

# Avulsion fractures of the pelvis – a qualitative systematic review of the literature

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**Objective:** *To assess a causal relationship between physical activity or bony surgical intervention and the occurrence of avulsion fracture in the pelvis. Secondly to assess the average age at which avulsion fracture occurs in cases associated with physical activity or bony surgery.*

**Method:** *A literature search was performed on a variety of databases using text words and MeSH terms. Results were limited to English language. Cases involving trauma or pathological disease were excluded. Causation Criteria scores were calculated for each paper to establish a link between the suspected mechanism of injury and avulsion fracture.*

**Results:** *48 papers were retrieved encompassing 66 cases of avulsion fracture. 88% of cases were associated with physical activity while 12% were associated with a history of surgery. Average age in the physical activity cases was 16.8(range 13–43) and 56.4(range 31–74) in the surgery related cases. Causation Criteria scores were definite in 76% of activity related cases and probable in 60% of bony surgery related cases.*

**Conclusions:** *Avulsion fractures of the pelvis represent a highly prevalent pathology among the adolescent athletic population. A population of skeletally mature*

**Objectif :** *évaluer la relation de cause à effet entre l'activité physique ou l'intervention chirurgicale des os, et l'occurrence d'une fracture d'avulsion du bassin. Ensuite, évaluer l'âge moyen des victimes d'une fracture d'avulsion dans les cas associés à l'activité physique ou à l'intervention chirurgicale des os.*

**Méthode :** *une recherche littéraire fut effectuée dans diverses banques de données à l'aide de mots du texte et de termes du MeSH. Les résultats obtenus étaient en anglais. Les cas impliquant une maladie traumatique ou pathologique furent exclus. Les pointages des critères de causalité furent établis pour chaque document afin de créer un lien entre le mécanisme soupçonné de blessure et de fracture d'avulsion.*

**Résultats :** *48 documents furent trouvés, et ceux-ci comprenaient 66 cas de fracture d'avulsion. 88 % des cas étaient liés à l'activité physique, tandis que 12 % étaient liés à des antécédents de chirurgie. Dans les cas liés à l'activité physique, la moyenne d'âge était de 16,8 ans (plage allant de 13 à 43) et de 56,4 ans (plage allant de 31 à 74) dans les cas liés aux interventions chirurgicales. Les pointages des critères de causalité furent définis dans 76 % des cas liés à l'activité physique, et jugés probables dans 60 % des cas d'intervention chirurgicale aux os.*

**Conclusions :** *des fractures d'avulsion du bassin représentent une pathologie très prévalente chez les athlètes adolescents. Il existe un groupe de patients dont*

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*patients with history of boney surgical intervention are also at risk.*

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KEY WORDS: avulsion, fracture, pelvis, athlete

## Introduction

Avulsion fractures represent a unique type of bone pathology which occurs when a fragment of bone is pulled away from the main boney mass as a result of a sudden tensile force applied through a powerful muscle contraction. The current literature reports the prevalence of avulsion fracture as being the highest among adolescents, which leads one to consider the stage of development of the bone to be crucial.<sup>1–12</sup> Accordingly, the weakest morphological structure in the bone is the physis. Once the growing cartilage ossifies, the connection between the apophysis and the body of the bone strengthens. As a result, the musculo-tendinous unit becomes the weakest structure in transferring the force between muscle and bone.

The body of literature surrounding avulsion fractures is largely comprised of case reports and case series. This form of literature provides researchers with direction for further research. However, it also provides a body of literature for situations where other forms of research may be unethical or too costly. Case reports and case series also provide an opportunity for authors to provide a great deal of information regarding the given case. This added information may be crucial in establishing a causal association.

