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Do Overweight Children Stand on Valgus Knees?

Stehen übergewichtige Kinder auf valgischen Knien?

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Summary

› **Background:** Pediatric overweight is associated with higher incidences of musculoskeletal pain and injuries. It is still not known exactly what causes these problems. The purpose of this study was to compare overweight children with their non-overweight counterparts with respect to the leg axis and joint mobility.
› **Methods:** In all, 46 overweight children (girls: age: 8y. 9m. ± 1y. 2m., BMI-Percentile: 97.7 ± 3.0; boys: age: 9y. 6m. ± 1y. 4m., BMI-Percentile: 98.2 ± 2.5 (mean value ± standard deviation)) were compared with 42 non-overweight children (girls: age: 9 y. 3 mo. ± 1 y. 3 mo., BMI-Percentile: 26.9 ± 20.8; boys: age: 9 y. 4 mo. ± 1 y. 2 mo., BMI-Percentile: 41.32 ± 27.6). The passive range of joint motion in the lower extremity was assessed. Knee alignment was determined by digital photographs. Injury and pain history were recorded.
› **Results:** Overweight children showed deficits in the range of motion of the hip and the knee joints. Overweight girls had significantly higher knee valgus angles than non-overweight girls. In overweight children, ankle sprain (13/46) was the most common injury compared with six of 42 non-overweight children.
› **Conclusions:** Overweight children showed joint mobility restrictions and increased knee valgus angles when compared with non-overweight ones. These factors could influence the risk of sustaining injuries at the lower extremities. Prevention programs need to be established already in childhood.

Zusammenfassung

› **Problemstellung:** Kindliches Übergewicht ist mit einer höheren Inzidenz an muskuloskelettalen Beschwerden und Verletzungen vergesellschaftet, ohne dass die kausalen Zusammenhänge vollständig geklärt sind. Ziel war es daher, Gelenkbeweglichkeit und Stellung der unteren Extremitäten von übergewichtigen und nicht-übergewichtigen Kindern miteinander zu vergleichen und vorausgegangene Verletzungen zu erfassen.
› **Methoden:** 46 übergewichtige Kinder (Mädchen: Alter: 8J 9M ± 1J 2M, BMI-Perzentile: 97,7 ± 3,0; Jungen: Alter: 9J 6M ± 1J 4M, BMI-Perzentile: 98,2 ± 2,5 (Mittelwert ± Standardabweichung)) wurden mit 42 nicht-übergewichtigen Kindern verglichen (Mädchen: Alter: 9J 3M ± 1J 3M, BMI-Perzentile: 26,9 ± 20,8; Jungen: Alter: 9J 4M ± 1J 2M, BMI-Perzentile: 41,32 ± 27,6). Das passive Bewegungsausmaß der unteren Extremitäten wurde mit Goniometer bestimmt, die Beinachsen mittels Digitalfotografie.
› **Ergebnisse:** Die übergewichtigen Kinder zeigten Defizite in der Hüft- und Kniegelenksbeweglichkeit im Vergleich zu den nicht-übergewichtigen. Übergewichtige Mädchen wiesen signifikant häufiger valgische Knie auf als nicht-übergewichtige. In der Gruppe der Übergewichtigen wurden Sprunggelenksverletzungen mit 13/46 am häufigsten angegeben versus 6/42 bei den Nicht-Übergewichtigen.
› **Zusammenfassung:** Übergewichtige Kinder zeigten Einschränkungen der Gelenkbeweglichkeit und vermehrt valgische Beinachsen im Vergleich zu ihren nicht-übergewichtigen Altersgenossen. Diese Faktoren könnten das Risiko für Verletzungen an den unteren Gliedmaßen beeinflussen. Präventionsprogramme sollten daher bereits in der Kindheit etabliert werden.

