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ABSTRACT

Purpose: The aim of this study was to compare ultrasonography stages of the tibial tuberosity development and physical features.

Methods: This study examined 200 knees in 100 male football players aged 10 to 15 years. Tibial tuberosity development on ultrasonography was divided into 3 stages: Sonolucent stage (stage S), Individual stage (stage I), and Connective stage (stage C). Age, height, quadriceps and hamstring muscle tightness, and muscle strength in knee extension and flexion were determined. These findings were compared with the respective stages of development.

Results: The tibial tuberosity was stage S in 27 knees, stage I in 69 knees, and stage C in 104 knees, with right and left sides at the same stage in 95%. Average age and height significantly increased with advancing tibial tuberosity development. Quadriceps tightness increased with tibial tuberosity development. Hamstring tightness decreased with development. The strength of both knee extension and flexion increased with advancing development, with a greater change seen in knee extension; hamstring/quadriceps ratio: Stage C, 0.74; Stage A, 0.64; Stage E, 0.53.

Conclusions: Osgood–Schlatter pathogenesis reportedly involves increased quadriceps tightness with rapidly increasing femoral length during tibial tuberosity development. In this study, it was confirmed that quadriceps tightness increased, yet hamstring tightness decreased, suggesting that quadriceps tightness is not due to femoral length alone. Other factors, including muscle strength, may be involved. The study shows that thigh muscle tightness and thigh muscle performance change with the skeletal maturation of the distal attachment of the patellar tendon. These results add new information to the pathogenesis of Osgood–Schlatter disease.

Level of evidence: III (Cross-sectional study)

Key Words: Osgood–Schlatter disease, Ultrasonography, Physical features, lower limb muscle tightness, lower limb muscle strength

Introduction

Osgood–Schlatter disease (OSD), named for the physicians that first described it in 1903 [15, 17], is a traction apophysitis of the tibial tuberosity caused by repetitive strain from the quadriceps muscle and chronic avulsion of the tibia. It may occur in either the preossification or ossified phase of the secondary ossification center. OSD is characterized by localized pain, swelling, and tenderness. It appears between the ages of 8 to 14 in girls, and 10 to 15 in boys, most commonly in children and adolescents who participate in sporting activities [2, 6]. Treatment is usually conservative, with medication, application of ice, protective knee padding and physical therapy to relieve pain [9]. It has been reported that symptoms tend to subside within 2 years and the prognosis is excellent in the majority of cases [9, 13]; however, Kaya et al reported that only half of patients totally recover according to ultrasonography results 2 years after diagnosis [11]. The most important considerations in OSD are prevention [14] and early diagnosis [9, 10], but in order to prevent a disorder, it is necessary to identify its risk factors [1]. An animal model of OSD has not been established, and the pathogenesis of OSD remains unknown.

Ultrasonography is effective in the early diagnosis of OSD [21]. It has been reported that early detection of OSD and conservative treatment can enable early return to sporting activities [9, 10]. Sonographic features include pretibial soft tissue swelling, cartilage swelling, fragmentation of the ossification center of the tibial tuberosity, thickening at the insertion of the patellar ligament, and inflammation of the deep infrapatellar bursa [3, 4]. Ultrasonography can also be used to observe the development of the tendon insertion (Achilles tendon insertion at the calcaneal tuberosity [8], and patellar tendon insertion at the tibial tuberosity [5, 21]). Ehrenborg et al. evaluated the tibial tuberosity radiographically and classified its development into 4 stages: cartilaginous stage, apophyseal stage, epiphyseal stage, and bony stage [7]. Ducher et al. used ultrasonography to classify development of the tibial tuberosity into 3 stages [5]. This classification includes the apophyseal stage of Ehrenborg's classification in the cartilaginous stage. The present study determined that development of tibial tuberosity cannot be examined in detail using this classification. The present study investigated the cause of Osgood–Schlatter disease by comparing subjects' physical features with stages that were created for a new classification of skeletal maturation of the distal attachment of the patellar tendon, defined by ultrasonography, The aim of this study was to compare ultrasonographic stages of the tibial tuberosity development and physical features of the subjects. The hypothesis was that thigh muscle tightness and thigh muscle performance change with the skeletal maturation of the distal attachment of the patellar tendon.

Materials and Methods

The subjects comprised 114 preadolescent male football players (soccer practice: 2 hours every day); 228 knees in subjects aged 10 to 15 years (mean, 12.0 ± 1.3 years) were examined. The players were informed of the aims of the study and the procedures involved and, along with their parents, gave written informed consent. The study was reviewed and approved by the university ethics committee.