The literature reports that the majority of pelvic avulsion fractures occur during the eccentric phase of a sporting activity due to the higher forces generated during eccentric muscular contractions.<sup>2,6,10</sup> Reports of pre existing pain in the hip or diagnosed osteitis have been shown in the literature; however, the reporting of these phenomena is inconsistent and may often be missed by practitioners.<sup>13–20</sup> Reports of avulsion fracture do exist in older populations despite skeletal maturity; however, these typically involve pathological processes.<sup>21</sup> Surgical interventions involving boney resection provide another possible explanation for a weakened state to exist at a pelvic apophysis despite skeletal maturity. Removal or alteration of a bone may leave it in a state of weakness making it susceptible to avulsion fracture. To date the strength of this causal association has not been studied.

*le squelette est mature qui ont subi une intervention chirurgicale aux os.*

(JCCA 2011; 55(4):247–255)

MOTS CLÉS : avulsion, fracture, bassin, athlète

The purpose of this review is to assess the strength of a causal association between activity or surgical intervention and the occurrence of avulsion fracture. The secondary aim of the paper is to assess the average age at which avulsion fracture occurs within cases reporting activity or history of surgery at onset of symptoms. To the knowledge of the authors, there has not been a review of the literature of this nature.

## Methods

### *Search Strategy*

A literature search was performed in EBSCO in the databases MEDLINE, CINAHL, Alt HealthWatch, AMED, SPORTDiscus, Rehabilitation & Sports Medicine Source, ICL and MANTIS. Text words used were Avulsion Fractur\*, Pelvic Bones, Anterior Superior Iliac Spine (ASIS), Anterior Inferior Iliac Spine (AIIS), Ischial Tuberosity (IT), Pubic Crest (PC), Pubic Symphysis (PS) and Iliac Crest (IC). The MeSH Term Pelvic Bone was used in MEDLINE. The search consisted of literature published from the start date of each database up to December 2010. Limiters included papers published in the English language and only case reports or case series were accepted for analysis. Reference lists were hand searched for additional relevant articles. Data from literature reviews on similar topics were not used for analysis, however were utilized for comparison with our results.

### *Inclusion and Exclusion Criterion*

Papers accepted for analysis must have shown objective evidence of osseous involvement in each case of reported avulsion fracture, and there must not have been a history of direct trauma to the area of injury or evidence of pathological disease such as metastasis. Only studies involving injury to an apophysis of the pelvis were included. Each paper retrieved by the search was assessed by the lead author for inclusion.

Table 1 Causation scoring strategy for avulsion fracture

Activity Factor	Value		
	Yes	No	Unknown
Did the adverse event appear within 24 hours of activity?*	+2	-1	0
Are alternative causes available in the case that could have caused the adverse reaction?	-1	+2	0
Was the adverse reaction proportional to the force of the suspected mechanism?	+1	0	0
Was the adverse reaction comparably related to the area of injury?	+1	0	0
Did the patient have a similar reaction to any previous exposure?	+1	0	0
Was the adverse event confirmed by objective evidence?	+1	0	0
Is the description of the mechanism of avulsion fracture first hand?	+1	0	0
Total Score of each column			
Final Score			
Scoring <sup>§</sup> : $\leq 0.68$ = doubtful; $0.69 - 3.45$ = possible; $3.46 - 6.18$ = probable; $\geq 6.19$ = definite.			

\*24 hours chosen as patient excitement and adrenaline levels during physical activity may mask pain at initial time of injury; for cases with history of surgery a time line of 6 weeks was used as this is the natural history for osseous healing.

§ The original causation criterion included a question on dose response which was deemed inappropriate for the current study; scores were adjusted accordingly.

### Causation Criteria of the Studies

In 1982, Naranjo et al. state that the lack of a method for establishing causality generates large inter and intra rater variability during assessment.<sup>22</sup> They also state that the estimation of the probability that an adverse event occurs due to a proposed mechanism is based on clinical judgement.<sup>22</sup> Therefore, Naranjo et al. devised an instrument to evaluate the degree of association and level of certainty that a drug treatment in question caused an observed adverse event.<sup>22</sup> McGregor et al. adapted the instrument to address adverse events related to spinal manipulation.<sup>23</sup> The instrument was revised for use in case literature reporting on vertebrobasilar compromise associated with cervical spine manipulation. Reliability of the adapted tool between practitioners was found to be high ( $r = 0.84$ ).<sup>23</sup> Scoring for Naranjo et al.'s work ranged from -4 to 13 with sub scoring ranges as follows:  $\leq 0$  being doubtful of a cause and effect relationship; 1-4 as possible; 5-8 as probable;  $\geq 9$  as definite.<sup>22</sup> McGregor et al. used the same boundaries as Naranjo et al., and therefore with a maximum score of 11 on their adapted version of the instrument had sub scoring ranges as follows:  $\leq 0$  being doubtful;  $0.84-4.22$  being possible;

