Regular article

Examination of the locomotor system of elementary school students using a diagnostic ultrasound system and lower limb flexibility assessment: Toward the early detection of Osgood-Schlatter disease during the growth period

Running title: Examination of the locomotor system of elementary school students

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Abstract

This study aimed to evaluate a musculoskeletal screening method for elementary school students using ultrasound and lower limb flexibility assessments, with the goal of early detection of Osgood-Schlatter disease during the growth period. A total of 143 boys in the fourth to sixth grades of elementary school from a single prefecture underwent musculoskeletal screening between November 2021 and February 2023. Using a diagnostic ultrasound device, the tibial tuberosity was observed, and its developmental stage was classified based on Ehrenborg's four-stage classification

(Ehrenborg, G and Lagergren, C. (1961). Acta Chir. Scand., 121: 315–327). The presence of Osgood-Schlatter disease was determined based on the presence of irregularities in the ultrasound image. Lower limb flexibility was assessed quantitatively using finger-floor distance (FFD) and heel-hip distance (HHD). The cartilaginous stage (C stage) was the most common developmental stage observed. Osgood-Schlatter disease was identified in eight children (5.6%) and was found only in the epiphyseal (E) and bony (B) stages ($P=0.004$, $\varphi=0.308$). HHD was significantly greater in the Osgood-Schlatter group ($P=0.040$, $r=0.680$). In some children without knee pain or tenderness, irregularities in the tibial tuberosity were detected on ultrasound imaging, suggesting that ultrasound imaging may be useful for the early detection of asymptomatic lesions. This screening approach, which combines ultrasound examination and flexibility assessment, is expected to serve as a novel method for the early detection and prevention of musculoskeletal disorders in children during their growth period. Further large-scale studies and continued investigation into methods for assessing flexibility in growing children are warranted.

Keywords: ultrasound examination, elementary school student, Osgood-Schlatter disease

超音波検査と下肢の柔軟性の評価を用いた小学生の運動器検診－成長期のオスグッド・シュラッター病の早期発見に向けて－

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要旨

本研究は，超音波検査と下肢の柔軟性の評価を用いて小学生の運動器検診を実施し，成長期のオスグッド・シュラッター病の早期発見に向けた検診方法を検討することを目的とした．対象は県内の小学生 4～6 年生 143 名で，2021 年 11 月から 2023 年 2 月に運動器検診を実施した．超音波診断装置を用い脛骨粗面部を観察し，Ehrenborg の 4 段階分類に基づき発達段階を評価し(Ehrenborg G and Lagergren C. (1961). Acta Chir. Scand., 121: 315-327)，オスグッド・シュラッター病は不整像の有無で評価した．下肢の柔軟性は指床間距離（FFD）および

踵臀間距離（HHD）で定量的に評価した．脛骨粗面部の発達段階はC期が最も多く，オスグッド・シュラッター病は8名（5.6%）に認められ，E期およびB期でのみ確認された（P=0.004, φ= 0.308）．HHDはオスグッド・シュラッター病あり群で有意に大きかった（P=0.040, r = 0.680）．膝の疼痛や圧痛のない児童においても，超音波画像上で脛骨粗面部の不整像が確認された事例があり，無症候性病変の早期発見においても超音波検査が有用である可能性が示された．超音波検査と柔軟性評価を組み合わせた本手法は，成長期における運動器障害の早期発見および予防に資する新たな検診アプローチとして活用が期待される．今後は大規模な検証を行うとともに，成長期の柔軟性の評価方法に関して継続して検討が必要である．

Introduction

The locomotor system of children is still developing and fragile. Chronic external forces, such as through excessive sports, lead to overuse and can readily cause locomotor system disorders [*1,2*]. In recent years, the effects of children specializing in sport disciplines from an early age have been identified [*2*]. The growth period involves rapid ossification of the epiphyseal lines, leading to epiphyseal closure, and locomotor system disorders such as Osgood-Schlatter disease may be seen at this time [*3*]. It has been reported that stiffness of the body is related to locomotor system disorders during the growth period [*4*], and there have been various studies of knee pain, including a study of the relationship with stiffness of the quadriceps muscle [*5*] and a study of the relationship with knee joint extensor strength [*3*].

