



# Operative treatment of pelvic apophyseal avulsions in adolescent and young adult athletes: a follow-up study

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## Abstract

**Introduction** Pelvic apophyseal avulsion can limit young athletes' performance for months and may result in permanent disability. Nonoperative treatment is most commonly preferred, while surgical management with reduction and fixation is reserved for selected cases. Our aim was to evaluate outcomes of operative management of pelvic apophyseal avulsions in a series of adolescents and young adult athletes.

**Materials and methods** Operative room registries and medical records were reviewed to identify patients who received surgical treatment for pelvic apophyseal avulsions who were younger than 24 years and with a minimum of 12 month follow-up.

**Results** Thirty-two patients (16.8 years  $\pm$  2.6) were identified. The most common avulsion sites were anterior inferior iliac spine (34.4%,  $N = 11$ ) and ischial tuberosity (34.4%,  $N = 11$ ). Other avulsions were five cases (15.6%) of the pubic apophysis, four cases (12.5%) of the anterior superior iliac spine apophysis and one case of the iliac crest apophysis. Seventeen cases (53.1%) underwent surgery early, i.e., during the first 3 months after the acute injury. Twenty-two cases (68.8%) involved reduction with internal fixation, and six cases (18.8%) involved resection of the fragment. Twenty-six athletes (81.3%,  $N = 26$ ) reported good outcomes and were able to return to preinjury sports level. Six patients (18.8%) had moderate outcome and reported activity limitations during high-level sports. Large displacement ( $> 20$  mm) or delayed ( $> 3$  months) surgery was not associated with inferior outcomes ( $P = 0.690$  and  $P = 0.392$ , respectively). Injury side ( $P = 0.61$ ) or gender ( $P = 0.345$ ) did not affect outcomes.

**Conclusions** Operative management of pelvic apophyseal avulsion results in return to the preinjury sports level in more than 80% of the cases. However, while both acute surgery for large displacement and delayed intervention for failed nonoperative treatment are generally successful in improving sports function in these cases, comparative studies are required to refine criteria for surgery.

**Level of evidence** Case series, IV.

**Keywords** Pelvic avulsion · Apophysis · Adolescent · Sports injury · Surgical treatment · Reduction · Fixation · Osteosynthesis · Outcomes

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## Introduction

Secondary ossification centers that function as the site of attachment of a tendon to bone are called apophyses. Avulsion fractures of apophyses are in particular common in the pelvis, where long muscles of lower extremities that cross two joints (i.e., hip and knee) are subjected to high eccentric overloads [29]. In some reports, up to eight-fold load compared to body weight have been recognized in the hip joint during sporting activities [4]. Football players, gymnasts and cheerleaders are in particular subjected to these injuries [2, 15, 25]. In accordance with other musculoskeletal trauma in adolescents, the majority (68.5%) of the patients that sustain pelvic avulsion are males [6, 11, 29].

The anatomy and biomechanics of pelvis is complex [2], and it varies with patient age. Pelvic apophyses do not appear until puberty, and their fusion occurs in late adolescence or early adulthood, between the age of 20 and 25 [10]. For that reason, pelvic avulsion fractures are seen exclusively in those with growing skeleton when the apophyses have not fused to the pelvic ring [16, 23, 31]. Avulsion fractures are more likely to occur than muscle or tendon sprain, because the growth plates between the primary and secondary ossification centers are the weakest link in the musculoskeletal chain in immature skeleton [21]. There are three primary (ilium, ischium and pubis) and five secondary ossification centers in the pelvic ring. Injuries can involve the ischial tuberosity (50%), anterior superior iliac spine (ASIS) (23%), anterior inferior iliac spine (AIIS) (22%) and pubic symphysis (2%) [21, 25, 31, 34]. Apophyseal avulsion is usually recognized on radiographs [23, 30], but computer tomography or magnetic resonance imaging can assist in planning treatment [37].

