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Title

Rehabilitation for Returning to Sports in Individuals with Sports-induced Pelvic Injuries—A Narrative Review

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Abstract

The purpose of this narrative review is to outline pelvic injuries caused by sports, and to clarify their trends, treatment, and management. We describe the rehabilitation for sports injuries of the pelvis, with a focus on pelvic avulsion injuries and pelvic bone stress fractures. This narrative review of fifteen articles published in the last 10 years (from 2013 to 2023) reveals a dearth of new rehabilitation knowledge regarding sports-induced pelvic injuries.

題目: スポーツによる骨盤損傷のスポーツ復帰のためのリハビリテーションに関するナラティブレビュー

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抄録: このナラティブレビューの目的は、スポーツによる骨盤損傷を概説し、その傾向、治療、管理を明らかにすることである。骨盤部スポーツ損傷として骨盤部剥離損傷と骨盤骨疲労骨折に関して、リハビリテーションを中心に述べる。過去 10 年間（2013 年から 2023 年まで）に発表された 15 編の論文のレビューを行い、スポーツによる骨盤損傷に関する新しいリハビリテーションの知識について概説する。

Introduction

The purpose of this narrative review is to outline pelvic injuries caused by sports, and to clarify their trends, treatment, and management. We describe sports injuries of the pelvis, with a focus on the following two common sports injuries of the pelvis: pelvic avulsion injuries and pelvic bone stress fractures. In particular, we summarize the current state of knowledge about the rehabilitation of patients with pelvic avulsion injuries and pelvic bone stress fractures in sports.

Previous literature was surveyed using PubMed. The survey period was from 2013 to 2023. Only articles written in English and investigating athletic populations were considered for inclusion. We included case reports, original papers, and review articles investigating the rehabilitation of athletes. We excluded other types of articles, such as notes, conference papers, letters, animal studies, short surveys, editorials, and author responses, as well as studies and case reports involving non-athletes.

For pelvic avulsion injuries, the search strategy in PubMed was as follows: "((((rehabilitation) AND (pelvic)) AND (avulsion)) AND (injury)) AND (athlete)." A total of 10 articles were retrieved. Abstract screening was conducted, and 7 articles were finally selected after excluding those that did not meet the study criteria[1][2][3][4][5][6][7]. For pelvic bone stress fractures, the search strategy in PubMed was as follows: "((((rehabilitation) AND (pelvic)) AND (stress)) AND (fracture)) AND (athlete)." A total of 22 articles were retrieved. Title and abstract screening were conducted, and 8 articles were finally selected after excluding those that did not meet the study criteria[8][9][10][11][12][13][14][15].

Rehabilitation of Athletes with Pelvic Avulsion Injuries

Pelvic avulsion injuries often occur in adolescent athletes. This injury is often a traction injury at the muscle-tendon attachment site where ossification of the pelvic region has not been completed.

As the entire ossification nucleus is tractioned, the term “avulsion fracture” is used. This injury can also occur in adults who have completed ossification. Since ossification is complete in adult patients, soft-tissue failure at the muscle-tendon attachment site is more common than avulsion fractures.

In general, cases of avulsion fractures with small dislocation of the avulsed bone fragments show good results with conservative treatment, while those with large dislocation may require surgery[1]. There is no scientific consensus regarding the amount of dislocation or the size of bone fragments for which surgery is indicated[1]. We discuss the 7 articles on the rehabilitation of athletes with pelvic avulsion injuries that were finally included[1][2][3][4][5][6][7].

1-1. Site of occurrence of pelvic avulsion injury

Eberbach et al. reported the frequency of pelvic/hip avulsion injuries[1][16]. The anterior inferior iliac spine (AIIS) was the most common site of pelvic avulsion injury (33.2%), followed by the ischial tuberosity (IT) (29.7%) and anterior superior iliac spine (ASIS) (27.9%)[1][16]. Among the articles included in this review, one article involved AIIS avulsion fracture[4], three involved IT avulsion fracture[3][4][5], and one involved ASIS avulsion fracture[7] in adolescent athletes. Moreover, one article involved adductor longus tendon avulsion fracture[2], and one involved rectus abdominis and adductor longus avulsion fracture[6] in adult athletes.

