

The Effect of High Body Mass Index on the Mechanism of Pediatric Tibial Tubercle Avulsion Fractures: A Series of Eight Cases

Yüksek Vücut Kitle İndeksinin Çocuklarda Tibia Tüberkülü Avülsiyon Kırıklarının Mekanizması Üzerindeki Etkisi: Sekiz Vakalık Bir Seri

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ABSTRACT

Background: Pediatric tibial tubercle avulsion fractures are uncommon injuries, typically occurring in adolescent males during jumping or sprinting. Recent studies suggest that an increased body mass index (BMI) may predispose individuals to these fractures, even in the absence of high-energy trauma. This study investigated the relationship between elevated BMI and injury among adolescents with tibial tubercle fractures.

Materials and Methods: After ethics approval, a retrospective review was conducted in patients aged 10-18 years diagnosed with tibial tubercle fractures between June 2020 and September 2023. Demographics, BMI, fracture type (Ogden), injury mechanism, and treatment were recorded. The correlation between fracture severity and treatment modality was analyzed using Spearman's test.

Results: Eight male patients (mean age 14.5 ± 1.1 years) were included; all had obesity (mean BMI 31.4 ± 0.4 kg/m²). Four fractures occurred during basketball training without direct trauma; another four occurred atraumatically while standing. Higher Ogden grades showed a trend toward requiring open reduction ($p = 0.61$, $p = 0.11$). Complete union was achieved in all patients; two patients underwent implant removal.

Conclusion: A high BMI may be associated with tibial tubercle avulsion fractures in adolescents, including cases occurring without significant trauma. Although fracture union was achieved in all patients, higher-grade fractures were more likely to require open reduction. Larger prospective studies are needed to further clarify the relationship between BMI and the fracture mechanism.

Keywords: Tibial tubercle fracture, pediatric obesity, body mass index, atraumatic fracture, adolescence

ÖZ

Amaç: Pediatrik tibial tüberkül avülsiyon kırıkları, genellikle ergen erkeklerde zıplama veya sprint sırasında görülen nadir yaralanmalardır. Son çalışmalar, yüksek enerjili travma olmaksızın bile artmış vücut kitle indeksinin (VKİ) bu kırıklara yatkınlığı artırabileceğini öne sürmektedir. Bu çalışma, tibial tüberkül kırığı olan ergenlerde yüksek VKİ ile yaralanma mekanizması arasındaki ilişki araştırılmıştır.

Gereç ve Yöntemler: Etik kurul onayının ardından, Haziran 2020 ile Eylül 2023 tarihleri arasında tibial tüberkül kırığı tanısı konmuş 10-18 yaş arası hastalar üzerinde retrospektif bir inceleme yapıldı. Demografik bilgiler, BMI, kırık tipi (Ogden), yaralanma mekanizması ve tedavi kaydedildi. Kırık şiddeti ile tedavi yöntemi arasındaki korelasyon Spearman testi kullanılarak analiz edildi.

Bulgular: Çalışmaya sekiz erkek hasta (ortalama yaş $14,5 \pm 1,1$ yıl) dahil edildi. Tüm hastalarda obezite vardı (ortalama BMI $31,4 \pm 0,4$ kg/m²). Dört kırık basketbol antrenmanı sırasında doğrudan travma olmaksızın meydana geldi, dört kırık ise ayakta dururken travma dışı olarak oluştu. Daha yüksek Ogden dereceleri, açık redüksiyon gerektirme eğilimini gösterdi ($p = 0,61$, $p = 0,11$). Tüm hastalarda tam kaynama sağlandı ve iki hastada implant çıkarılması işlemi uygulandı.

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Sonuç: Yüksek VKİ, ergenlerde tibial tüberkül avülsiyon kırıkları ile ilişkili olabilir ve bazı olgularda travma olmaksızın gelişebilir. Klinik sonuçlar genel olarak iyi olmakla birlikte, daha yüksek kırık dereceleri açık redüksiyon gereksinimi ile ilişkili bulunmuştur. Bulguların küçük örneklem nedeniyle dikkatli yorumlanması gerekmektedir.