$4.23-7.55$  being probable;  $\geq 7.56$  being definite.<sup>23</sup> Adaptations to the instrument formulated by McGregor et al. were made to ensure suitability when dealing with case literature on avulsion fracture. Following these changes the maximum total score for the instrument utilized in the current study was 9. In keeping with the original boundaries set out by Naranjo et al., and maintained by McGregor et al., the resulting sub scoring ranges for our adapted version of the instrument are as follows:  $\leq 0.68$  being doubtful;  $0.69-3.45$  being possible;  $3.46-6.18$  being probable;  $\geq 6.19$  being definite.<sup>22,23</sup> These sub scoring ranges represent accurate boundaries for division of groups, however it is to be expected that individual scores for each case will result in a whole number which will fall into one of four sub scoring ranges.<sup>23</sup> Each paper was independently assessed by two of the authors according to the Causation Criteria, and consensus was then met for a final score for each paper.

### Data Collection

All cases presented in the accepted papers were reviewed for relevant data. Data was collected on age, sex, causative

mechanism, signs and symptoms, imaging, displacement, treatment rendered and complications. Results of data collection are available upon request as Appendix 1.

### Analysis

Causation Criteria scores were analyzed between the activity related papers and the surgical papers to assess for a significant difference between groups. Descriptive statistics, including mean scores and standard deviations, will also be reported.

### Results

The authors were able to retrieve 48 case reports and case series on avulsion fractures that met the inclusion criterion. This accounted for 66 cases reported in the literature, 8 (12%) which were associated with previous surgical procedures and 58 (88%) which were associated with physical activity. A summary of the cases of avulsion fracture by site can be found in Table 3. The average age at onset of avulsion fracture in the activity causally related cases was 16.8 (range 13–43) and in the surgical causally related cases it was 56.4 (range 31–74). Conservative treatment was utilized in 68% (45/66) of cases and surgical intervention was used in 32% (21/66) of cases. All cases of avulsion fracture with a proposed history of surgery as a causative agent were treated by conservative means. Cases related to physical activity had a gender distribution of 84% males, while the cases related to a surgical causal agent had a 100% female gender distribution. Detailed results for data collection are available upon request as Appendix 2.

### Causation Criteria

For the papers reporting on avulsion fracture occurring as a result of physical activity, 76% (37/49, range 7–3) scored a definite rating on the causal relationship between avulsion fracture and a history of physical activity. They had a mean score of 6.63 with a standard deviation of 1.07 (95% CI 6.2 – 6.9). In the surgical group 60% (3/5, range 6 to –1) scored in the probable range for a causal relationship between avulsion fracture and a history of surgical intervention. They had a mean score of 4.4 with a standard deviation of 3.05 (95% CI .613 – 8.19). Evaluation of the criterion-based scored data indicated a non-normal distribution. Wilcoxon rank-sum was undertaken in order to determine if there was a statistically significant differ-

