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MAGNETIC RESONANCE

Obesity-related juvenile form of cartilage lesions: a new affliction in the knees of morbidly obese children and adolescents

Harald K. Widhalm · Stefan Marlovits · Goetz H. Welsch · Albert Dirisamer · Andreas Neuhold · Martijn van Griensven · Rudolf Seemann · Vilmos Vécsei · Kurt Widhalm

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Abstract

Objectives Overweight and obesity are afflictions that lead to an increased risk of health problems including joint problems. The aim of the study was to assess the condition of articular cartilage in obese adolescent patients suffering from knee pain.

Methods MRI of 24 knees of 20 morbidly obese patients, mean age 14.2 years, was performed in an open 1.0 Tesla MR system, where the cartilage, the quality and structure of the menisci, and the presence or absence of surrounding changes was examined.

Results In all patients a cartilage lesion in at least one region of the knee could be detected. Retropatellar cartilage lesions have been found in 19 knees. Ten cartilage lesions grade I, and four lesions grade II have been described in the lateral compartment of the knee, whereas the medial compartment showed in eight cases a grade I, in 13 cases a grade II and in two cases a grade III cartilage lesion. Meniscal changes were assessed in most patients.

Conclusion Morbidly obese children and adolescents show major abnormalities in the articular cartilage of the knee. Whether obesity alone is the causal factor for

H. K. Widhalm (✉) · S. Marlovits · V. Vécsei
Center for Joints and Cartilage, Department of Traumatology,
Medical University of Vienna,
Vienna, Austria
e-mail: harald.widhalm@meduniwien.ac.at

S. Marlovits
e-mail: Stefan.marlovits@meduniwien.ac.at

V. Vécsei
e-mail: Vilmos.vecsei@meduniwien.ac.at

G. H. Welsch
MR Center, Department of Radiology,
Medical University of Vienna,
Vienna, Austria
e-mail: welsch@bwh.harvard.edu

G. H. Welsch
Department of Trauma Surgery, University Hospital of Erlangen,
Erlangen, Germany

A. Dirisamer
Department of Radiology, Medical University of Vienna,
Vienna, Austria
e-mail: Albert.dirisamer@meduniwien.ac.at

A. Neuhold
Department of Radiology, Private Hospital Rudolfinerhaus,
Vienna, Austria
e-mail: A.neuhold@rudolfinerhaus.at

M. van Griensven
Ludwig Boltzmann Institute for Experimental
and Clinical Traumatology,
Vienna, Austria
e-mail: martijn.van.griensven@lbitrauma.org

R. Seemann
Department of Cranio-Maxillofacial and Oral Surgery,
Medical University of Vienna,
Vienna, Austria
e-mail: Rudolf.seemann@meduniwien.ac.at

K. Widhalm
Division of Nutrition and Metabolism, Department of Pediatrics,
Medical University of Vienna,
Vienna, Austria
e-mail: Kurt.widhalm@meduniwien.ac.at

the development of the pattern of these changes, remains to be seen.

Key Points

- *Morbidly obese children and adolescents often suffer from knee pain*
- *Prospective study showed cartilage and meniscal lesions in morbidly obese adolescents*
- *MRI is an adequate tool for assessing cartilage lesions even in morbidly obese patients*
- *It is unclear whether cartilage abnormalities are mainly due to mechanical overload*

Keywords Magnetic resonance imaging · Adolescents · Obesity · Knee pain · Cartilage lesions

Introduction

In the last two to three decades the prevalence of overweight children has doubled in the United States [1]. Furthermore, prevalence rates of morbid obesity in childhood and adolescence (defined as body mass index [BMI] above the 99.5th percentile for age and sex) registered a dramatic rise both in the USA [2–4] and in Europe [5–7].

Among overweight children in the European Union, it is estimated that there are at least 3 million obese children, and the number will increase by more than 85,000 each year [8].