Osgood-Schlatter disease is common in children who practice sports. It is characterized by the appearance of pain with changes in the epiphyseal line [*6,7*], and it can greatly affect everyday life and athletic performance. Reports of the prevalence of Osgood-Schlatter disease range from 4% to 28% [*8-10*], and there has been research

94 into its association with development of the tibial tuberosity [*11-13*].

95 Past studies of bone development in children have used X-ray imaging, such as a study

96 of carpal bone maturity [*14*] and a study by Ehrenborg et al. that classified

97 development of the tibia into four stages (cartilaginous stage, apophyseal stage,

98 epiphyseal stage, and bony stage) [*15*]. More recent evaluations have used diagnostic

99 ultrasound systems, which are less invasive, and ultrasound studies of the association

100 between tibial development and Osgood-Schlatter disease have reported the disease to

101 be more common during the apophyseal and epiphyseal stages [*10,16-18*]. Studies

102 using diagnostic ultrasound systems have looked at the elbow and shoulder in baseball

103 [*19,20*], as well as the knee, and have investigated the usefulness of such systems.

104 In our previous research, we found that Osgood-Schlatter disease is commonly seen in

105 elementary school girls and junior high school boys. However, due to the small number

106 of male elementary school participants and the predominance of the cartilaginous stage

107 in tibial development, that study was unable to elucidate the condition of

108 Osgood-Schlatter disease in this group. As previously mentioned, an association

between flexibility and musculoskeletal disorders during the growth period has been reported [*3-5*]. In school-based musculoskeletal screening in Japan, flexibility has typically been assessed through parental observation of forward bending and squatting ability, which is then reported via questionnaires. Our previous studies also evaluated flexibility using these methods. However, the validity of forward bending and squatting as indicators of flexibility during the growth period has not been fully examined. Therefore, in the present study, the participants were limited to elementary school boys, a group that was inadequately represented in our previous research. In addition to the ultrasonographic evaluation of tibial tuberosity development and Osgood-Schlatter disease as in our prior research, finger-floor distance (FFD) and heel-hip distance (HHD) were newly included as objective and quantifiable measures of flexibility. The aim was to examine whether these methods could be useful for the early detection of Osgood-Schlatter disease. In the future, we hope that these findings will contribute to the refinement of flexibility assessment methods and screening protocols incorporating ultrasonography in musculoskeletal health examinations during

124 the growth period, thereby aiding in the early detection and prevention of
125 musculoskeletal disorders in children.
126
127 **Materials and Methods**
128 This study was carried out in accordance with the appropriate guidelines and was
129 approved by the Ethics Committee of Akita University Graduate School of Medicine
130 (approval number 1738 of 14 October 2021). The participants were 143 boys in
131 elementary school grades 4–6 who were members of six baseball teams within Akita
132 Prefecture, Japan. Examinations were carried out between November 2021 and
133 February 2023. The students and their guardians were informed in advance, both orally
134 and in writing, of the objective of the study, the methods, the voluntary nature of
135 participation, the protection of privacy, and the publication of the results of the study.
136 Only when appropriate consent was obtained did the children participate in the study.
137 The participants filled in a questionnaire before the study to provide basic data (grade,
138 age, presence of bone or joint pain, presence of knee pain).

The locomotor system examinations were carried out in the district where each baseball team was located by a team that included an orthopedic surgeon, a physiotherapist, an occupational therapist, and a registered nurse. The responses to the questionnaire were checked, and each participant's height and weight were measured. For examination of the tibial tuberosity, the participant sat with the knee flexed 90°, and the probe of a diagnostic ultrasound system (Noblus; Probe: 18 MHz L64, Hitachi, Ltd., Tokyo, Japan) was placed longitudinally on the tibial tuberosity. The four-stage classification of Ehrenborg et al. (1961) [*15*] was used to evaluate the developmental stage of the tibia [*21*] (Fig. 1). Osgood-Schlatter disease was evaluated by observing whether there was any irregularity of the tibial tuberosity on imaging. Flexibility was assessed by measuring the FFD and the HHD. Generally, FFD is considered to reflect the tightness of the hamstrings in the posterior thigh, whereas HHD reflects the tightness of the quadriceps in the anterior thigh. These measures have been incorporated into sports screening evaluations. Both FFD and HHD are objective indicators that allow for simple assessment of lower limb flexibility. They were