Table 2 Summary of causation scores for all accepted papers

Paper	Causation Criteria Score
Aksoy et al., 1998 <sup>24</sup>	7
Atalar et al., 2007 <sup>25</sup>	7
Bahk et al., 2000 <sup>26</sup>	7
Bolglia et al., 2001 <sup>27</sup>	7
Byrne et al., 2008 <sup>28</sup>	7
Davis et al., 1998 <sup>13</sup>	7
Deehan et al., 1992 <sup>29</sup>	7
DePalma et al., 1965 <sup>14</sup>	7
Doral et al., 2005 <sup>30</sup>	7
Dosani et al., 2004 <sup>31</sup>	7
Draper et al., 1992 <sup>32</sup>	7
Gidwani et al., 2004 <sup>3</sup>	7
Gomez, 1996 <sup>33</sup>	7
Kaneyama et al., 2006 <sup>34</sup>	7
Karakas et al., 2009 <sup>35</sup>	7
Kusma et al., 2004 <sup>36</sup>	7
Khoury et al., 1985 <sup>37</sup>	7
Lambert et al., 1993 <sup>38</sup>	7
Mader, 1990 <sup>39</sup>	7
Nanka et al., 2003 <sup>40</sup>	7
Oldenburg et al., 2009 <sup>41</sup>	7
Pointinger et al., 2003 <sup>15</sup>	7
Rajasekhar et al., 2001 <sup>42</sup>	7
Resnick et al., 1996 <sup>16</sup>	7
Rosenberg et al., 1996 <sup>43</sup>	7
Rossi et al., 2001 <sup>9</sup>	7
Salvi et al., 2006 <sup>44</sup>	7
Schlonsky et al., 1972 <sup>45</sup>	7
Servant et al., 1998 <sup>46</sup>	7
Steerman et al., 2008 <sup>47</sup>	7
Swischuk, 2004 <sup>48</sup>	7
Thanikachalam et al., 1995 <sup>49</sup>	7
Vajnar, 2008 <sup>50</sup>	7
Valdes et al., 2000 <sup>51</sup>	7
Vogt et al., 2007 <sup>52</sup>	7
Watanabe et al., 1995 <sup>18</sup>	7
Yazzie, 2001 <sup>53</sup>	7
Yildiz et al., 2005 <sup>20</sup>	7
Kuhn, et al., 1986 <sup>54</sup>	6
Stellon et al., 1985 <sup>55</sup>	6
Zijdeveld et al., 2004 <sup>56</sup>	6
Samartzis et al., 2006 <sup>57</sup>	5
Winkler et al., 1987 <sup>19</sup>	5
Spinner et al., 1998 <sup>17</sup>	4
Tompkins et al., 2010 <sup>58</sup>	4
Miller et al., 1987 <sup>59</sup>	3
Miller, 1982 <sup>60</sup>	3
Smith et al., 1998 <sup>61</sup>	–1

Table 3 *Number of cases by site of avulsion fracture and associated causative mechanism*

Site/ Mechanism	Running	Kicking	Extreme ROM	Jumping	Surgical Hx <sup>£</sup>	Other	Total	%
ASIS	6	2	1	0	7	3*	19	28.8
AIIS	4	8	0	1	0	0	13	19.7
PC	0	0	1	0	0	0	1	1.5
AC	0	0	1	0	0	0	1	1.5
IC	7	1	0	0	0	2 <sup>¤</sup>	10	15.2
IT	10	2	4	1	1	4 <sup>§</sup>	22	33.3
Total	27	13	7	2	8	9	66	
%	40.9	19.7	10.6	3.0	12.1	13.6		100.0

\* 1 breakdancing, 1 raising from seated position, undefined athletic training.

¤ 1 wrestling, 1 batting.

§ 1 weighted squatting, 1 raising from seated position, 1 getting out of vehicle, 1 skating.

£ All cases occurred following harvesting of IC for grafting except for IT case that followed total hip replacement.

ASIS – Anterior Superior Iliac Spine, AIIS – Anterior Inferior Iliac Spine, PC – Pubic Crest, AC – Acetabulum, IC – Iliac Crest, IT – Ischial Tuberosity.

ence between groups (physical activity versus surgery). A statistically significant difference was found with  $z = 4.19$  and  $p < 0.00$  with 12% of the activity-related papers scoring five or less on the Causation Criteria, and 40% of the surgical cases scoring five or less on those same criteria. A summary of the Causation Criterion Scores for all papers is summarized in Table 2 (detailed results are available upon request as Appendix 2).