Presently, at least one out of five children in the USA is overweight and similar figures have been reported in Europe. Interestingly the highest prevalence of obesity in the paediatric age seems to be in the Mediterranean region [9]. Excess body weight is the sixth most significant risk factor contributing to the overall burden of disease worldwide, whereas obesity represents one of the most important public health issues (World Health Organisation—Food and Agriculture Organisation [WHO-FAO], 2002) [10].

There are estimations that over 22 million children under the age of 5 are severely overweight worldwide [11].

Referring to several studies, obese children often show serious co-morbidities such as dyslipidaemia, insulin resistance and impaired glucose tolerance [12] as well as non-alcoholic fatty liver disease, sleep apnoea and asthma [13–15]. Even cardiovascular diseases, like cardiomyopathy and hypertension are linked to childhood obesity [10, 16–18], which could be an important early risk factor for adult morbidity and mortality [19–21].

Additionally early structural changes in arteries and impaired endothelial function can be observed in morbidly obese children, moreover a proinflammatory state has been detected in obese children, accompanied by functional vascular changes like inter-cellular adhesion molecule 1 (ICAM-1) and vascular cell adhesion molecule 1 (VCAM-1) [22].

In obese adults, joint problems such as arthritic or degenerative changes, especially of the knee and hip region, often occur [23]. Additionally, musculoskeletal disorders [24, 25] such as slipped capital femoral epiphysis, Blount's disease, forearm fracture or flat feet are reported occasionally, however, there are very few reports with regard to alterations in cartilage, which are associated with remarkable pain in severely obese subjects, especially in obese adolescents.

Magnetic resonance imaging has been reported to be the gold standard in establishing the diagnosis and monitoring of cartilage lesions in the knee joints. Owing to restrictions regarding available MR systems with which morbidly obese patients can undergo MRI, few studies are available on the constitution of articular cartilage in the knee joint in morbidly obese patients. To the best of our knowledge, there are no reports of joint abnormalities in adolescents with severe forms of obesity.

We hypothesised that in young subjects with morbid obesity, who reported painful knee problems, morphological and structural changes in the cartilage might be the cause of the complaints. Therefore, the aim of the present study was to confirm this hypothesis by means of high-resolution MR using an open MRI system.

Materials and methods

Definition of study cohort

The study was carried out according to the Helsinki Declaration, was approved by the local ethical committees and written, informed consent was obtained from all patients before enrolment. For the present study, the database of the Department of Pediatrics, Division of Nutrition and Metabolism, of the Medical University of Vienna was screened for morbidly obese children, who were admitted between January 2002 and April 2007 because of being severely overweight.

Patients, who took part in this study, had to meet the following inclusion criteria: subjects had to be between 8 and 20 years of age and morbidly obese, BMI exceeding the 99.5th percentile using the German curves for children and adolescents according to Kromeyer-Hauschild et al. [26]

Patients with regular medications like painkillers or psychotropic drugs, or those who had suffered trauma, which could have caused knee pain, were excluded. The data were analysed retrospectively, retrieving both, anthropometric data as well as additional anamnestic information. Patients identified were sent after an examination by a paediatric specialist in obesity (K.W.) to the outpatient clinic of the Department of Trauma Surgery, Division for

Joints and cartilage, where they had to undergo several examinations. The detailed basic anthropometrical data of the study population are listed in Table 1.

Of the total number of 505 overweight (>90th BMI-percentile for age) patients who were referred to the department between 2002 and 2007, 50 subjects had to be classified as being morbidly obese. Twenty morbidly obese patients—4% of the whole group—complained about painful knee joints and were therefore selected for participating in the study. Children's pain occurred regularly after a few minutes of walking or running, so that they were unable to do exercise using their knees.

For this study 20 morbidly obese patients, BMI>99.5th percentile, mean BMI 39.8 kg/m^2, mean weight 107.4 kg, mean age 14.2 years (9–19 years), who were suffering from chronic knee pain, have been included. Sixteen of these patients reported severe pain in one of their knees, and further four patients complained about pain in both knees. For this reason, 20 patients have been included in this study, but 24 knees in 20 patients were examined. Because there is no clear pathophysiological concept with regard to the possible cause of knee pain in obese children and adolescents, the following procedure has been established.