The skeletal maturation of the distal attachment of the patellar tendon was examined using ultrasonography. The HI VISION Avius (Hitachi Medical Corporation; Tokyo, Japan) and MyLabFive machines (Esaote; Genoa, Italy) were used with a 12 MHz (10–14 MHz) high-resolution linear probe, with musculoskeletal calibration. Subjects were in the supine position, with the back of the knee supported. A new ultrasonographic classification was created to evaluate the skeletal maturation of the distal attachment of the patellar tendon referred to by the Ehrenborg classification. Ultrasonography images of asymptomatic knees that are representative of the three stages of the maturation process of the patellar tendon insertion were used in the new classification system. The Sonolucet stage (Stage S) is characterized by a large amount of apophyseal cartilage (“Sonolucent”). The Individual stage (Stage I) is characterized by apophyseal cartilage with an “individual ossicle”. The Connective stage (Stage C) is characterized by a connection of the secondary ossification and tibial epiphysis (Figure 1). To investigate the relationship between the immature tibial tuberosity and subjects’ physical features, 13 boys who were affected by OSD and 1 boy who had completion of groove on ultrasonography were excluded. The study therefore involved 100 patients and 200 knees. To confirm the diagnosis of OSD, a patient had to fulfill all of the following clinical criteria: pain with direct pressure on the tibial apophysis; pain before, during, and after physical activities; enlargement or prominence of the tibial apophysis; pain with resisted knee extension; and pain with jumping. The following ultrasonographic findings were also required: delamination tear/fracture of the tibial tuberosity epiphysis; deep infrapatellar bursitis; and superficial infrapatellar bursitis.

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These physical findings were compared with the respective stages of tibial tuberosity development.

Statistical analysis

The data were analyzed with Statistical Package for the Social Sciences 19.0 (SPSS Inc., Chicago, IL, USA). One-way ANOVA and the Bonferroni correction were used for comparisons among the 3 groups. The level of significance for all statistical analyses was set at an α value of 0.05.

Results

The development of the tibial tuberosity was at Stage S in 27 knees, Stage I in 69 knees, and Stage C in 104 knees. The right and left sides were at the same stage of development in 95% of cases. The average age and height significantly increased with advancing development of the tibial tuberosity. Quadriceps tightness increased with the development of the tibial tuberosity. On the other hand, hamstring tightness decreased with tibial tuberosity development, measuring. The strength of both knee extension and knee flexion increased with advancing tibial tuberosity development. The change in muscle strength was greater in knee extension compared with flexion. The hamstring/quadriceps ratio was 0.74

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Discussion

The most important finding of the present study was that thigh muscle tightness and thigh muscle performance change with the skeletal maturation of the distal attachment of the patellar tendon. This result was consistent with our hypothesis.

It is currently widely accepted that OSD is a traction apophysitis of the tibial tubercle, caused by overload/microfractures in the attachment of the patellar tendon [2, 3, 10]. The repetitive strain, in turn, is caused by the strong pull produced by the quadriceps muscle during sporting activities.

A number of studies have approached the importance of rectus femoris shortening [9, 14]. It is well known that the quadriceps femoris muscle contracts eccentrically during the stance phase of running until the beginning of propulsion when the knee reaches the highest level of flexion [16]. And shortening of the rectus femoris may substantially affect the biomechanical function of the knee with respect to the lever arm, peak torque, and discharge of compressive forces at 30° and 60° [9]. This study establishes the relationship between skeletal maturation of the distal attachment of the patellar tendon and lower limb muscle strength. In particular, the strength of knee extension increased dramatically between Stage I and Stage C. Furthermore, quadriceps tightness increased along with the development of the tibial tuberosity. It was concluded that partial avulsion of the secondary ossification center occurs because of this observed increase in muscular strength and quadriceps tightness. Although the increase in quadriceps tightness may be attributable to sudden growth in femur length, an increase in hamstring tightness should also have been seen; instead, a decrease was observed. There must be an explanation other than, or in addition to, femoral growth. The femoral neck detorsion that occurs around 5 years of age may influence and may influence muscle insertion and muscle fatigue. Further future investigation is planned.

Hirano et al. [10], evaluating magnetic resonance imaging studies, stated that some type of injury occurs in the secondary ossification center of the tibial tuberosity during apophyseal stage by Ehrenborg classification in patients with OSD. The injury leads to a crack which progresses to separation of the epiphysis from the tibial shaft. In our experience, medical examinations revealed no subjective or objective knee symptoms during Stage I, yet 1 month later OSD was diagnosed in 2 of these patients. In both patients, ultrasonographic findings at disease onset were characteristic of OSD

[4], the secondary ossification center was avulsed, and patients had progressed to Stage C. These results suggest that OSD is caused by overuse in the period from Stage I to Stage C [3, 9], and that the tibial tuberosity changes dramatically in the short period between these stages. Ultrasonography was beneficial to evaluate immature tibial tuberosity.

Muscle-tendon complexes are stretched as bones grow in length; adaptation occurs in which muscle fibers increase their numbers of sarcomeres. If the increase in sarcomeres does not catch up to the increase in bone length, muscle tightness is said to increase [12, 18], although this increase can be prevented by stretching [12]. This increase might have implications in avoiding OSD (for example, avoiding particular exercises and using stretching programs), but further studies are needed. If the timing of each stage, particularly Stage I, can be predicted from parameters such as the growth rate of height, it will be very useful in the prevention of OSD and medical examinations can become more effective.