Pelvic avulsion can limit young athletes' training program for months and may have long-lasting effects on their sports career [2]. Universal guidelines for treatment of pelvic apophyseal avulsions are lacking [27], but most apophyseal avulsions have usually been recommended nonoperative treatment. Operative treatment has been suggested for displaced larger avulsions and those with complicated healing [33, 35]. However, in high-level athletes, surgical treatment may be considered more commonly as it may decrease the risk of long rehabilitation programs with the potential of suboptimal outcomes with nonoperative management [5, 14]. The purpose of this study was to report injury patterns, clinical characteristics, surgical treatment and postoperative outcomes in a series of young athletes who sustained pelvic apophyseal avulsion fractures.

## Materials and methods

Operative room registries of authors' institutions were reviewed to identify all consecutive young (< 25 years of age) athletes who underwent surgical management following avulsion fracture of the pelvic ring between 1994 and 2013 by the senior authors (SO, ES, WS) and who had a minimum 12-month follow-up. Clinical recordings were reviewed retrospectively, and data extracted included sex, age, type and level of sports activity during the injury, and the fragment avulsion distance before the operation as seen on anterior–posterior (AP) or lateral radiographs. The distance (in millimeters) between the donor site of the pelvic bone and the displaced avulsion fragment was measured on radiographs, and the displacement was classified as follows: Severe displacement requiring surgical fixation (> 20 mm), moderate displacement (15–20 mm) and minimal (< 15 mm) displacements [32].

Self-reported outcomes were assessed according to the ability to return to preinjury sports level, which was the primary outcome of the study. The information was obtained at the time of last follow-up office visit. The results of the surgery were classified as excellent or good, moderate or poor as follows [22]: *Excellent or good* outcome referred to ability to return to preinjury activity level. Minor pain or discomfort during sports was accepted in this regard. *Moderate* outcome referred to inability to resume preinjury activity level because of significant pain and discomfort during such activity with only minor symptoms during daily activities. *Poor* outcome referred to discomfort in activities of daily living. Complications such as fixation failures and heterotrophic ossification were also recorded.

Frequencies and means were calculated with ranges and standard deviations (SD) for continuous variables. Categorical variables were analyzed by Chi-square test or Fisher's exact test and McNemar's test. Statistical significance threshold was set at  $P = 0.05$ . The statistical tests were performed using IBM SPSS version 23.0.0.0.

The ethical consideration regarding the study was performed according to written rules of Ethical Board of Oulu University Hospital, Finland.

## Results

### Patient characteristics

There were 32 patients, and 30 (93.8%) of them were males. Mean age was  $16.8 \pm 2.6$  years (range 12–23 years). Right side was affected in 20 (62.5%) and left side in 12 cases.

**Table 1** Type of sports causing the pelvic apophyseal avulsions among the study population

	N	%
Soccer	16	50.0
Track and field		
Sprint	7	21.9
Decathlon	1	3.1
High jump	2	6.3
Long running	1	3.1
110-m hurdles	1	3.1
Gymnastics	1	3.1
Ice hockey	1	3.1
Rugby	1	3.1
Wrestling	1	3.1

**Sports activity**

All patients were high-level athletes, and all injuries were sports-related. A half (N = 16) of the injuries happened in soccer. Other activities included primarily track and field athletic, while sprinting alone caused 7 injuries (21.9%) and other track and field events caused 5 injuries (15.6%) (Table 1).

**Avulsion site**

The most common avulsions involved the rectus femoris direct head (AIIS) and the hamstrings (ischial tuberosity) apophyses. These accounted for 11 injuries each (34.4% each). Adductors apophysis avulsion (pubic symphysis) affected five patients (15.6%), sartorius avulsion (ASIS) and tensor fasciae lata avulsion (ASIS) affected four cases (12.5%), and one patient had an external oblique avulsion at the iliac crest apophysis (Table 2).

**Fragment size and displacement**

Avulsion distance was on average 34.0 mm (range 10–70 mm). The largest fragments involved the ischial tuberosity (47.7 mm, SD 13.9 mm), while fragments avulsed from other donor sites were smaller (AIIS 31.4 ± 13.4 mm; ASIS 26.7 ± 5.8 mm; pubic ramus 19.6 ± 2.8 mm).

Of 32, 26 cases (81.3%) were operated on the basis of a significant displacement (> 20 mm). Three patients (9.4%) showed moderate displacement (15–20 mm), and another three patients (9.4%) had < 15 mm displacement. All three with less than 15 mm displacement had avulsion of the pubic symphysis as a result of soccer injury (Table 2).