Design of the examination setting

Participating subjects were examined in underwear (± 0.1 kg), and body weight was measured in the morning in the fasting state on a scale. A comprehensive clinical investigation of the whole body, particularly of the joints of the painful knees was conducted. Principally the lower extremities were examined according to the patient's mechanical axis and the collateral ligaments of the knees. The testing of the stability of the knees was followed by the Lachman test [27], to obtain information about the cruciate ligaments, and tests concerning lesions of the menisci were also accomplished. The exterior aspect of the knee concerning swelling, effusion and reddening was appraised and the knee was measured precisely concerning the diameter of the joint, the height and the breadth. To measure the extent of the patient's knee mobility, the knees were moved passively by the investigator.

Table 1 Basic anthropometrical data

	Age Years	Height cm	Weight kg	BMI kg/m^2
Mean	14.2	162.5	107.4	39.8
Max	19.1	190.0	201.0	65.6
Min	9.5	144.0	60.0	28.6
SD	2.8	12.6	38.9	10.7

Clinical description

Participating children and adolescents had to fill in a standardised questionnaire according to the "CARRERA" Sheet (CARRERA: CARtilage REpair Registry Austria), in order to describe the clinical symptoms of patients suffering from cartilage lesions and to follow-up surgical cartilage repair procedures. This questionnaire includes questions according to the level of pain in different activities of daily living. It is a standardised evaluation system that was created for the description of cartilage repair procedures in a nationwide registry [28]. For the analysis used in this study, subjective patient evaluation of validated scores was used, specifically, the Visual Analogue Score (VAS) and the Knee Injury and Osteoarthritis Outcome Score (KOOS) [29–31]. KOOS is a 42-item self-administered, self-explanatory questionnaire that covers five patient-relevant dimensions, which were scored separately. Scores are transferred to a 0–100 scale, with zero representing extreme knee problems and 100 representing no knee problems [31] and scores between 0 and 100 representing the percentage of the total possible achievable score [32]. Results are provided in Table 2.

MR imaging

After completing the clinical examination, an MRI of the painful knees was performed in a special 1.0-Tesla open Panorama MRI tool (Panorama HFO High Field, Philips, Netherlands).

A standardised MRI examination protocol was used and the following four sequences were performed for each patient:

1. Sagittal PDW TSE: FOV 180 mm, rFOV 162 mm/90%, TR 1400 ms, TE 25 ms, 3-mm thickness. Matrix: 512*512.
2. Sagittal 3D WATS: FOV 180 mm, rFOV 160 mm/89%, TR 20 ms, TE 7.9 ms, 3-mm thickness. Matrix: 512*512.
3. Coronal PDW TSE SPIR: FOV 190 mm, rFOV 190 mm/100%, TR 1500 ms, TE 60 ms, 4-mm thickness. Matrix: 256*256.
4. Axial T2 TSE: FOV 150 mm, rFOV 150 mm/100%, TR 5897 ms, TE 100 ms, 3-mm thickness. Matrix: 512*512.

MRI and grading of cartilage and meniscal lesions

All the MR images have been reviewed by two independent radiologists who have experience in musculoskeletal diagnostic of 7 and 22 years respectively. After separate diagnostic sessions the radiologists have agreed on each score in a final consensus session. Tables given in results only show these values.

Table 2 Characteristics of the study sample

Characteristic	Subjects (n=20)		
	Mean	SD	Range
Age—years	14.2	2.8	[9.5–19.1]
Female Sex—no. (%)	9 (45%)		
Body mass index	39.8	10.7	[28.6–65.6]
Height	162.5	12.6	[144.0–190.0]
Weight	107.4	38.9	[60.0–201.0]
Characteristics of the knees			
Brittberg[a]	2	0	[1–3]
IKDC	67.2	13.6	[44.83–90.8]
Koos—quality of life	63.9	18.6	[37.5–93.8]
Koos—pain	74.1	17.2	[38.9–97.2]
Koos—sport	61.2	25.4	[15.0–90.0]
Koos—symptoms	67.0	7.6	[53.6–78.6]
Koos—daily activity	84.6	8.8	[70.6–100.0]
Noyen	71.2	16.7	[40.0–100.0]
Tegener/Lysholm	4.5	2.0	[1.0–6.0]
Visual analogue scale[a]	5	1.5	[1–7]
Outerbridge—cartilage[a]	3	2.7	[1–7]
Meniscal lesion score[a]	1.5	0.7	[0–4]
Effusion (volume in mL)	1.4	2.0	[0.0–6.9]
Baker cyst (volume in mL)[b]	2.9 (n=7)	2.7	[0.7–8.1]