Anahtar Kelimeler: Tibia tüberkül kırığı, çocukluk çağı obezitesi, vücut kitle indeksi, travma dışı kırık, ergenlik

Introduction

Some childhood fractures have traditionally been common, while others are quite rare. However, the increased participation of children in professional sports and their involvement in different sports branches have led to significant changes in the epidemiology of pediatric fractures (1,2). This change has led to an increase in both the incidence of some rare fractures and the frequency of atypical fracture patterns (3). One such fracture is the pediatric tibial tubercle fracture. These injuries, previously reported only as case reports, are now being published as case series.

Pediatric tibial tubercle fractures constitute a small subgroup of childhood epiphyseal injuries, with an incidence of less than 1% reported in the literature (4). Almost all cases occur in adolescent males during a period of rapid skeletal development (5). The primary reason for this predisposition is a mechanical weakness at the junction between the secondary ossification center of the tubercle and the tibial epiphysis. The traction force generated by a strong contraction of the quadriceps muscle in this region leads to avulsion-type fractures (6).

Classically, tibial tubercle fractures have been identified in adolescent athletes participating in sports that involve jumping and sprinting, such as basketball (5). However, recent studies have reported that similar fractures can also develop after low-energy trauma in children with a high body mass index (BMI) (7). Because the injury affects the knee's extensor mechanism, accurate diagnosis and appropriate treatment are crucial. Treatment decisions are generally based on the Ogden classification, and appropriate treatment achieves a high rate of uncomplicated union. The most frequently reported complications are minor, such as implant irritation (8).

The majority of the existing literature focuses on sports-related injuries, but the role of increased BMI and low-energy trauma in the development of proximal tibial epiphyseal injuries has been limitedly examined (9). This study aims to contribute to current knowledge by describing the clinical and radiological features of proximal tibial epiphyseal and tubercle fractures observed in adolescents with high BMI during athletic and non-athletic activities.

Materials and Methods

Following approval by the Ankara Bilkent City Hospital Ethics Committee (approval number: TABED 2/1341/2025, date: 25.06.2025), this study was conducted in accordance with the principles of the Declaration of Helsinki. Retrospective data were collected from the hospital's automated system. Patients presenting to our clinic with a diagnosis of a tibial tubercle fracture between June 2020 and September 2023 were included in the study. Written informed consent was obtained from all patients and/or their legal guardians prior to inclusion in the study. Patient examination notes, surgical notes, and imaging records were reviewed.

The study included patients aged 10-18 years with a clinically and radiologically confirmed diagnosis of tibial tubercle fracture and a follow-up period of at least 6 months. Patients with a previous fractures in the same extremity, concomitant multiple traumas, or metabolic bone disease were excluded. Cases with incomplete clinical or imaging data were also excluded from the analysis.

The patients' ages, gender, mechanism of trauma, sports participation, and body structure were assessed. Fracture type was determined using the Ogden classification, and BMI was calculated from the patients' height and weight. The treatment method (closed or open reduction, screw fixation, etc.) was recorded in the operative notes and on postoperative radiographs. Outpatient clinic follow-up notes documented the time to return to daily life, the development of complications, and the need for implant removal (Figures 1,2).

Statistical Analysis

Data are summarized using descriptive statistics. Continuous variables are presented as means $\pm$ standard deviation or medians (minimum-maximum), and categorical variables are presented as numbers and percentages. Patients' mean BMIs were evaluated to determine general trends. Analyses were conducted using SPSS 22.0 (IBM Corp., Armonk, NY, USA).