KEY WORDS:
Paediatric Overweight, Paediatric Obesity, Leg Axis, Range of Motion, Injury

SCHLÜSSELWÖRTER:
Kindliches Übergewicht, Kindliche Obesitas, Beinachsen, Bewegungsausmaß, Verletzungen

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Introduction

Early onset of obesity has been associated with musculoskeletal changes and pain (6). Previous studies found a correlation between body weight and the intermalleolar distance (1, 2, 7). In addition, by means of radiographic assessment, valgus alignment was found more often in overweight children (19). However, our knowledge of the functional consequences of these anatomic changes of the leg axis and restricted range of motion (ROM) in the lower limb is limited. Kinematic alterations were previously shown in the hip and knee joints (18). Obese children are significantly more likely to sustain lower extremity injuries than upper extremity injuries (14) and they show a higher incidence of extremity fractures than observed in non-overweight children (16, 20).

In order to design efficient prevention and intervention programs, some baseline data are needed to identify the major changes and deficits.

The primary aim of this study was to compare the ROM of the lower extremities and knee alignment of overweight children with those of non-overweight subjects.

Our main hypotheses were that the ROM would be restricted in the joints of the lower extremities in overweight children and that knee alignment would be different from that in non-overweight children.

Methods

In all, 88 children participated in the study: 46 overweight children (f(emale): 8 y.(ears) 9 mo.(nths)±1 y. 2 mo., BMI 25.2±3.6 kg/m^2, perc(entiles) 97.7±3.0, m(ale): 9y. 6mo. ± 1y. 4mo., 26.2±2.8 kg/m^2, perc.: 98.2±2.5 (mean value ± standard deviation)) and 42 non-overweight subjects (f: 9 y. 3 mo. ± 1 y. 3 mo., BMI: 15.3±1.5 kg/m^2, perc.: 26.9±20.8, m: 9 y. 4 mo. ± 1 y. 2 mo., 16.4 ± 2.0 kg/m^2, perc. 41.32 ± 27.6). The overweight children were recruited for a major prospective, randomized study investigating the influence of ball games and nutrition counseling on different health parameters (12).

In this paper, the baseline data are presented; in the following, German paper, we report how six months of ball games and/or nutrition counseling influenced range of motion and leg axis.

Children were determined to be overweight (inclusion criteria) when their BMI was greater than the gender-, race-, and age-specific 90th percentile from the National Children Health and Nutrition Examination Survey (5, 13). Among the participants, 3 girls and 2 boys were overweight; all the others were obese. In our data presentation, the term "overweight children" is used for both overweight and obese children.

Informed written consent was obtained from the parents and guardians of all children. The independent Ethical Committee of the University of Heidelberg approved this study. This study was performed in accordance with the ethical standards in sports and exercise science research (10, 11).

Medical history of musculoskeletal pain, previous injuries, operations, and malformations was assessed.

Range of Motion

The passive ROM in the lower extremity was assessed in degrees in a supine position on a gymnastics mat by means of a goniometer (the hip extension by means of the Thomas test). The ROM of the lower limbs of the overweight children was normalized as follows: First, for each joint, the difference between the individual and the mean ROM of the non-overweight children was calculated and divided by the standard deviation. The mean of this standardized parameter ("normalized ROM") of all lower limb joints was compared to the BMI.

Leg Axis

A frontal and a lateral digital photo were taken of the child wearing shorts or briefs, standing barefoot with straight legs. The children were asked to position the feet hip-width apart. The toes were pointing forward and the body weight was equally distributed. The camera (Nikon Coolpix 990, 3.34 MP) was placed on a tripod (Cullmann 2502) at a distance of three meters at hip level.

The biomechanical leg axis was determined according to the technique developed previously by Schmitt et al. (17).

