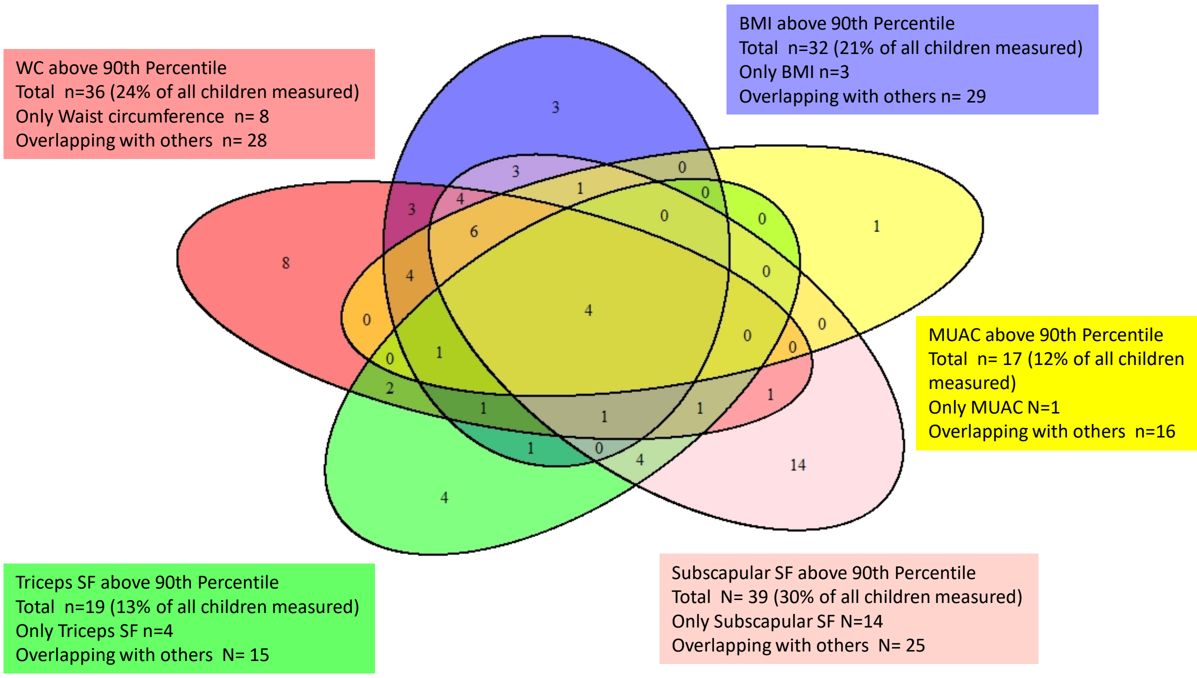

Figure 2 Venn diagramm of anthroprometric parameters above the 90th percentile shown as areas and their overlap (WC = waist circumference, SF = skinfold thickness, MUAC = middle upper arm circumference, BMI = body mass index).

significant for BMI and ball throwing test (p=0.015) as well as triceps SF and pPrel of high jump on the mechanograph. Sit and reach, shuttle run and standing long jump showed no significant association with any anthropometric parameter.

Looking at one single anthropometric parameter above the 90th percentile, children with high triceps SF showed significantly poorer performance in standing long jump, shuttle run and at high jump on mechanograph (pPrel) (Table 3).

The Venn diagram (Figure 2) visualizes overlapping of the different anthropometric measurements above the 90th percentile among the children. Bigger overlapping areas can be seen for BMI and WC (n=24) as well as BMI and WC together with upper arm circumference (n=15) or with subSF (n=15). Only for four children all parameters exceeded the 90th percentile.

Using BMI above the 90th percentile as the defining measure, 22% of the children (n=32) can be classified as overweight and 10% (n=15) as obese (97th percentile).

When analysing combinations of parameters in subgroups as described above (Sample and methods):

1. Indicating overweight in combination with BMI:

- Group 1 (elevated BMI combined with one other parameter above the 90th percentile): No significant differences comparing physical performance with “all non-overweight” group.
- Group 2 (elevated BMI combined with two other elevated parameters): The following combinations had n>10 children: BMI, subSF and WC (n=15);

BMI, subSF and MUAC (n=11) and BMI, WC and MUAC (n=15). None of these subgroups showed lower fitness compared with the "all non-overweight" group.