Results

A total of eight male patients, aged 13 to 16, were included in the study. The mean age of the patients was 14.5 ± 1.1 years. The mean height was 184 ± 3 cm, the mean body weight was 106 ± 3 kg, and the mean BMI was 31.4 ± 0.4 kg/m². All patients had a BMI above 30 kg/m², meeting the criteria for obesity. Half of the patients ($n = 4$) sustained injuries during the jumping phase of basketball training, with no record of a fall; the other half ($n = 4$) sustained injuries while standing, without a history of exercise or trauma. No additional trauma or accompanying injuries were found in any of the cases (Table 1).

The fracture type was determined according to the Ogden classification: Type 2B in three patients, Type 1B in one patient, Type 3A in one patient, and Type 2A in three patients. Examination of treatment methods showed that open reduction and cannulated screw fixation were performed in six patients, and closed reduction and internal fixation were performed in two patients. A positive correlation was observed between fracture type and the need for open reduction (Spearman's $\rho = 0.61$, $p = 0.111$),

although this did not reach statistical significance. The need for open reduction tended to increase with fracture severity, but the relationship was not statistically significant.

The average postoperative splinting period was 3 weeks, and the average time to weight-bearing was 4.2 weeks (range, 2-6 weeks). Patients who participated in sports returned to active sports participation within an average of 3.5 months (range, 3-6 months). A statistically non-significant toward a longer time to return to sports with increasing fracture severity was observed ($p = 0.54$; $p = 0.163$).

Complications included mild pain during early kneeling in all cases; however, no limitation of joint movement or non-union were during the late period. Implant removal was performed on two patients because of irritation. The follow-up period ranged from 6 to 18 months (mean 10 months); no recurrent injury or deformity occurred during this period. Patients who required implant removal had longer follow-up periods.

Discussion

Although pediatric tibial tubercle avulsion fractures are a rare fracture type, their fracture mechanism and patient

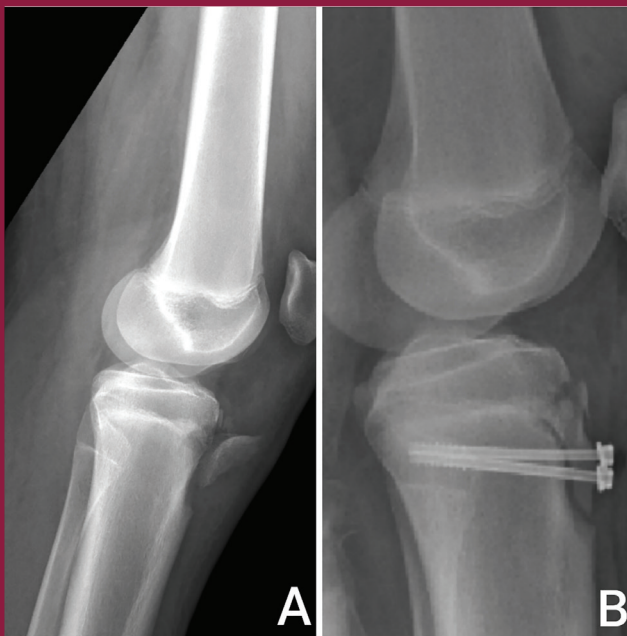


Figure 1. Preoperative and postoperative radiographs of a 14-year-old boy with a type IIA tibial tubercle avulsion fracture. (A) Lateral radiograph showing a displaced avulsion fragment at the tibial tubercle without intra-articular extension. (B) Postoperative lateral radiograph demonstrating anatomical reduction and fixation performed using a closed reduction technique with two cannulated screws, with complete restoration of the tibial tubercle alignment.