154 selected for this study because they can be safely and reliably implemented in
155 school-based musculoskeletal screening in the future.
156 Statistical evaluation was performed using SPSS (Ver. 29.0, IBM Japan, Tokyo, Japan).
157 After basic statistics were calculated, they were examined by means of a *t*-test,
158 one-way ANOVA, χ^2 test, or Fisher's exact test, as appropriate. The significance level
159 was set at $P<0.05$.
160
161 **Results**
162 The results for age, tibial tuberosity development stage, and locomotor system
163 examination of the boys who participated in this study are shown in Table 1. Their age
164 ranged from 9 to 12 years, and the tibial tuberosity development stage was C in 50.3%,
165 A in 11.2%, E in 18.9%, and B in 19.6% of participants; C was thus the most common
166 stage. The results of the locomotor system examination showed bone or joint pain in 28
167 (19.6%), knee pain in 9 (6.3%), and pressure pain at the tibial tuberosity in 2
168 participants (1.4%). Osgood-Schlatter disease was seen in 8 participants (5.6%).

Place Table 1 here.

The results comparing physique, tibial tuberosity development stage, and flexibility by age are shown in Table 2. Height and weight increased with age ($P<0.001$, $\eta^2= 0.336$) ($P<0.001$, $\eta^2= 0.316$). Height and weight were largely the same as the mean national values in the results of the FY2021–2023 School Health Examination Survey. The tibial tuberosity development stage was significantly different by age ($P<0.001$, $\varphi= 0.591$), with all participants aged 9 years at stage C, 14.5% of participants aged 10 years at stage A, and by age 11 years, the proportion of students at stage E and stage B had increased to over 20% for each stage. By age 12 years, 30% of participants were at stage E, and 50% were at stage B; thus, half of all participants had reached epiphyseal line closure. For flexibility, no significant difference due to age was seen in FFD. With HHD, the distance increased significantly with age ($P<0.001$, $\eta^2= 0.273$).

Place Table 2 here.

The results for bone or joint pain, knee pain, pressure pain at the tibial tuberosity, and Osgood-Schlatter disease were compared by tibial tuberosity development stage (Table 3). No significant differences in bone or joint pain, knee pain, or pressure pain at the tibial tuberosity were seen among the tibial tuberosity development stages, but all eight

Place Table 3 here.

participants with Osgood-Schlatter disease were at either stage E or stage B, and the difference was significant (P=0.004, φ= 0.308).

Flexibility, knee pain, and pressure pain at the tibial tuberosity were compared by the presence of Osgood-Schlatter disease (Table 4). No significant difference was seen in FFD, but mean HHD was significantly greater for participants with Osgood-Schlatter disease than for those with no Osgood-Schlatter disease (5.4±4.4 cm vs. 1.4±2.6 cm, P=0.040, r=0.680). No differences were seen in knee pain or pressure pain at the tibial tuberosity.

Place Table 4 here.

The individual details of the eight participants with Osgood-Schlatter disease are summarized in Table 5. All eight participants were in elementary school grade 5 or 6, and seven of the eight participants were aged either 11 or 12 years. The tibial tuberosity of all eight participants was stage E or stage B. Two of the eight participants had knee pain, and only one had pressure pain at the tibial tuberosity. There were individual differences in FFD and HHD, and two participants had HHD ≥10 cm.

Place Table 5 here.

Ultrasound images of the tibial tuberosity are shown in Fig. 2. Both Fig. 2e (participant

5) and Fig. 2f (participant 6) show cases of Osgood-Schlatter disease, and both were at tibial tuberosity development stage B. The figures clearly show irregularity of the tibial tuberosity. Fig. 2d (participant 4), in which no Osgood-Schlatter disease is seen, shows tibial tuberosity development stage B, but no irregularity of the tibial tuberosity line is found. Clear irregularity of the tibial tuberosity can be seen in Fig. 2e (participant 5) and Fig. 2f (participant 6), but there was no knee pain or pressure pain at the tibial tuberosity in either participant.