[a]Median instead of mean and median absolute deviation (mad) instead of standard deviation

[b]Number of patients with a Baker cyst in round brackets

MRI and grading of cartilage lesions

Lesions of the cartilage were evaluated using the modified version of the Outerbridge Classification following the International Cartilage Repair Society (ICRS) [33–36]. According to the localisation and the extent of the cartilage lesions, four different grades had been analysed and evaluated.

Grade 0 indicated a normal cartilage situation with no abnormalities and no signal alterations in the MR sequences; Grade I was characterised by abnormal intra-chondral signal on the MR sequences but normal cartilage surface. Grade II was assigned if the articular surface showed further irregularities and a loss of the cartilage thickness of less than 50%, or if a separation between the superficial and deep cartilage layers was observed. A lesion was assigned as Grade III when severe surface irregularity with focal loss of 50% to 100% of the cartilage thickness was detected. If there was a complete chondral defect with bruising of the subchondral bone noted then it was assigned to Grade IV. The cartilage was assessed within three compartments of the knee joint: medial femorotibial, lateral femorotibial and patellofemoral. In compartments with multiple cartilage lesions of different grades, the most severe grade was used to classify the compartment. For the overall Outerbridge classification, the most severe grade of the whole knee was used.

MRI and grading of meniscal lesions

Meniscal lesions were also analysed by MRI and classified into three grades according to Stoller et al. [37]: MR grade I represented one or several punctate signal intensities not contiguous with an articular surface, grade II was a linear intrameniscal signal intensity without articular surface extension and grade III lesions of the meniscus were characterised by signal intensities, which showed an extension to at least one articular surface.

Statistical methods

Normal distribution of cartilage, meniscal score and effusion was tested by means of the Shapiro test of normality. The coefficient of overweight was tested in a t-test. To decide whether children and adolescents with BMI above the 99.5th percentile and knee pain show damage to the cartilage, a t-test was performed (H0: $\mu=0$; H1: $\mu>0$) for several parameters. As two parameters out of three did not show normal distribution, parameters were equally tested with non-parametric tests (Table 3). Additionally a Wilcox signed rank test was conducted, which was used in the case of several variables that were not normally distributed (Table 4). A Bonferroni correction was applied in a second step to compensate for multiple testing.

Table 3 Analytical statistics: *t*-test of damage to cartilage, lesions of the menisci or effusion. Outermost column on the right shows *p* value of Shapiro-Wilk normality test

Parameter	Test value	Degrees of freedom	*p*=	95% CI	*p* of Shapiro-Wilk
t-Test of cartilage score	t=8.13	df=19	6.6E-8	[2.9 – ∞]	0.093
t-Test of meniscal score	t=5.82	df=19	6.7E-6	[1.12 – ∞]	0.049
t-Test of effusion	t=3.2	df=19	0.0024	[0.64 – ∞]	2.9E-5

Interobserver reliability of radiological scores (i.e. cartilage and meniscal scores) was determined by means of Cohen's Kappa, percentage of agreement in detailed scores as well as percentage of agreement on existence of pathologic scores. Statistics were performed with open source software package R.

Results

Descriptive statistics of the 20 patients are displayed in Table 1. Patients (11 male/9 female), with an average age of 14.2 years (range 9–19 years) showed a mean BMI (body mass index) of 39.8 kg/m^2 (range 28.6 and 65.6 kg/m^2). On the MRI, meniscus tears have been identified in 16 out of 20 patients. In three cases a bone bruise in at least one location was seen (Fig. 1), in two patients the bone bruise was located in the medial compartment and in one patient in the lateral compartment. Baker cysts were detected in ten patients, and in seven patients the cyst was greater than 5 cm^2.