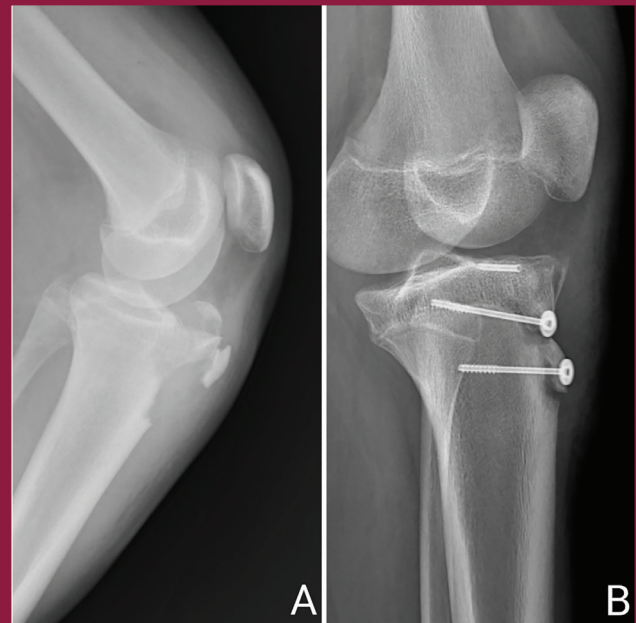


Figure 2. Preoperative and postoperative radiographs of a 14-year-old boy with a type IIB tibial tubercle avulsion fracture. (A) Lateral radiograph demonstrating a displaced tibial tubercle fragment with intra-articular extension, consistent with an Ogden type IIB fracture. (B) Postoperative lateral radiograph showing anatomical reduction and fixation performed through an open reduction technique using a cannulated screw and an Acutrak screw, achieving restoration of the tibial tubercle and extensor mechanism alignment.

profile are well described in the literature (1,8,10). However, in recent years there has been a significant increase in both the number of cases reported and the number of publications on this topic. Recent studies have reported strikingly high BMIs in patients with these fractures (7,11). Our series, in which similarly high mean BMIs were observed and fractures occurred atraumatically in half of the cases, represents a novel contribution to the literature.

A systematic review by Pretell-Mazzini et al. (8) reported that the mean age of tibial tubercle fractures was 14.6 years; 97% of these cases were male and they were most frequently associated with jumping sports such as basketball. Similarly, the mean age and male predominance are consistent with both our study and other series in the literature. In a recent systematic review including a large series of 919 cases, Kalifis et al. (9) reported a surgical treatment rate of 88% and a union rate of 99.8%. In our series, the open reduction rate was consistent with the literature, and the need for

open reduction correlated significantly with higher Ogden fracture types. However, Kalifis et al. (9) emphasized that the quality of reduction, rather than the type of fracture, is a determinant in treatment decisions. Checa et al. (12) reported successful results in cases where a higher rate of conservative treatment was administered. When the current literature and our findings are considered together, it appears that tibial tubercle fractures are generally uneventful, with a high union rate and a low complication rate.

In our series, implant irritation, particularly pronounced in the kneeling or squatting positions, was observed in all patients. However, implant removal was required in only two patients. Pretell-Mazzini et al. (8) reported a complication rate of 28%, with implant irritation being the most common complication. Similarly, Reyes et al. (6) and Kalifis et al. (9) also emphasized in their reviews that implant intolerance and bursitis are among the most common minor complications following tibial tubercle

Table 1. Detailed demographic and clinical characteristics of the patients.

Case	Age (years)	Sex	BMI (kg/m ²)	Mechanism of injury	Fracture type (Ogden)	Treatment method	Residual complaint	Implant Removal
1	14	Male	31.69	Atraumatic	2B	Open reduction, cannulated + Acutrak screw	Anterior knee pain during kneeling	No
2	13	Male	30.75	Basketball training	1B	Closed reduction, cannulated screw	Anterior knee pain during kneeling	Yes
3	14	Male	31.50	Basketball training	3A	Open reduction, cannulated screw	Anterior knee pain during kneeling	Yes
4	15	Male	31.40	Atraumatic	2B	Open reduction, cannulated screw	Anterior knee pain during kneeling	No
5	15	Male	31.74	Atraumatic	2A	Closed reduction, cannulated screw	Anterior knee pain during kneeling	No
6	14	Male	31.05	Atraumatic	2A	Open reduction, cannulated screw	Anterior knee pain during kneeling	No
7	13	Male	31.07	Basketball training	2A	Open reduction, cannulated screw	Anterior knee pain during kneeling	No
8	14	Male	30.67	Atraumatic	2B	Open reduction, cannulated screw	Anterior knee pain during kneeling	No