## Discussion

To date the largest analysis of avulsion fracture of the pelvis is a retrospective analysis of competitive athletes by Rossi and Dragoni, where they analyzed 203 cases that presented to an Italian Sports clinic.<sup>9</sup> The authors reported an average age of 13.8 with 68.5% of cases occurring in males.<sup>9</sup> The percentage of males reported with avulsion fracture is significantly lower than what was found by the authors, however this could be a reflection of the larger sample size. Rossi and Dragoni further reported that the IT, ASIS and AIIS were the three most commonly reported sites of avulsion fracture in the pelvis, which is in accordance with the results of the activity related cases in this study.<sup>9</sup>

Typically avulsion fractures are described as having a specific presentation and more importantly a specific patient history involving a forceful muscular contraction during sport activities.<sup>2,6,7,9,10</sup> Patients are frequently skeletally immature and experience pain and a popping sensation at the site of injury.<sup>2,6,7,9,10</sup> The most commonly reported sites of avulsion fracture in the pelvis are the ASIS, AIIS and IT.<sup>7,9,41</sup> The results of this review are in agreement with previous work; however, several important factors have been revealed. Although avulsion fractures most commonly occur in a skeletally immature population, specifically in the cases involving physical activity, a population of skeletally mature post surgical patients was identified as being at risk. Within the cases involving physical activity as a causative agent, there were cases in the literature of avulsion fractures occurring in skeletally mature patients. These cases involved extreme ranges of motion and likely an associated protective forceful muscular contraction.

The strength of causative association evaluated in this study showed that the mean score for 76% the activity related cases placed them in the definite category while in the surgical groups 60% scored in the probable group.

It appears from these results that there is a very strong causal association between physical activity and avulsion fracture. Although there does appear to be a causal association between the surgical group and avulsion fracture it is significantly different from the causal link with activity ( $p = 0.00$ ). This difference may be due to the significantly fewer number of cases available in the literature at this time. Another explanation may be that there was much less thorough reporting in the surgical cases than the activity cases.

The role of apophysitis in the occurrence of avulsion fracture has been proposed in the literature.<sup>13–20</sup> It is thought that perhaps apophysitis may act as a precursor. Saunderson et al. discuss that avulsion fractures may occur in cases where no acute episode is present and instead results from chronic repetitive traction on a developing apophysis.<sup>10</sup> In the current study 6 cases were presented with a history of preexisting bony pain in the area of avulsion fracture representing preexisting osteitis.

Of the cases involving physical activity the most commonly reported mechanisms were kicking (19.7%) and running (40.9%) (Table 2). This is in accordance with previous work identifying soccer and running sports as the two most prevalent activities associated with avulsion fractures.<sup>5,9,43</sup> Rossi and Dragoni reported soccer and gymnastics as the two activities most commonly related to the onset of avulsion fractures of the pelvis.<sup>9</sup> Reporting of the mechanism of injury was poor across the majority of cases analyzed making it impossible to confirm eccentric loading as the prime mechanism of injury. Cases were not reported first hand and there may have also been difficulty recounting the details of injury by the patient as many of these injuries occur in a very short period of time and in a very dynamic manner. Also proper historical data on pre-exercise warm up activities and pre-season strengthening programs may be of value in understanding possible preventative mechanisms.

All but one of the cases proposing history of surgery as a causative mechanism for avulsion fracture involved bone harvesting from the iliac crest for the purpose of bone grafting elsewhere in the body. Authors have suggested that removal of a segment of bone close to the ASIS may predispose skeletally mature patients to avulsion fractures in this region.<sup>56</sup> The current study revealed 7 cases of avulsion fracture in the area of the ASIS as a result of bone harvesting from the iliac crest. In response

to the occurrence of avulsion fractures following bone harvest from the iliac crest, authors have recommended using a site 3–4 cm posterior to the ASIS.<sup>62</sup> In these 7 cases the details of the mechanism of injury such as hip or knee positioning, were poorly described leaving clinicians with no indications for possible preventative measures. Reporting of preexisting co-morbidities such as osteoporosis and osteomalacia are also essential details needed in these cases.