In all 24 knees of 20 patients cartilage lesions were detected in at least one region of the knee joint. In 23 knees a lesion of the articular cartilage could be described in the medial femorotibial (Fig. 2) and in 14 knees in the lateral femorotibial compartment. In 19 knee joints a cartilage defect was found in the retropatellar (patellofemoral) region (Fig. 3).

Five juvenile subjects did not have any alteration in the retropatellar cartilage. Nevertheless all four patients with bilateral knee pain showed retropatellar lesions in both knee joints. Out of 24 knees, there was a clearly diagnosed intrachondral signal alteration in nine cases and hence a diagnosed grade I lesion according to the Outerbridge classification, in eight cases a grade II, and in two cases a grade III lesion of the retropatellar cartilage.

In 8 out of 24 knees a grade I cartilage lesion was detected in the medial compartment, a grade II lesion was diagnosed in 13 knee joints, and a grade III lesion was exposed in two cases in the medial compartment of the knee joints.

In the lateral compartment a lesion of the cartilage was only rarely found. Out of 24 knee joints, a grade I lesion was detected in ten knees, and a grade II cartilage lesion according to the modified Outerbridge classification in four knees. None of the subjects showed any grade III lesion in the lateral compartment. No grade IV lesions, characterised by a full thickness defect of the cartilage with bruising of the subchondral bone were detected using MRI. The evaluation of the menisci revealed in the medial meniscus a grade I lesion in ten knees and a grade II lesion in seven

Table 4 Non-parametric test. Wilcox signed rank test with continuity correction. The outermost column to the right shows Bonferroni-corrected *p* values

Parameter	V	*p* value	Adjusted p value
Outerbridge cartilage score[a]	210	4.5E-5	5.8E-4
Meniscal score[a]	136	2.1E-4	2.7E-3
Effusion (volume in mL)[a]	171	1.0E-4	1.3E-3
Baker cyst (volume in mL)[a]	28	1.1E-2	0.15
IKDC[b] (μ=80)	7	3.9E-3	5.1E-2
Koos—quality of life[b] (μ=80)	12	1.0E-2	0.14
Koos—pain[b] (μ=80)	36	0.26	1.0
Koos—sport[b] (μ=80)	8.5	1.6E-2	0.21
Koos—symptoms[b] (μ=80)	0	8.1E-4	1.1E-2
Koos—daily activity[b] (μ=80)	69	0.95	1.0
Noyen[b] (μ=80)	14.5	5.3E-2	0.69
Tegener/Lysholm[c] (μ=6)	0	2.8E-2	0.37
Visual analogue scale[c] (μ=3)	80	8.3E-3	0.11

[a] H0: μ=0, H1: μ>0

[b] H0: mean(x) => μ given in round brackets, H1: mean(x)<μ

[c] H0: mean(x) <= μ given in round brackets, H1: mean(x)>μ

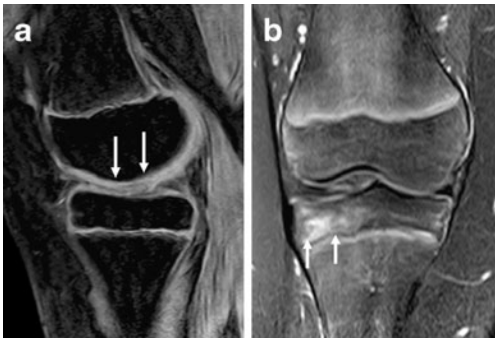

Fig. 1 Sagittal 3D WATS (**a**) and coronal PD TSE SPIR (**b**) MRI of an 11-year-old young boy suffering from pain in his right knee with no trauma. The patient is classified as morbidly obese with a height of 152 cm, a weight of 66 kg, exceeding a BMI of 28.6 kg/m^2. Range of motion of the young patient is 0-0-145. In **a** the cartilage lesion grade 1–2 according to Outerbridge in the medial compartment is seen (*white arrows*). In **b** the knee shows a marked bone bruise area in the lateral tibial region predominantly (*white arrows*)

knee joints. The lateral meniscus showed changes in 12 knee joints with grade I lesions in eight knees and grade II lesions in four knees. No grade III lesions were diagnosed in the 24 knee joints.