The leg axis was measured on the frontal digital photo using the software constructional program "Mechanical desktop 4 power pack / AutoCAD 2000" as previously described (17):

The centers of three horizontal lines are used: the most proximal and therefore widest level of the thighs, the inflection point of the curve between distal thigh and proximal tibia medially, and the maximum width of the malleoli. The software aligned the line between thigh-knee and knee-ankle, representing the mechanical axes. Angles were determined by the software in degrees, positive values being documented as valgus, negative as varus angles. Since the intermalleolar distance was not used for determining the leg axis, the feet were positioned hip-width apart, and the measurements were done in the center of the extremities (thighs, knees, malleoli), the measured angle approximates the biomechanic leg axis also in cases with a higher amount of soft tissue at the thigh. The method was validated by Schmitt et al. (17).

Table 1

Comparison of the lower extremity passive range of motion between overweight and non-overweight children. Difference in the mean values overweight – non-overweight (Diff. MV). T and p (T-Test for indep. samples), Hip (H) extension/flexion (Ext/Flex), ab-/adduction (Abd/Add), external/internal rotation (Ero/Iro), Knee (K) extension/flexion (Ext/Flex).

GIRLS	RIGHT DIFF. MV	T	p	LEFT DIFF. MV	T	p
H Ext	-2.73	-1.99	0.052	-2.73	-1.99	0.052
H Flex	-20.67	-8.44	<0.001	-20.68	-8.36	<0.001
H Abd	-13.31	-7.40	<0.001	-13.31	-7.40	<0.001
H Add	-6.69	-5.58	<0.001	-6.69	-5.58	<0.001
H Ero	1.63	0.62	0.540	1.68	0.67	0.497
H Iro	-8.97	-3.53	0.001	-8.54	-3.55	0.001
K Ext	2.01	1.34	0.188	1.93	1.29	0.204
K Flex	-13.49	-7.28	<0.001	-13.10	-7.14	<0.001
BOYS	**RIGHT DIFF. MV**	**T**	**p**	**LEFT DIFF. MV**	**T**	**p**
H Ext	-1.21	-0.82	0.420	-1.21	-0.82	0.420
H Flex	-16.49	-6.55	<0.001	-16.49	-6.55	<0.001
H Abd	-11.34	-5.6	<0.001	-11.09	-5.37	<0.001
H Add	-8.32	-5.43	<0.001	-8.17	-5.42	<0.001
H Ero	5.70	1.83	0.077	4.72	1.65	0.109
H Iro	-10.71	-4.3	<0.001	-11.00	-4.53	<0.001
K Ext	-2.26	-1.36	0.183	-2.26	-1.36	0.183
K Flex	-9.58	-4.52	<0.001	-9.58	-4.52	<0.001

Statistical Analysis

The statistical analysis was performed with Microsoft Excel (Microsoft Incorporation) and SPSS (SPSS Inc., Chicago, Ill, USA). Measures of central tendency and dispersion were calculated for all variables, and normal distribution was assessed by using the KS Test. The comparisons were calculated by using the Student's t-test for normally distributed data and by non-parametric tests for non-normally distributed data (MWU for independent samples). Correlations were calculated by means of the Pearson's correlation coefficient.

Due to the observational nature of the study, the significance level was assigned at 5% for all comparisons.

The biomechanic leg axis of the obese children was compared to the mean +2 SD of the non-overweight children group in order to determine the number of obese children with valgus knee alignment: Right leg: 0.7° + 2 x 2.7° = 6°; left leg: 1.5° + 2 x 2.7° = 7°.

Table 2

Biomechanic leg axis in overweight and non-overweight children. Right = right leg, Left = left leg, SD = Standard Deviation, Min = Minimum, Max = Maximum, p = p-value (T-Test for independend groups).