Discussion

In this study, the relationship between the developmental stages of the tibial tuberosity and Osgood-Schlatter disease in elementary school boys was evaluated using a diagnostic ultrasound device. By limiting the age and sex of the participants more than in the previous study, it was confirmed that, as in elementary school girls and junior high school boys, elementary school boys whose tibial tuberosity development was at stage E showed a high prevalence of Osgood-Schlatter disease. Furthermore, there was

214 also a high prevalence in stage B, which is more advanced than stage E, similar to the
215 prevalence in stage E. In a prior study of elementary school students that we conducted,
216 Osgood-Schlatter disease was mostly found in stage E [*11*], but this may have been
217 related to the fact that there were few children at stage B. In the present study, the same
218 incidence of Osgood-Schlatter disease was found in children at stage B as in children
219 at stage E, indicating the need to pay attention to growing children during the period of
220 transition from stage E to stage B.
221 A relationship between tibial tuberosity development stage and Osgood-Schlatter
222 disease has been reported by Kaneuchi et al. [*22*], and since the present study found
223 Osgood-Schlatter disease in both stages E and B, it is highly likely that rapid
224 ossification of the epiphyseal line during growth is a major factor in Osgood-Schlatter
225 disease onset. Concentration of external forces on the tibial tuberosity during the
226 ossification process may exert strong traction force on the knee extension mechanism,
227 in turn causing excess stress on the epiphyseal line. This suggests that management of
228 loads that are appropriate to the tibial tuberosity development stage through proper

exercise guidance is important for managing the risk of Osgood-Schlatter disease.

Nakase et al. have reported an association between Osgood-Schlatter disease and reduced flexibility of the quadriceps femoris muscle [*12,13*]. Previous studies [*5*] have indicated that stiffness of the quadriceps may exert excessive traction on the tibial tuberosity via the patellar tendon.

In the present study, a higher incidence of Osgood-Schlatter disease was observed in children with greater HHD, suggesting a potential link between reduced quadriceps flexibility and the disease. However, no causal relationship between HHD and Osgood-Schlatter disease could be established, and the findings should be interpreted with caution. Longitudinal studies are needed to determine whether quadriceps tightness precedes the onset of Osgood-Schlatter disease, whether the disease leads to muscle stiffness, or whether both develop concurrently. Furthermore, continued investigation is warranted regarding appropriate methods for assessing flexibility during the growth period and effective strategies for teaching stretching exercises.

Furthermore, the usefulness of the diagnostic ultrasound system should be noted. In the

244 past, X-ray examinations have normally been performed to evaluate tibial development,
245 but from the point of view of the problem of exposure to X-rays and the invasiveness
246 of the procedure, ultrasound is a safer method that can be used repeatedly. In the
247 present study, clear irregularity of the tibial tuberosity could be observed in subjects
248 with Osgood-Schlatter disease, indicating the usefulness of ultrasound evaluation. In
249 addition, since there were cases that were diagnosed with Osgood-Schlatter disease
250 despite having no knee pain or pressure pain, it is likely that ultrasound testing can be
251 used for early detection in asymptomatic cases. In growing children in particular,
252 carrying out regular ultrasound examinations may be expected to allow early diagnosis
253 and prevention of the disease. It has been reported that knee pain is affected by the
254 condition of the patellar tendon [*23*], and it will be important in the future to use
255 ultrasound for objective evaluation of the status of the quadriceps muscle and the
256 patellar tendon, in addition to the tibial tuberosity.
257 In this study, FFD and HHD were used as indicators of flexibility for the first time.
258 Notably, HHD was significantly greater in the group with Osgood-Schlatter disease.

Although causality could not be determined, the findings suggest that HHD may have potential utility in musculoskeletal screening during the growth period. Traditionally, school-based musculoskeletal screening has focused on evaluating the ability to perform forward bending or squatting. However, FFD and HHD provide objective and quantitative assessments. Combining these measurements with real-time ultrasonographic findings may lead to more precise evaluations of musculoskeletal conditions during growth.

In cases of Osgood-Schlatter disease, particular attention should be paid to the E and B stages of tibial development. Real-time observation of tibial development using ultrasound, combined with HHD results, may enable individualized exercise guidance in real time.