Cartilage and menisci score, as well as effusion showed significant abnormalities (Tables 3 and 4). The results of the Interobserver reliability are shown in detail in Table 5.

Fig. 2 Sagittal 3D WATS MRI of a 12-year-old young morbidly obese patient of his right knee with a height of 159 cm, a weight of 77 kg, exceeding a BMI of 30.4 kg/m^2. No trauma was responsible for knee pain measured by the VAS score of 6. The *two arrows* mark the region of the cartilage lesion in the medial compartment grade 3 according to Outerbridge. Furthermore, the MRI showed a lesion of the medial meniscus, and a slight lateralisation of the patella with a grade 2 cartilage lesion in the retropatellar area

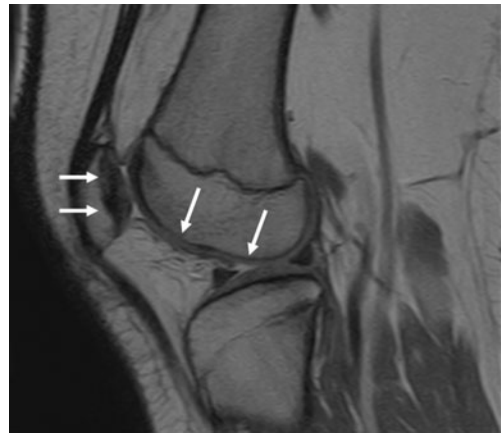

Fig. 3 Sagittal PDW-TSE MRI sequence of a 12-year-old girl complaining of severe knee pain in both of her knees with no memorable trauma. The young girl corresponds to morbid obesity classification indicating a BMI of 42.2 kg/m^2. The patient exhibits a genu valgus, with a hyperextension in the knees of 15 grade exceeding a range of motion of 15-0-130. The region tagging between the *two white arrows* in the femur and retropatellar region shows the abnormalities within the cartilage

KOOS score was shown to be significantly reduced regarding the symptoms dimension. Weak significances were found for Baker cysts, IKDC, KOOS quality of life, KOOS sport, Tegner and VAS scores (Table 4). Furthermore, two young obese patients showed changes in the form of an incipient osteoarthritis (Fig. 4). In five patients additionally a plica mediopatellaris and a lateralisation of the patella was seen. Further on the MRI the presence of joint fluid, Baker cysts excluded, was observed and measured in 18 patients, with an average size of 4.5 cm^2. In one patient a grade III osteochondritis dissecans was diagnosed.

Discussion

The present study demonstrates for the first time that in morbidly obese children and adolescents, who suffer from pains in their knees, marked morphological changes of the cartilages from different grades and in different compartments could be detected.

These defects are similar to those that can be seen in patients who were victims of various accidents or immediate sequelae of traumatic influences, which can be found in older people, due to mechanical injuries or as an inflammatory response to their joints. However, so far, those changes have not been described in young subjects without any traumatic history or any severe disease that could be responsible for this damage. Moreover the observed Baker cysts and effusions of greater extent, which were detected in some of the young subjects could be interpreted as a sign of osteoarthrosis or advancing lesions of the cartilage [38–40].

Table 5 Interobserver reliability measured with Cohen's Kappa test; percentage of agreement in all scores, percentage of agreement of healthy (score 0) vs. pathologic scores (scores >0)

Score	Cohen's Kappa	Percentage agreement of scores	Percentage agreement of pathologic scores
Cartilage retropatellar	0.764	83.3	87.5
Cartilage medial	0.661	79.2	95.8
Cartilage lateral	0.670	79.2	83.3
Meniscus medial	0.563	70.8	79.2
Meniscus lateral	0.341	62.5	75.0

However, these lesions, which can often be found in adults, have not been described in young subjects.