**Surgery timing**

Seventeen (53.1%) patients were treated within the first 3 months after the injury, of which 10 (59%) were operated

**Table 2** Pelvic apophysis involved in the study population, their surgical treatment and outcomes

	N (%)	Treatment						Outcomes				
		Displacement			Anchor fixation	Resection	Osteosuturation	Donor site drilling	Screw fixation	Hamstring syndrome operation	Good	Moderate
		> 20 mm	15–20 mm	< 15 mm								
Anterior inferior iliac spine	11 (34.4%)	11 (100%)	0	0	7 (63.6%)	2 (18.2%)	2 (18.2%)	0	0	0	9 (81.8%)	2 (18.2%)
Ischial tuberosity	11 (34.4%)	9 (81.8%)	2 (18.2%)	0	4 (36.4%)	3 (27.3%)	1 (9.1%)	1 (9.1%)	0	2 (18.2%)	8 (72.7%)	3 (27.3%)
Pubic symphysis	5 (15.6%)	1 (20%)	1 (20%)	3 (60%)	4 (80.0%)	1 (20.0%)	0	0	0	0	5 (100%)	0
Anterior superior iliac spine	4 (12.5%)	4 (100%)	0	0	0	1 (25%)	2 (50%)	0	1 (25%)	0	3 (75.0%)	1 (25.0%)
Iliac crest	1 (3.1%)	1 (100%)	0	0	0	0	0	1 (100%)	0	0	1 (100%)	0

acutely within a month after the injury. A majority ( $N = 11$ , 64.7%) of the fractures operated early were displaced more than 20 mm. However, three pubic avulsions with displacement of  $< 15$  mm were operated early as well due to the concern of chronic disability with nonoperative management.

Fifteen patients (46.9%) were operated at more than 3 months after the injury, during which nonoperative treatment that comprised of rest, anti-inflammatory medication and supervised, limited exercises were applied but resulted in unsatisfactory outcome. The indication for surgery in these cases was persistent pain and weakness which resulted in inability to resume sports activities. Delayed operations were most common in AHS avulsions ( $N = 8$ , 72.7%) and ischial tuberosity avulsions ( $N = 6$ , 54.5%).

The interval between the injury and first surgical intervention varied from immediate surgery to 72 months ( $12 \pm 18.5$  months) among the study population. Furthermore, one patient with adductor avulsion developed heterotrophic ossification as a late complication with worsening pain, and it was excised 15 years after the injury, beyond the active professional sports career of the patient.

### Surgical technique

In total, 22 out of 32 (68.8%) operations were reconstructive re-fixations, six (18.8%) were resection procedures of the nonunited fragments, two (6.25%) were osteostimulating donor site drilling, and two (6.25%) were partial hamstring sections for traumatic hamstring syndrome. Patients were positioned prone for hamstrings avulsion surgery and supine in all other operations. Upon re-fixation techniques, the subcutaneous fat was dissected after skin incision, followed by exposure of the underlying fascia and musculotendinous layers. Bone particles were traced by direct inspection and using the fluoroscopy when needed. The fragments were mobilized by dissecting them out from the fibrotic scar. The defect of the pelvic bone was debrided to bleeding bone. The most common tendon-to-bone repair technique involved metallic suture anchor fixation ( $N = 16/22$ , 72.7%). Five (22.7%) were fixed by osteosuturing the fragment by conventional biodegradable sutures through drilled bone tunnels, and one (4.5%) was fixed by using a screw. Postoperative guidelines included full movement with limited weight bearing and prohibited stretching. Long leg brace could be used for the hamstring reattachments for 6 weeks, gradually reducing knee extension and increasing weight bearing [17].

There were 13 (40.6%) patients with heterotopic bone formation after the apophyseal avulsion injury. This was found in 86.7% of the patients operated at more than 3 months after the injury. All patients with heterotopic bone formation ( $N = 13$ ) showed  $> 20$  mm displacement, compared with no heterotopic bone formation cases among patients with less than 20 mm displacement ( $P = 0.059$ ). During

the operation, heterotopic bone resection was performed in order to make the avulsion fragment more anatomically fit for re-fixation. However, in case of posttraumatic hamstring syndrome, including chronic disability associated with heterotrophic ossifications that developed at the proximal hamstrings after sports-related trauma [22], the heterotopic bone and the avulsion fragment were resected (Table 2).