GIRLS	OVERWEIGHT	NON-OVERWEIGHT	COMPARISON OVERWEIGHT VS. NON-OVERWEIGHT	OVERWEIGHT	NON-OVERWEIGHT	COMPARISON OVERWEIGHT VS. NON-OVERWEIGHT
	Right Mean±SD (Min-Max)	Right Mean±SD (Min-Max)		Left Mean±SD (Min-Max)	Left Mean±SD (Min-Max)	p
Biomech. Axis [degrees]	4.7±2.9	0.6±2.8	<0.001	4.9±3.5	1.6±2.6	0.001
	(-2-11)	(-3-6)		(-3-12)	(-3-7)	
BOYS	**OVERWEIGHT**	**NON-OVERWEIGHT**	**COMPARISON OVERWEIGHT VS. NON-OVERWEIGHT**	**OVERWEIGHT**	**NON-OVERWEIGHT**	**COMPARISON OVERWEIGHT VS. NON-OVERWEIGHT**
	Right Mean±SD (Min-Max)	Right Mean±SD (Min-Max)		Left Mean±SD (Min-Max)	Left Mean±SD (Min-Max)	p
Biomech. Axis [degrees]	3.8±3.2	0.84±2.7	0.003	2.6±3.7	1.4±3.0	0.304
	(-1-8)	(-3-6)		(-4-8)	(-4-7)	

Table 3

Number of overweight children (n=46) with a valgus knee alignment, when compared with the non-overweight control group's mean + 2 SD. Normal=normal biomechanic leg axis, age in years (y.) and months (m.).

	NUMBER	AGE
Normal	26	9 y. 2 m.
Single leg valgus	14	9 y. 3 m.
Both leg valgus	6	9 y. 2 m.

Results

In both genders the hip flexion, abduction and adduction and knee flexion ROM of the overweight children were significantly lower than that of the non-overweight children (Tab. 1). The hip extension of the overweight girls was significantly lower than that of the non-overweight girls. The higher the BMI of the overweight children, the lower the mean of the normalized ROM of their lower limbs (calculation see: Methods): Pearson's r=-0.72 (Fig. 1).

Overweight girls had biomechanic leg axis with significantly higher valgus angles than non-overweight girls, overweight boys only on the right leg (Tab. 2). The higher the BMI (all children), the more the biomechanic leg axis tended to valgus values (Fig. 2).

When compared to the non-overweight group (calculation: please see methods), 20 of 46 overweight children had a valgus knee alignment on one or both legs (Tab. 3). No case of tibia vara (Blount's disease) was observed.

Whereas 11 of the 46 overweight children reported musculoskeletal pain (lower extremities, upper extremities, or back pain), only one non-overweight child (n=42) had pain (lower extremities).

In all, 25/46 of the overweight and 21/42 of the non-overweight children reported an injury in the past. In overweight children, ankle sprain (13/46) was the most common injury compared with six of 42 non-overweight children. Analyzing the number of ankle sprains in overweight children with and without valgus knee: 7/20 with valgus versus 6/26 without valgus suffered from ankle sprains (n.s.). In the non-overweight group, fractures of the upper extremities (9/42) were the most common injury (versus 5/46 overweight children), followed by sprains/entrapments of fingers/upper extremities with 7/42 (versus 6/46 overweight children).

Discussion

Body Mass Index and Range of Motion

The purpose of this study was to investigate the differences between overweight children and their non-overweight counterparts with respect to the musculoskeletal system. The reduced ROM in the hip and knee joint of overweight children was mainly due to the soft tissue excess preventing flexion. However, the hip joint restriction in internal rotation and abduction shows that excess weight early in life causes significant restrictions in joint motion, which indicates that there are changes in the capsular and/or in the bony articulation. This relationship was evident in the strong negative correlation between the normalized ROM and the BMI in overweight children. A limited ROM could also alter kinematics: Compared with normal-weight children, overweight children show greater absolute peak joint moments at the hip and the knee (18).

Leg Axis

This study is the first to apply a photographic leg axis measurement in overweight children. No x-rays were needed. The method does not use the intermalleolar distance which could lead to overestimated angles in overweight persons due to soft tissue contact at the knees. Furthermore, in our group, the biggest fat mass was located at the trunk and the soft tissue layers at the thighs were symmetric. Fig. 2 shows that there is a continuous correlation between the BMI and the biomechanic leg axis also throughout the normal BMI range. Therefore, overweight does not seem to add a systematic bias in this method. The differences between non-overweight and overweight children were higher in girls than in boys. Normally, no gender differences should be observed in that age group (4). However, overweight seems to influence the female body more than that of the male (3). This might also explain why valgus knee osteoarthritis develops more often in women (8).