2. Indicating overweight irrespective of BMI:

- Group 3 (combinations of two parameters above the 90th percentile): Significant difference in fitness performance can be seen in Table 4.

Moreover, correlation analysis between standing long jump and high jump on Leonardo Mechanograph showed a highly

Table 2 Multiple Regression Analysis of fitness performance and anthropomentric parameters.

Fitness Test	Standing Long Jump		High Jump on Mecanograph				Shuttlerun		Ball Throwing Test		Sit and Reach	
			pPrel		hmax							
Anthropometric Measurement		p		p		p		p		p		p
BMI (z-score)	-1.781	0.539	-0.331	0.624	0.008	0.381	-0.129	0.502	-0.428	**0.015**	0.692	**0.145**
MUAC (z-score)	1.261	0.652	1.304	**0.048**	0.008	0.374	0.107	0.565	0.439	**0.010**	0.242	0.589
WC (z-score)	0.198	0.936	-0.692	0.226	-0.014	0.074	0.202	0.218	0.248	0.096	-0.171	0.281
triSF (z-score)	-3.769	0.051	-1.057	0.020	-0.004	0.482	0.066	0.602	-0.185	0.110	-0.112	0.471
subSF (z-score)	-2.037	0.415	-0.413	0.493	-0.002	0.769	0.051	0.758	-0.050	0.738	-0.343	0.165
Age	18.664	<0.001	3.365	**<0.001**	0.035	**<0.001**	-1.069	**<0.001**	1.3776	**<0.001**	-0.739	0.072
Sex	4.115	0.275	-1.653	0.061	0.003	0.813	-0.398		1.203	**<0.001**	-1.932	**0.016**
R2	0.5075		0.395		0.238		0.422		0.658		0.123	

Significant association in bold. BMI = body mass index, MUAC = middle upper arm circumference, WC = waist circumference, triSF = triceps skinfold thickness, subSF = subscapular skinfold thickness, R2 = coefficient of determination, pPrel = relative peak Power, hmax = maximal height, = regression coefficient, p = P-value

Table 3 Subgroups with one parameter above 90th percentile showing those fitness tests that differed significantly comparing to "all non-overweight" group (n=72).

	BMI≥90th P	WC≥90th P	triSF≥90th P	subSF≥90th P	MUAC≥90th P
Respective z-value: median	1.84	1.89	1.67	1.61	1.82
Subgroup size (n/N)	32/147	36/147	19/147	39/131	17/147
Number of male/female	17/15	18/18	9/10	21/18	8/9
Number of children with BMI ≥90th P/subgroup size	32/32	24/36	8/19	19/39	16/17
Fitness tests(s) that differed significantly	none	none	LJ (p < 0.001) SR (p = 0.032) M: pPrel (p=0.002)	none	none

WC = waist circumference, TriSF = triceps skinfold thickness, SubSF = subscapular skinfold thickness, MUAC = middle upper arm circumference, pPrel = relative peak Power (two leg jump on mechanograph) P = percentile, LJ = Long Jump, SR = Shuttle Run, M = Mechanograph significant (p<0.001) correlation of r=0.7 for relative peak power (pPrel) and r=0.618 for maximal jumping height (hmax).

Discussion

The main findings of the present study are:

1. BMI, both SFs, WC and MUAC define different individuals as overweight or obese. Among them, only four individuals are commonly characterized by all parameters.
2. Only elevated triSF alone and in combination with subSF or WC (but not BMI) were associated with reduced PF as a possible indicator for health impairing overweight.
3. Low PF indicated by jumping on the force plate occurs in similar overweight groups as low PF indicated by test of the field test battery (jumping and running).

The Venn diagram illustrates the very heterogeneous distribution of the different anthropometric parameters above the 90th percentile among children. While BMI, WC and MUAC had higher overlap in being elevated in the same children, SF (especially triSF) and BMI had lower overlap. Only eight of the 19 children with high triSF also have a high BMI.

In line with comparable data on German preschool children, published by Hesse et al. (Hesse et al. 2016a; Hesse et al. 2016b; Hesse et al. 2017), the studied boys show lower values of MUAC (boys: -0.42, girls: 0.49) and triceps SF (boys:-0.45, girls: 0.11) than girls (table 1).