### Outcomes

The majority (26/32, 81.3%) reported excellent or good outcomes during the follow-up. They were able to return to the preinjury activity level at the time of last follow-up visit, at a mean  $11.5 \pm 1.9$  weeks after the operation. Six patients (18.8%) suffered symptoms and limitations in high-level sports, but they still managed well in conventional daily activities, resulting in moderate outcomes. Three (9.4%) re-operations were performed: two osteosuturings following broken anchor fixation and one excision of heterotopic ossification, again following anchor fixation (Fig. 1). There were no poor results (Table 2).

Early (less than 3 months) versus delayed ( $> 3$  months) surgery did not differ in outcome, while 76.5% ( $N = 13$ ) and 86.7% ( $N = 13$ ) of the patients with early and delayed treatment achieved excellent or good outcomes, respectively ( $P = 0.392$ ). Excision ( $N = 6$ ), suture fixation ( $N = 5$ ), donor site drilling ( $N = 2$ ) and screw fixation ( $N = 1$ ) all resulted in excellent or good outcomes, while anchor fixation resulted in good outcomes in 68.8% ( $N = 11/16$ ). Two patients developed posttraumatic hamstring syndrome after



**Fig. 1** Ischial tuberosity apophysis avulsion in an adolescent athlete, fixed by two bone anchors. The postoperative radiograph at the follow-up demonstrates bone union, but a heterotrophic ossification was symptomatic and re-operation was performed to excise the ectopic bone (arrow)

ischial tuberosity avulsion, resulting in the need for late-stage operation. One recovered well and resumed sports, and another had persistent symptoms 6 years after the injury.

There was no difference in excellent or good versus moderate outcomes between the left and right sides ( $P = 0.61$ ) or between male and female ( $P = 0.345$ ). Higher displacement ( $> 20$  mm) was not associated with inferior outcome compared with lower ( $\leq 20$  mm) displacement ( $P = 0.690$ ). Ischial tuberosity avulsion resulted in moderate outcomes in 72.7% of the cases, while the respective numbers were 75.0 and 81.8% in ASIS and AIIS avulsions. Pubic symphysis avulsions and iliac crest avulsions resulted inclusively in excellent or good outcomes ( $P = 0.733$ ).

## Discussion

The main finding of this study was that more than 80% of the young athletes, who were all younger than 24 years of age, were able to return to sports at the preinjury level after operative management of pelvic apophyseal avulsion fractures. In the recent meta-analysis including 598 adolescent patients, the rate of return to sports after surgical treatment was 92% [7]. However, return to sports was evaluated in a total of 103 patients (17.2%) out of 598 and the patients were younger (mean 14.3 years), compared to our study (mean 16.8 years). Furthermore, the patients in our research were all high- or elite-level athletes, which set the requirements of return to the sports still higher. The mean time from operation to full participation in sports was 11.5 weeks, which is similar to nonoperative treatment of pelvic avulsions, with minor displacement of the avulsed fragment [18]. These findings are encouraging and particularly in view of the fact that these injuries can have serious negative impact on the career of young athletes and result in permanent sequelae such as weakness and chronic pain in the pelvis and hip areas [10]. There were no patients with poor outcomes in this series, although six patients (18.7%) with moderate outcomes reported pain and limitations in high-level sporting, resulting in inability to resume elite-level sports.

In this consecutive series, more than 80% had over 20 mm displacement of the avulsed fragment. This is in accordance with previous reports that recommend considering internal fixation for displacements greater than 20 mm, due to the concern of nonunion or the development of exostosis or heterotopic ossification [19, 26]. Of note in this respect, patients with displacement greater than 20 mm in this series had as good outcomes as patients with displacement of less than 20 mm. Therefore, it is advisable that any decision about operative intervention in adolescent athletes would be made on an individual basis instead of relying on categorical thresholds such as amount of displacement in millimeters. Furthermore, if the patient primarily shows

the “border-line” displacement (10–20 mm) and nonoperative treatment is chosen, a close follow-up may be recommended during the first 2 weeks in order to early recognize the increase in the displacement. In addition to radiographs, magnetic resonance imaging (MRI) can assist in determining the severity of the injury [28]. The higher the level of professional involvement in sport, the lower the threshold for surgery may be, with less relying on crude numbers in millimeters of displacement as an indication for surgery [3, 5, 9, 13, 24].