As summarised in Tables 3 and 4 morbid obesity shows a significant impact on pathological MRI findings in knee joints in children and adolescents. Especially typical pathological signs such as cartilage and menisci lesions (expressed in scores) and effusion were found. Whilst cartilage scores showed to be reliable (Table 5), meniscal scores depend more on the observer. The investigated patients showed significant symptoms, which were measured by KOOS score.

In a recent Australian study, Anandacoomarasamy et al. observed in about 50% of 111 severely obese adults (mean BMI 39.9 ± 5.8%) marked lesions of the cartilage of the knee [41]. Furthermore, they were able to show that the percentage of cartilage lesions was associated with the degree of obesity. The authors were able to show, that the knee cartilage defects were associated with physical disability and reduced knee range of motion, even after accounting for the presence of clinical knee osteoarthritis. Nevertheless, in this study, it does not come out clearly, how many of those patients with cartilage lesions complained of knee pain. In none of these patients cartilage lesions have been observed in both knees. Additionally in this study knee pain calculated, according to the WOMAC Score, was associated with cartilage defect scores in all compartments except the lateral tibiofemoral region, in multivariate analysis.

In another study by the same group the authors were able to describe knee cartilage lesions in the history of patients, who had undergone knee replacement. It could be shown, that the presence of cartilage lesions in the knee was associated with BMI and decreased after a period of weight loss [42]. The positive association between the presence of knee cartilage lesions has been described by another Australian group in 337 patients in 2005 with a preponderance of these lesions in obese women.

A study by Ding et al. described in detail the association between age and knee structural changes, measured by cross-sectional MRI in a sample of 372 male and female non-obese subjects, mean age 44 years [43]. They showed that the most consistent knee structural changes with increasing age are an enlargement in cartilage defect severity and prevalence, cartilage thinning and an increase in bone size.

Jones et al. were able to show, that in 74 healthy normal weight children (9–18 years of age/mean BMI 20,5 kg/m^2) the cartilage volume in the tibial region, but not in the patella bone, correlated significantly only with height, not with weight. In overweight children the articular cartilage volume did not differ significantly from the healthy normal weight children.

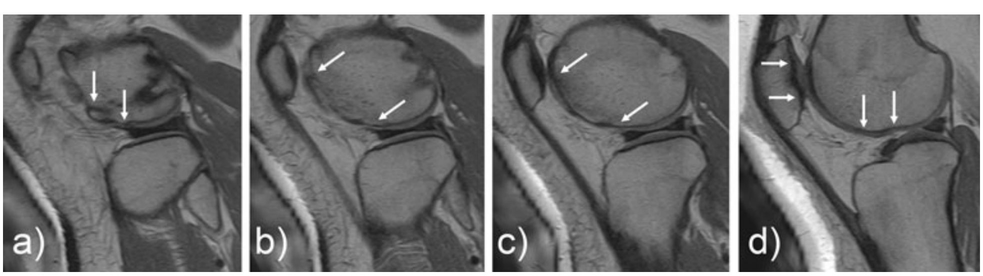

Fig. 4 Sagittal PDW-TSE (**a**–**d**) MRI of a morbidly obese young male patient, 15 years of age, with a height of 168 cm, a weight of 170 kg, exceeding a BMI of 60.2 kg/m^2. The patient complained of severe knee pain for 2 years; it was observed that the intensity of the pain was directly correlated with the young patient gaining weight. The mean VAS score was 5, and the motion of the knee was slightly reduced by a range of motion of 5-0-120. The images (**a**–**d**) show abnormality in the form of an incipient knee arthrosis beginning in **a** the lateral-most area dragging towards the medial, showing the medial compartment, and a cartilage lesion grade 2–3 according to Outerbridge in the retropatellar region (*white arrows*)

The authors were also able to describe an interesting phenomenon indicating that those children who participated in vigorous sport programmes, gained twice as much articular cartilage as those who participated less in sports [44]. These data make it very likely that the observed cartilage lesions in morbidly obese adolescents in our study are due to overweight. The fact that those subjects could not participate in vigorous sport programmes in previous years, an additional factor that led to insufficient development of an appropriate volume of the knee cartilage, might be taken into consideration. An important question in that regard is whether adolescents who are affected by those cartilage lesions could be involved in any kind of sport programmes, and if so, to what extent. Furthermore, the question whether weight loss has the potential to lead to a change or improvement in cartilage defect morphology must be answered soon.