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Legends of figures and tables

Fig. 1 New ultrasonographic classification of tibial tuberosity development.

Table 1. Age, height, lower-limb muscle tightness and lower-limb muscle strength

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Legends of figures and tables

Fig. 1 New ultrasonographic classification of tibial tuberosity development.

Table 1. Age, height, lower-limb muscle tightness and lower-limb muscle strength

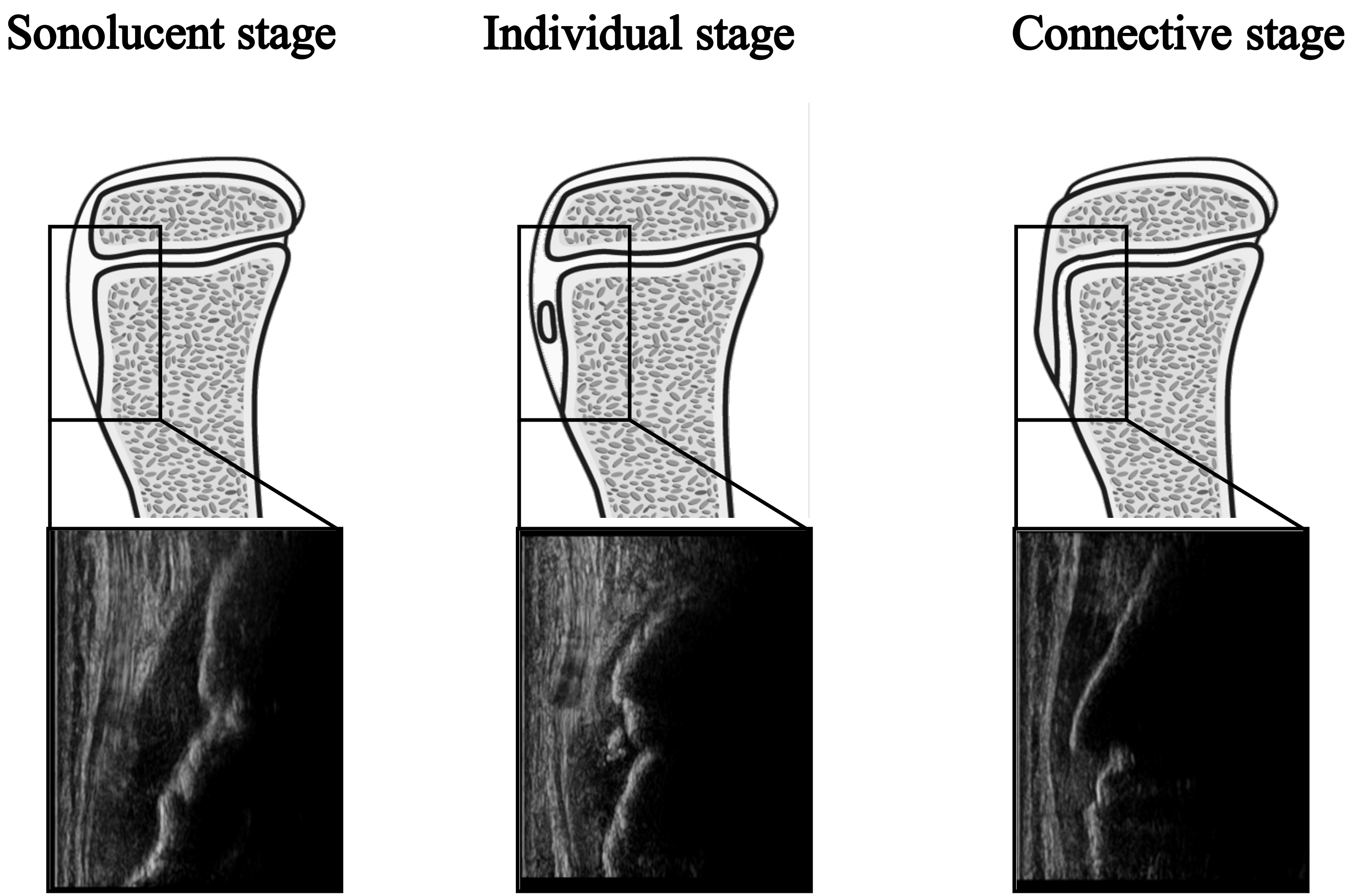

Figure 1

*$P < 0.05$

			Lower-limb muscle tightness		Lower-limb muscle strength		
	Age (years)	Height (cm)	Quadriceps (mm)	Hamstrings (degree)	Knee extension (N)	Knee flexion (N)	H/Q ratio
Stage S (27 knees)	10.7±0.7	136.9±4.5	16±20	67 ±11	158±61	108 ±32	0.74
Stage I (69 knees)	11.3±0.9	145.0 ±7.4	20 ±31	72 ±10	202±60	123±31	0.64
Stage C (104 knees)	12.8 ±1.0	156.9±7.8	33±30	79 ±11	308±92	156±35	0.53

Table 1