FFD and HHD are safe and simple methods that can be performed using only a ruler, once the measurement technique is learned. If these assessments are routinely conducted in schools and sports settings, ongoing monitoring of flexibility may allow for timely and appropriate stretching interventions, potentially contributing to the

prevention of musculoskeletal disorders.

There are, however, a number of limitations to this study. First, since the subjects were limited to a specific region, caution must be exercised in generalizing to the whole country. Furthermore, the limited sample size may have meant that detailed statistical analysis by developmental stage could not be adequately performed. Furthermore, HHD and FFD were used as indices for evaluation of flexibility, but there is the possibility of variation in the results due to differences in technique between observers and in the degree of cooperation of the children being measured. A more objective method of evaluation will need to be studied, such as evaluation of muscle and tendon elasticity by means of elastography using a diagnostic ultrasound system.

In summary, this study demonstrated that ultrasonographic evaluation of the tibial tuberosity is effective for the early detection and prevention of Osgood-Schlatter disease. It also highlighted the potential utility of objective and quantitative indicators such as HHD and FFD for assessing lower limb flexibility during the growth period. Future research should include validation with a larger sample size, longitudinal

studies to examine the causal relationship between flexibility and Osgood-Schlatter disease, and interventional studies aimed at improving flexibility. These efforts are essential for establishing effective strategies for the prevention and management of Osgood-Schlatter disease.

Conclusion

This study evaluated the relationship between the developmental stages of the tibial tuberosity and Osgood-Schlatter disease in male elementary school students using a diagnostic ultrasound device, alongside assessments of lower limb flexibility using FFD and HHD. The results indicated that Osgood-Schlatter disease was more frequently observed in children at the E and B stages, suggesting that rapid epiphyseal ossification during the growth period may be associated with increased risk of onset. In addition, the disease was more common in children with greater HHD, although further longitudinal studies are needed to clarify whether there is a causal relationship.

Moreover, the detection of irregularities in the tibial tuberosity on ultrasound imaging

304 in children without knee pain or tenderness suggests that ultrasonography is also useful
305 for the early detection of asymptomatic lesions. Traditionally, flexibility assessments in
306 schools have been limited to observational evaluations such as forward bending;
307 however, FFD and HHD provide objective and quantitative measures. When combined
308 with ultrasound imaging, these indicators may enable more accurate musculoskeletal
309 screening during the growth period.
310 Future efforts should focus on studies with larger samples, longitudinal research to
311 explore the causal relationship between flexibility and Osgood-Schlatter disease, and
312 studies of interventions such as stretching programs to verify preventive effects. These
313 steps are essential for establishing effective screening systems to support the early
314 detection and prevention of musculoskeletal disorders during childhood and
315 adolescence.
316
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Conflicts of Interest: MM is the Chief Executive Officer of Sonic Japan Holdings Co., Ltd. (Tokyo, Japan), a company that provides technical guidance for ultrasound examinations. The other authors declare that there are no conflicts of interest.

Author Contributions

MO and AS conceptualized the study design and protocol and selected the study institutions. MM was in charge of technical guidance for imaging of the musculoskeletal system using ultrasound diagnostic equipment and participated in discussions regarding image analysis. All authors collected and assembled the data. All authors carried out the analysis and interpretation of data. MO drafted the manuscript. All authors have critically reviewed, revised, and approved the manuscript.

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408

409 Figure legends

410 Figure 1. Evaluation of tibial tuberosity development stage

411 Evaluation of the morphology of the tibial tuberosity based on the classification of

412 stages of Ehrenborg et al. (1961).

413 Source: Partially modified from Hiroshi Minagawa. 2010. Musculoskeletal Ultrasound:

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415

416 Figure 2. Ultrasound images of the tibial tuberosity

417 a: Case 1. Elementary school grade 4, boy, age 10 y, tibial tuberosity development

418 stage C

419 b: Case 2. Elementary school grade 6, boy, age 12 y, tibial tuberosity development

420 stage A

421 c: Case 3. Elementary school grade 5, boy, age 11 y, tibial tuberosity development

422 stage E

423 d: Case 4. Elementary school grade 6, boy, age 12 y, tibial tuberosity development

stage B

e: Case 5. Elementary school grade 5, boy, age 11 y, tibial tuberosity development stage B, with Osgood-Schlatter disease, no knee pain, no pressure pain at the tibial tuberosity (An irregular outline is observed at the tibial tuberosity indicated by the white arrow.)

f: Case 6. Elementary school grade 6, boy, age 12 y, tibial tuberosity development stage B, with Osgood-Schlatter disease, no knee pain, no pressure pain at the tibial tuberosity (An irregular outline is observed at the tibial tuberosity indicated by the white arrow.)