Three cases of sciatic nerve irritation and one case of meralgia paresthetica were presented in the literature. Patients may present to their primary care provider with chief complaints revolving around these two pathologies. Thorough history and physical examination are essential to rule out the various causes of these pathologies.

The diagnosis of avulsion fracture in nearly all cases was made using radiographic imaging, although use of CT, MRI and bone scan was also reported in the literature. Patient history was an integral part of diagnosis and typically revealed a history of physical activity with forceful muscular contraction followed by a popping sensation and pain in the affected area resulting in difficulty with ambulation. The clinical presentation of an avulsion fracture is often identical to that of a simple muscle strain and therefore must always be considered when dealing with at risk populations. In the cases with a history of surgery present, often minimal trauma such as tripping or rising from a seated position was associated with the onset of symptoms.

Treatment for avulsion fractures included surgical or conservative interventions. The determinant for treatment method depended on the site of avulsion and the amount of displacement of the avulsed segment. Some authors recommend that fragments displaced greater than 2 cm be treated surgically.<sup>14,34,46</sup> While 53% of IT avulsion fracture cases in the Rossi and Dragoni paper were treated conservatively<sup>9</sup>, a study by Barnes et al. reported that 68% of AF of the IT do not reunite which may lead clinicians to consider surgery for AF affecting this area.<sup>63</sup> Another argument for surgical intervention does exist for the athletic population arguing improved return to full function, however no difference was noticed in the current study regarding recovery times for surgical versus conservative intervention.<sup>45</sup>

The typical conservative treatment included a period of bed rest for 3 days followed by a progressive ambulation

program typically involving a period of crutch use until the patient was able to walk without pain. A continual increase of pain free activity was prescribed with return to full sport occurring around the 6 week mark. A similar approach is also utilized for post operative therapy. Although this was the trend, no set guidelines or protocols have been reported on in regards to conservative or surgical treatment. Metzmaker and Pappas<sup>2</sup> propose a five stage conservative treatment timeline which correlates patient perceived pain, palpation findings, range of motion, muscle strength and osseous separation to the amount of activity the patient should be engaging in. The level of activity ranges from none to normal pre-injury levels.

All cases involving a history of surgery as a causative mechanism were managed conservatively. This is in accordance with work by Zijderfeld et al. where they propose that treatment of iliac crest fractures is most often conservative.<sup>56</sup>

### Limitations

Several limitations exist within the study. Only English language papers were included for this search which may have excluded potential cases of avulsion fracture. One must also be cautioned when concluding causality based on low level evidence such as case reports and case series. Due to ethical and logistical concerns, the study of avulsion fractures is limited to retrospective analysis. Therefore the use of a tool such as the Causation Criteria helps establish causality when clinical judgment is typically employed. Often case reports and case series are the only forms of literature that provide enough detail for such an instrument to be utilized. While the sample size for the activity related cases was relatively strong, the surgical cases are highly under reported in the literature, and therefore only allowed for a small sample size in the current study. Lastly, the reliability of the Causation Criteria following the alterations is unknown.

### Future Research

The muscles that are typically involved in pelvic avulsion fractures act very differently from a functional point of view on the low back, hip and knee. As such, an understanding of the functional implications of avulsion fractures at each site on the pelvis may be very important for the patient. This information would be of particular im-

portance in the treatment and rehabilitation of these patients both from a surgical and non surgical perspective, and therefore is an important direction for future research.

### Conclusion

Patients suffering from avulsion fractures of the pelvis typically present as adolescents engaging in physical activity that requires sudden and forceful muscular contraction that results in a popping sensation with local pain, tenderness and difficulty with ambulation. A special population of skeletally mature patients at risk of avulsion fracture has been identified as those with a history of bone harvest from the iliac crest. A diligent history and physical is required along with radiographic imaging for an accurate diagnosis of avulsion fractures, typically followed by a course of conservative therapy. Surgical consultation may be warranted in cases displaying a displacement greater than 2 cm or involvement with the IT.

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