BMI, Body mass index.

fractures. Prospective studies evaluating the effectiveness of biodegradable or low-profile implants to prevent implant irritation, particularly in patients with high BMI, may help resolve this issue.

The fracture mechanism has been identified as an avulsion, which results from the tensile force exerted on the tibial tubercle apophysis by a strong contraction of the quadriceps muscle. Therefore, this type of fracture has been reported to occur more commonly among adolescent male basketball players with high muscle mass. Data on increased BMIs in patients have been limited in the literature until recently. However, the emphasis on increased quadriceps muscle mass indirectly suggests that a high BMI may also play a role. Köksal et al. (7) reported a mean BMI of 26.3 kg/m² in their study. Kocur et al. (11), on the other hand, identified obesity as an independent risk factor for tibial tubercle avulsion fractures and reported that more than half of the patients in their series of 21 cases were obese, where obesity was associated with an increased complication rate. In our series, the mean BMI was 31.4 kg/m², which is well above the average reported in the literature. Furthermore, the fact that the fractures developed atraumatically (i.e., without exercise or other trauma) in half of our cases supports the possibility that a high BMI may be an independent factor in fracture development. Günelan et al. (13) reported a significant increase in mean BMI in Turkish adolescent males compared to previous averages, and increases in average BMI have been observed worldwide in adolescents (14). The increasing interest in sports among children and adolescents in our country and the widespread use of fitness and strength-based activities, particularly among adolescents, are considered important risk factors that may further increase the incidence of this fracture type.

Tibial tubercle avulsion fractures may occur in adolescents with a high BMI, even in the absence of significant trauma. Excess mechanical load generated by quadriceps contraction in overweight individuals may contribute to low-energy injury patterns. Although outcomes were favorable in our series, higher-grade fractures tended to require open reduction. Given the limited sample size, these findings should be interpreted cautiously, and larger prospective studies are needed to better clarify the relationship between BMI and fracture mechanism.

Study Limitations

This study has some limitations due to its retrospective design and small sample size. The small number of cases made it difficult to achieve statistical significance. Prospective, multicenter studies with larger sample sizes will more clearly demonstrate the impact of a high BMI on fracture type, trauma mechanism, and treatment

requirements. Additionally, the relatively short follow-up duration limited the assessment of mid-term functional outcomes and potential late complications. Future studies with longer follow-up periods are required to better evaluate long-term clinical and radiological results.

Conclusion

A high BMI may be associated with pediatric tibial tubercle avulsion fractures, potentially predisposing adolescents to injury even via atraumatic or low-energy mechanisms. While clinical outcomes were favorable, with high union rates, more severe fracture patterns tended to require open surgical reduction. Given the rising prevalence of childhood obesity, larger prospective studies are needed to better clarify the mechanical impact of BMI on fracture severity and to inform preventive strategies.

Ethics

Ethics Committee Approval: Following approval by the Ankara Bilkent City Hospital Ethics Committee (approval number: TABED 2/1341/2025, date: 25.06.2025), this study was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from all patients and/or their legal guardians prior to inclusion in the study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: N.K.Ü., B.G., Ö.D., Concept: N.K.Ü., B.G., Design: B.G., C.Ç., Data Collection or Processing: C.Ç., F.H., S.S., Analysis or Interpretation: N.K.Ü., Ö.D., Literature Search: N.K.Ü., B.G., Writing: N.K.Ü., B.G.

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