Table 1. Age, tibial tuberosity development stage, and results of locomotor system examination of the participants (male, elementary school grades 4–6, n=143)

	Number (%)
Age (y)	
9	12 (8.4)
10	55 (38.5)
11	56 (39.2)
12	20 (14.0)
Tibial tuberosity development stage	
Cartilaginous stage (stage C)	72 (50.3)
Apophyseal stage (stage A)	16 (11.2)
Epiphyseal stage (stage E)	27 (18.9)
Bony stage (stage B)	28 (19.6)
Locomotor system examination	
Bone or joint pain	28 (19.6)
Knee pain	9 (6.3)
Pressure pain at the tibial tuberosity	2 (1.4)
Osgood-Schlatter disease	8 (5.6)

Table 2. Comparison of physique, tibial tuberosity development stage, and flexibility by age

(n=143)	Age (y) 9 (n=12)	10 (n=55)	11 (n=56)	12 (n=20)	P value	Effect size
Physique						
Height (cm) [*1]	138.7 ± 6.7	140.9 ± 6.0	147.2 ± 6.6	152.8 ± 7.0	<0.001**	η^2= 0.336
Weight (kg) [*1]	36.7 ± 9.1	36.9 ± 7.4	41.5 ± 8.2	46.3 ± 10.8	<0.001**	η^2= 0.316
Tibial tuberosity development stage [*2]						
C Stage (n=72)	12/12 (100)	39/55 (70.9)	19/56 (33.9)	2/20 (10.0)	<0.001**	φ= 0.591
A Stage (n=16)	0	8/55 (14.5)	6/56 (10.7)	2/20 (10.0)		
E Stage (n=27)	0	5/55 (9.1)	16/56 (28.6)	6/20 (30.0)		
B Stage (n=28)	0	3/55 (5.5)	15/56 (26.8)	10/20 (50.0)		
Flexibility						
Finger Floor Distance (FFD) (cm) [*1]	1.7 ± 7.1	1.6 ± 6.4	0.1 ± 7.2	0.1 ± 5.5	0.617	η^2= 0.313
Heel Hip Distance (HHD) (cm) [*1]	−0.1 ± 0.3	0.8 ± 1.7	2.4 ± 3.5	2.9 ± 3.1	<0.001**	η^2= 0.273

**:P<0.01

[*1] Values are means ± SD, one-way ANOVA

[*2] Values show numbers of participants (%), χ^2 test

Table 3. Comparison of results of locomotor system examination at each tibial tuberosity development stage

(n=143)	Tibial tuberosity development stage				P value	Effect size
	C Stage (n=72)	A Stage (n=16)	E Stage (n=27)	B Stage (n=28)		
Locomotor system examination						
Bone or joint pain (n=28) [*1]	14/72 (19.4)	4/16 (25.0)	7/27 (25.9)	3/28 (10.7)	0.496	φ= 0.129
Knee pain (n=9) [*2]	3/72 (4.2)	2/16 (12.5)	2/27 (7.4)	2/28 (7.1)	0.640	φ= 0.109
Pressure pain at the tibial tuberosity (n=2) [*2]	1/72 (1.4)	0	0	1/28 (3.6)	0.667	φ= 0.105
Osgood-Schlatter disease (n=8) [*2]	0	0	4/27 (14.8)	4/28 (14.3)	0.004**	φ= 0.308

**:P<0.01

[*1] Values are numbers of participants (%), χ^2 test

[*2] Values are numbers of participants (%), Fisher's exact test

Table 4. Comparison of flexibility and pain by presence of Osgood-Schlatter disease