Another important question that therefore has to be raised is whether these abnormalities are only due to mechanical overload, or whether other possible metabolic factors could be co-responsible for these changes. Due to the fact that the observed cartilage changes are described in detail for the first time, we are presently not able to provide detailed pathophysiological mechanisms, which could explain the underlying cause of the marked alterations.

However, these findings are of great interest, because one of the cornerstones for the treatment of severe obesity is physical activity. These results make it clear that physical activity without any professional diagnosis and observation is clearly contraindicated and could be associated with further damage to the knees due to uncontrolled movements of the joints.

One limitation of the study is the fact—due to a missing of a permission of the ethical committee—that no control group could be included. A further limitation is the lack of a gold standard insofar as none of the studied subjects underwent arthroscopy or any other surgical treatment of their knees. Moreover no longitudinal observation of those lesions is available so far and the present report represents a novel cross-sectional evaluation of young morbidly obese individuals with clinical symptoms. Nevertheless further studies have to show whether these changes really lead to early osteoarthritis in these patients and, furthermore, if these changes can be reduced after substantial weight loss, which could be achieved exclusively after bariatric surgery [45].

A further limitation of this study is that the image quality is limited in the present MRI measurements, because of the oversized knee joints and the open MR system used, and the diagnosis of cartilage alterations together with early osteoarthritic changes could already be well established.

It is currently unknown when these morphological changes in children's joints start to emerge and which joints are predominantly affected. Furthermore it is not quite clear, whether the described changes only occur at a definite body weight, in the presence of a certain metabolism derangement, or at certain changes in the anatomy, in terms of alterations in the axis of the leg. As no control group was included in this study, it would be of interest to study whether these morphological changes, which were shown on the MRI, can also be observed in young subjects with overweight or obesity (BMI<99.5°). The fact that it has been clearly shown by Jones et al. that in normal weight in healthy children no lesions of the knee cartilage could be detected, makes it more likely that obesity is the main causal factor [44].

In addition, morbidly obese adolescents, who do not suffer from any pain, should be examined by way of MRI of the knees. Thereby, the status of all joints should be assessed, with regard to whether certain joints were affected more than the others. Further studies that cover this topic more closely are being carried out at present and will therefore provide more information in the near future.

Looking from a therapeutic point of view, it would be relevant to carry out a knee arthroscopy with a possible cartilage smoothing in addition to weight reduction. Meanwhile, in the case of profound cartilage damage, it is important to consider possible microfracturing. Another method of reducing pain is the application of a hyaluronic acid compound [46–48]. Correspondingly, obtaining a steady state of cartilage morphology by means of the intake of reconstructing substances, such as chondroitin sulphate in the form of tablets is reasonable.

Morbidly obese children show severe damage to the knee joints affecting (according to Table 4); abnormalities correlate with reduced quality of life and pain. Future therapy might be monitored using the KOOS score or the IKDC score. Further studies should reassess these correlations between knee changes and symptoms in a healthy collective. MRI should be a good and diagnostically valuable method and might be used to prove reversibility of knee damage in morbidly obese children who reduce their weight. Reversibility of cartilage damage might be verified to depend on age and weight.

In conclusion children and adolescents with morbid obesity and knee pain show significant lesions of the cartilage, abnormal features within the menisci and effusions. These patients are very likely to complain about loss of quality of life. They experience pain and suffer arthrosis-related symptoms. Morbidly obese children have significant pain, due to the higher body weight, whereby higher forces are having negative effects on children's joints, so that they are not able to do physical activity regularly, and increase their weight further. It has been confirmed that many morbidly obese patients have severely lesions of the cartilage. Further research has to be done to ascertain whether factors other than obesity are causal for these marked changes.

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