The reduced ROM of the hips in the frontal plane, paired with shortening of the adductors might be one of the reasons why the valgus deformity develops. Negative functional consequences of the valgus knee deformity are due to the lateral shift of the weight-bearing axis (15).

Injuries

The overweight children reported previous ankle sprains twice as often as non-overweight children. In a previous study,

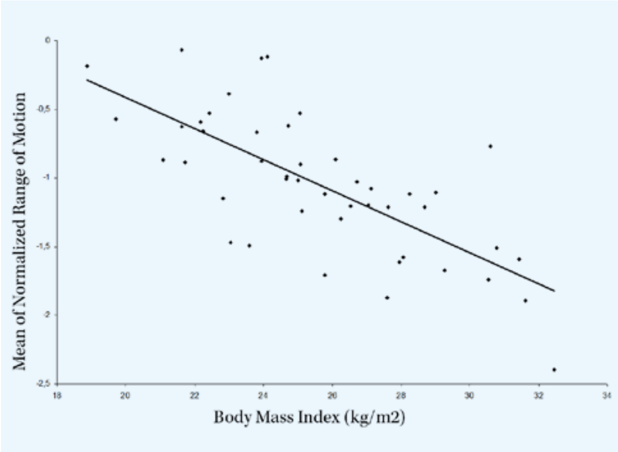

Figure 1

Normalized range of motion of the lower limbs in overweight children (n=46) as a function of their body mass index (in kg/m^2). Line: Pearson's correlation. (Calculation of the normalized range of motion: please see Methods, Statistical Analysis).

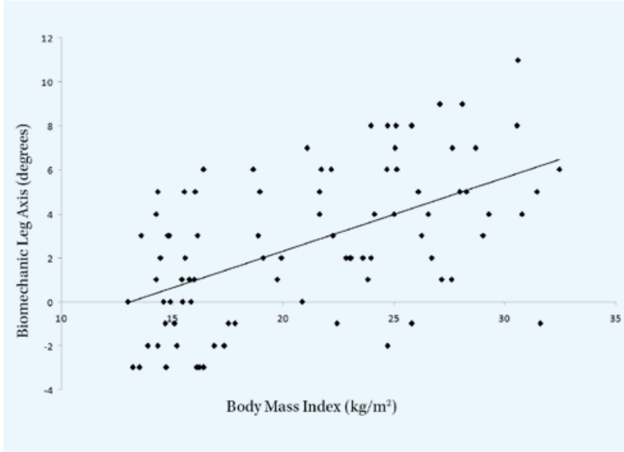

Figure 2

Biomechanic leg axis (in degrees) as a function of the body mass index (in kg/m^2) in the overweight and non-overweight children (n=88). Line: Pearson's correlation. Positive values: valgus, negative values: varus.

the risk for fractures was found to be higher in obese children due to falls (9). It is possible that additional weight combined with postural control deficits in overweight children influences the rate of lower extremity injuries (14, 16). In our sample, more than a third of the children with valgus knees suffered from ankle sprains versus less than a forth in the ones with normal leg axis. However, this might also be related to the higher BMI.

Limitations of this study include the relatively small sample size. Furthermore, the validity of the injury assessment is based on retrospectively collected, self-reported injury data, allowing for the possibility of recall bias.

Conclusions

Already in early childhood, with excess weight, the skeletal system shows changes as a decreased ROM in the hip, the knee joint and a higher frequency of valgus knee alignment. Thus, overweight children should participate in multidisciplinary programs aiming to improve the joint flexibility and to correct the leg axis.

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Authors' Contributions

All authors have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data.

BK, NER, HS, FW have been involved in drafting the manuscript, and NER, FW, UH, CR, and HS in revising it critically for important intellectual content.

All authors have given final approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of Interest

The authors have no conflict of interest.

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