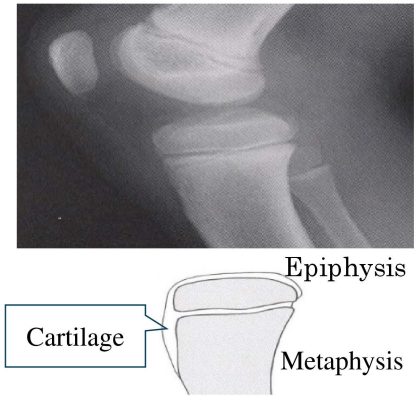
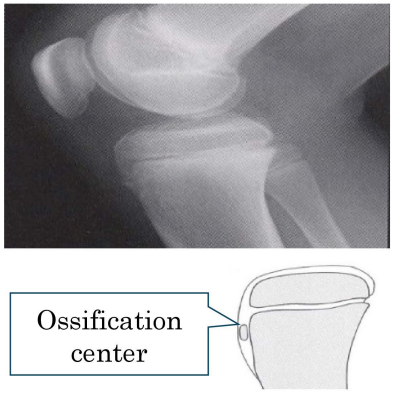
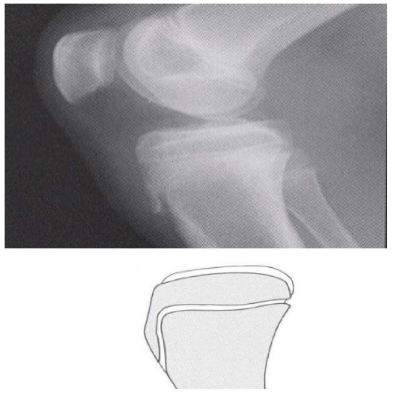
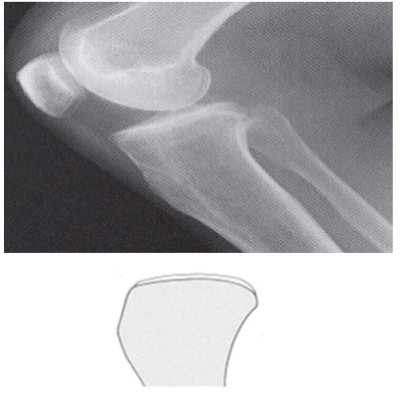
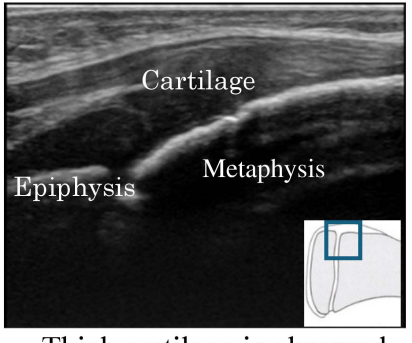
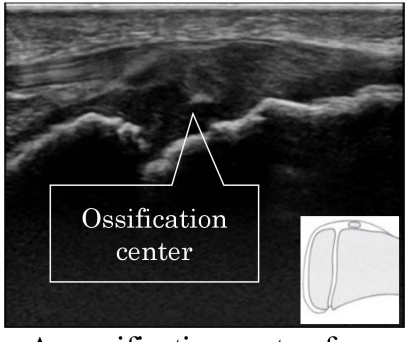
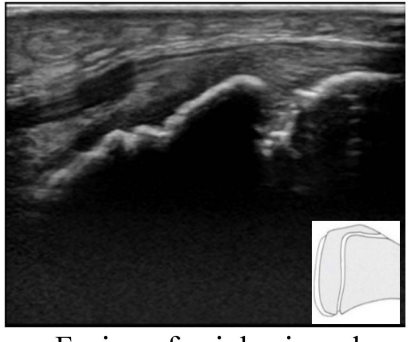
(n=143)	Osgood-Schlatter disease		P value	Effect size
	Yes (n=8)	No (n=135)		
Flexibility				
Finger Floor Distance (FFD) (cm) [*1]	−1.6 ± 7.0	0.9 ± 6.6	0.292	r = 0.090
Heel Hip Distance (HHD) (cm) [*1]	5.4 ± 4.4	1.4 ± 2.6	0.040*	r = 0.680
Locomotor system examination				
Knee pain (n=9) [*2]	1/8 (10.5)	8/135 (5.9)	0.414	φ= 0.062
Pressure pain at the tibial tuberosity (n=2) [*2]	0	2/135 (1.5)	1.000	φ= -0.029