Different surgical procedures were used in this cohort, which included reconstructive anchor re-fixations, resection procedures of the nonunited fragments, resections and osteostimulating donor site drilling and partial hamstring releases for traumatic hamstring syndrome. The outcomes of all operatively treated patients did not demonstrate any difference between the surgical procedures. However, this should be viewed in light of the heterogeneity of the series and the retrospective study design. Excision of the nonunited fragment, osteosuturation, resection, donor site drilling and screw fixation resulted in excellent or good outcomes. Excellent or good outcomes were found in 50% in relation to post-traumatic hamstring syndrome operation. Anchor fixation resulted in excellent or good outcomes in 68.8% of cases and moderate outcomes in 31.3%. Among the entire study population, 83.3% of patients with moderate outcomes were treated with anchor fixation. The rate of full return to sports after anchor fixation was lower in this study, compared with 92% after all operatively treated patients in the recent meta-analysis [7]. Traditionally, bone fixation by suture anchors is usually used in cases with relatively small or comminuted avulsion particles, when anatomic bone reconstruction is purposed, but screw fixation is not feasible. There were two broken anchor fixations resulting in re-operation, which may indicate that straightforward excision would have been advantageous in these circumstances primarily. Therefore, our findings may indicate that anatomic reconstruction of the pelvic apophysis after avulsion fracture may not be justified in all cases. Instead, less anatomic removal of the nonunited avulsion, possibly accompanied by donor site drilling, may contribute to bone healing and result in superior outcomes. This conclusion is in accordance with others who reported that a half of apophyseal avulsions (48%,  $N = 12/25$ ) underwent fragment excision rather than fixation [12]. Further randomized studies are needed to compare different surgical methods. In particular, clinical trials are needed to study the potential disadvantage of anchor fixation of pelvic avulsions over straightforward excision of the avulsed fragment.

Limitations of this study are the retrospective design which means recommending specific treatment strategy on the basis of these findings is not straightforward. Second, five different sites of pelvic avulsions were included, which makes the cohort heterogeneous. While surgical fixation of



ischial tuberosity avulsions was generally indicated for displacement over 15 mm, the threshold of surgery in iliac crest avulsion cases was suggested to be higher than 30 mm [28]. Furthermore, AIIIS avulsions were considered to warrant reduction if displacement was greater than 20 mm, but no specific guidelines are available for ASIS or pubic symphysis avulsions [28, 33]. As a weakness, we did not make difference in pain or other symptoms among the patients with full return to preinjury sports level (excellent or good result).

The uniqueness of this study is that all 32 consecutive athletes, aged < 24 years, who were operatively treated for pelvic apophyseal avulsion, were reviewed. To the best of our knowledge, this is the largest series reported in this regard. Pelvic avulsions are uncommon [21, 23], and most previous reports were case reports [1, 10, 35, 36] or very small series [8, 14, 18, 20]. Furthermore, the study population was homogenous regarding the sports level. The mean age (16.8 years) of the patients in this study was slightly higher than that in the previous reports [12], which is reasonable as higher age associates with more complicated injuries and higher need for operative treatment compared with younger children [14].

In conclusion, operative management of pelvic apophyseal avulsion in young athletes results in return to the preinjury sports level in more than 80% of the cases. However, while both acute surgery for large displacement and delayed intervention for failed nonoperative treatment are generally successful in improving sports function in these cases, comparative studies are required to refine criteria for surgery.

**Authors' contribution** JJS contributed to study design, data collection, analysis and writing; IH contributed to study design, analysis and writing; ES helped in study design, data collection, writing and supervising; LL helped in study design, analysis and writing; WS designed and supervised the study; and SO conceived the study and participated in study design, data collection, writing and supervising. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest** The authors declared no competing interests related to this study.

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