However, this does not affect the sex distribution of the overweight groups (parameters above the 90th per-centile). In these groups boys and girls show similar distribution (table 3 and 4).

In accordance to our study, a cross sectional study by Talma et al. reported a strong correlation of MUAC and BMI as well as MUAC and weight stating MUAC as a good substitute for indicating overweight where weight cannot be taken (Talma et al. 2019). However, it is questionable if this correlation is generally due to increasing fat mass, as BMI and MUAC do not differ between lean and fat mass. Little research exists on association of MUAC and health or fitness. Children with elevated MUAC did not show lower PF in our study. Instead, MUAC was positively associated with higher single two leg jump and better ball throwing performance. It might be possible that elevated MUAC rather indi-

Table 4 Subgroups with elevated measures irrespective of BMI, showing which fitness tests differed significantly compared with ”all non-obese” group (n=72), (Mann-Whitney-U-Test).

Overweight irrespective of BMI (subgroup 3)	WC & subSF>90th P	WC & triSF >90th P	Both SF>90th P	WC & MUAC>90th P	subSF&MUAC >90th P
	17/131	10/147	10/131	15/147	11/131
Subgroup size (n/N)	11/8	5/5	4/6	8/7	6/5
Number of male/female	15/17	7/10	5/10	15/15	11/11
Number of children with BMI > 90th P/subgroup size	none	LJ (p=0.01) SR (p=0.009) M: pPrel (p=0.013)	LJ (p=0.024) M: pPrel (p=0.026)	none	none

WC = waist circumference, TriSF = triceps skinfold thickness, SubSF = subscapular skinfold thickness, MUAC = middle upper arm circumference, P= percentile, SF = Skinfold thickness, LJ = Long Jump, SR = Shuttle Run, M = Mechanograph cates higher lean mass implicating muscle mass instead of unhealthy fat mass in this age group. In line with our results, no or even a positive association of elevated BMI with PF was found in several studies on preschoolers (Butterfield et al. 2002; Kakebeeke et al. 2017; Toia et al. 2009). This further indicates the importance of the ineffective distinction of lean mass/muscle mass and fat mass by BMI (Talma et al. 2019).

Although its suitability is discussed controversially, according to current international guidelines, BMI is used as the main indicator for overweight. A systematic review found low sensitivity for BMI to detect high fat mass in children (Javed et al. 2015). Other anthropometric measurements like SF are described to be more adequate parameters to estimate body fat mass although predominantly assessed in older children (Freedman et al. 2007; Liem et al. 2009; Bogin 2020).

If PF is used as an indicator for health impairment to further identify which parameters really detect health endangering overweight, our study supports the use of additional anthropometric parameters to BMI in preschool children. Our study confirms the importance of SF to detect health impairing excessive body fat that is not captured by BMI: Children with elevated triSF showed significant poorer performance for high jump on mechanograph, shuttle run and long jump compared to the “all non-overweight” group of children. Elevated triSF alone and in combination with elevated subSF or WC showed lower PF (especially jumping exercises) when performance was compared with the group of “all non-overweight” children. The combination of central (subSF and WC) and peripheric fat (triSF) might therefore be a good indicator in assessing health impairing overweight in preschool children. In children aged 6 to 12 years SF was identified as the only parameter inversely correlated with lower PF. Milanese et al. identified SF as the only parameter inversely correlated with lower PF in children aged 6 to 12 years (Milanese et al. 2010).

Individuals with average or low BMI values but high fat mass, are described in the literature as “normal weight obese” (NWO), have higher health risks than non-obese individuals (García-Hermoso et al. 2020). As previously described the instruments and cut-off values to detect “high fat mass” differ which impedes to consistently define NOW (Barros et al. 2021; Agha-Alinejad et al. 2015).

Concordantly to our findings several studies show that children of NWO body composition experience poorer PF than normal-weight non-obese children at their age (Barnett et al. 2016; Musalek et al. 2017; Franco et al. 2016). Concerning our results, it seems that NWO children might be well captured by using measurements of SF. Every fifth child of the study population showed normal BMI but elevated SFs (either one). And all groups with significant lower fitness performance involved elevation of either one of the SFs measured.