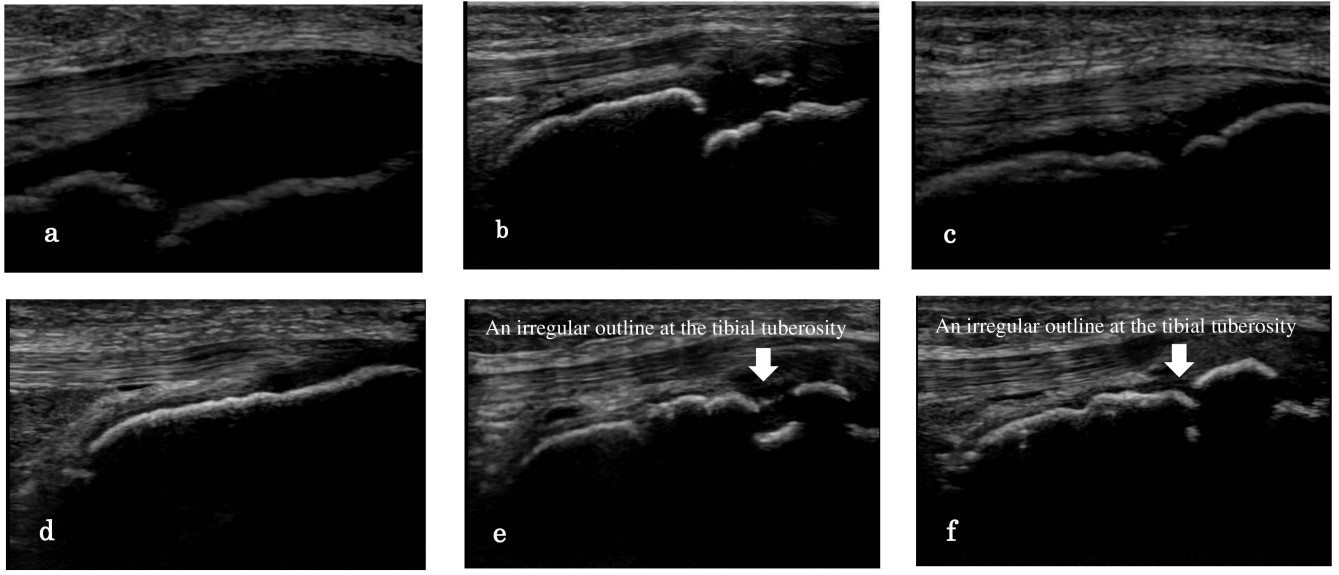
*:P<0.05

[*1] Values are means ± SD, *t*-test
[*2] Values are numbers of participants (%), Fisher's exact test

Table 5. Details of participants with Osgood-Schlatter disease (n=8)

	Grade	Age (y)	Height (cm)	Tibial tuberosity development stage	Knee pain	Pressure pain at the tibial tuberosity	FFD (cm)	HHD (cm)
1	5	10	156	B Stage	No	No	−7.0	4.0
2	5	11	141	E Stage	No	No	−12.0	10.0
3	5	11	151	B Stage	No	No	−4.0	13.0
4	6	11	144	E Stage	No	No	8.0	0
5	6	12	162	B Stage	Yes	No	4.0	1.0
6	6	12	152	E Stage	No	No	−7.0	5.0
7	6	12	160	E Stage	Yes	Yes	0	3.0
8	6	12	154	B Stage	No	No	5.0	7.0

	Before epiphyseal line closure			After epiphyseal line closure
	Cartilaginous Stage (stage C)	Apophyseal Stage (stage A)	Epiphyseal Stage (stage E)	Bony Stage (stage B)
X-ray image				
Ultrasound image				
	Thick cartilage is observed	An ossification center, from which ossification begins, appears in the thick cartilage	Fusion of epiphysis and ossification center	Epiphyseal line closes


a
b
c
d
An irregular outline at the tibial tuberosity
e
An irregular outline at the tibial tuberosity
f