The observed positive association between BMI and performance in ball throwing might be due to lower explosive muscle strength of upper extremity or as well worse coordination skills. Association of high BMI and bad coordination skills is reported in a systematic review (Barnett et al. 2016; Kakebeeke et al. 2017). Butterfeld et al. found better muscle strength of upper extremity (hand grip strength) in children with higher BMI which supports that in our study results are rather due to lower coordination skills (Butterfield et al. 2002). The coordination skills needed for good performance in ball throwing test was also seen as an important factor in preschool children by Oja et al. as it is quite a technical activity (Oja and Jürimäe 1997). For a test battery focussing on PF in preschool children, ball throwing as a task seems rather problematic due to its susceptibility to errors and the question of suitability at this age needs further evaluation.

However, further research with bigger samples on younger children is needed (Wood et al. 2021).

The present study contributes to the research gap of PF assessment and its relation to body composition in preschool children. A systematic review by Ortega et al. on existing fitness tests for preschool children found low evidence for a clear statement on a fixed fitness battery and the need for further research especially on the relationship of fitness tests and health outcomes (Ortega et al. 2015). The here used field fitness battery was feasible to perform in the settings of kindergartens without using expensive equipment.

The second approach to assess PF by using a special electric tool (force plate, Leonardo Mechanograph) for exact measurements of power (explosive muscle strength) showed high correlation with standing long jump, a field test measuring the same quality of fitness (power of lower extremity) which supports the validity of the test. The mechanograph itself was feasible to use with the young children and didn't require any bigger space for running or jumping. However, the force plate is heavy to carry, requires electric power and needs to be purchased. Settings with limited time and space but capacity to purchase a force plate might therefore pick this tool as a time saving single test for measuring PF in young children.

Musculoskeletal fitness tests for explosive muscle strength where body mass needs to be mobilized like jumping, seem to detect fitness deficits in overweight children most effectively. These findings are in line with other studies showing that among different PF tests hopping and jumping is associated with overweight in children (Oja and Jürimäe 1997). Lower muscle strength was found to be associated with higher mortality in adolescents (Ortega et al. 2012) and higher overall obesity later in life (Ruiz et al. 2009) which endorses the focus on this quality of physical fitness.

Limits of the study

Due to the heterogeneous distribution of the different anthropometric parameters, studied (sub)groups were rather small. For reasons of practicability a rather passive recruiting process was used and out of the 635 children of 12 randomly selected kindergartens, only 166 children (response rate 26%) participated in the study. There is a chance of selection bias if the group of non-participating children differ from the participating group. If that would be the case the most probable consequence would be a dilution of the measured effect as parents of less overweight children are more likely to participate. Further studies with a bigger sample size comparing these anthropometric measurements with fitness performance are necessary. A well standardized and validated PF battery with age and sex adjusted reference values for young children from 3 to 6 years of age would help to improve comparability for further studies on this topic. Although this study focuses on PF it should be noted that certain coordination skills are needed to fulfil the tasks of tests for PF. In young children these skills depend on general dexterity of the child and also on developmental aspects.

Conclusion

In summary, the focus of preventive examinations in preschool children should not be placed exclusively on BMI. In our study, 3- to 6-years-old children with elevated peripheral fat mass by triSF alone and in combination with parameters of central fat (as WC or subSF) showed poor PF, which might indicate health impairing overweight and obesity. The presented fitness battery was an easy applicable method in preschool children for clinical practice and field research.

Author contributions

Conceptualization, KO.S., R.M., M.L., V.S, E.M and U.W.-B.; methodology, KO.S., R.M. and E.M.; for-mal analysis, E.-M.M., R.M., V.S. and M.L.; investigation, V.S. and M.L.; resources, KO.S.; data curation, E.-M.M., R.M., V.S. and M.L.; writing—original draft preparation, E.M., R.M., V.S. and M.L.; writing—review and editing, KO.S., R.M., M.L., V.S, E.M and U.W-B.; visualization, E.M.; supervision, KO.S.; project administration, KO.S.; All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.
Institutional Review Board Statement:
The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Ethics Committee of University of Freiburg Medical Centre (protocol code 276/18, date of approval: 13th September 2018).

Acknowledgements

We would like to thank all children, parents and kindergartens that contributed data to this study. We also thank all students and the research team for their valuable contribution.

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