1-2. AIIS avulsion injury in adolescent athletes

The AIIS is the attachment site of the rectus femoris muscle. The muscle originates from the AIIS and terminates on the tibial coarse surface via the patella and patellar ligament. It is a bifid muscle that straddles the hip and knee joints. The rectus femoris muscle flexes the hip joint and extends the leg at the knee joint.

Rehabilitation after percutaneous fenestration was adapted from the protocol devised by

Metzmaker and Pappas[17], which was utilized for the treatment of acute avulsion fractures. The Metzmaker rehabilitation protocol was empirically guided by biological tissue healing parameters and set clinical criteria encompassing subjective pain, palpation, range of motion, muscle strength, and radiographic appearance. Based on these indicators, rehabilitation progressed step by step from phase 1 to phase 5. The rehabilitation approach for each of these five phases is further detailed in 1-week increments[4]. A previous case series included six male players who were full-time members of a category 1 status Premier League football academy. The mean age of the players was 13.9 years (range, 12.7–15.2 years), and the mean time for return to full training following an AIIS avulsion fracture was 14.8 weeks[4]. A detailed rehabilitation description is helpful in the treatment of anterior AIIS avulsion fractures in adolescents.

A late complication to watch for after the rehabilitation process is anterior hip impingement due to heterotopic ossification[18]. This is a symptomatic condition in which the space between the acetabulum and femur narrows in the anterior aspect of the hip joint as a result of ossification. Of note is potential extensive heterotopic callus formation at the superior aspect of the acetabulum that may cause femoroacetabular impingement due to narrowing of the space between the greater trochanter and acetabular roof. This femoroacetabular impingement may cause chronic hip pain in youth.

1-3. IT avulsion injury in adolescent athletes

The IT represents the site of insertion of the hamstring muscle group, namely the long head of the biceps femoris, and the semitendinosus and semimembranosus muscles. The stop points are at the tibial and fibular heads. The hamstring extends the hip joint and flexes the knee joint. Like AIIS avulsion fractures, IT avulsion fractures are common in football players, sprinters, jumpers, and dancers[1].

In a previous report, five male patients with a mean age of 14 years (range, 12–17 years) who failed initial conservative treatment underwent internal fixation (four patients) or bone marrow aspirate injection (one patient)[3]. In these patients, botulinum injection chemoprotection was used to prevent subsequent rehabilitation. A phased rehabilitation program[3] was implemented, and all patients underwent supervised physical therapy with the following progression:

1. Passive and active assisted range of motion (ROM) initially
2. Gentle active ROM
3. Isometric activities
4. Closed chain strengthening and static proprioceptive activities
5. Concentric to eccentric strengthening
6. Release to dynamic activities such as jumping

Weight-bearing as tolerated was initiated at a mean of 5.8 weeks (range, 4.4–6.8 weeks). It is not clear to what extent chemoprotection accelerates rehabilitation progression. The authors noted that chemoprotection eliminated the need for bracing, which limits hip flexion and keeps the knee in 90 degrees of flexion[3].

There is another report on three patients who failed initial conservative treatment[5]. In this report, ultrasound-guided percutaneous needle fenestration was used as an intervention to promote fusion of the avulsed bone fragments. The authors stated that rehabilitation after this procedure was the same as in the acute setting because the situation was similar to that of fresh trauma. Rehabilitation after percutaneous fenestration was adapted from the protocol devised by Metzmaker and Pappas[17].

In this review, we found that the rehabilitation approach of Metzmaker and Pappas[17], which was published in 1985, is still the basis for today’s rehabilitation and has not changed significantly in the nearly 40 years that have passed since the publication of this paper. Two other reports only described advocating a period of rest[19] and delayed stretching[20].

Sciatic nerve palsy requires attention in both the acute and chronic phases. As a complication of an avulsed IT, sciatica may occur, which is related to irritation of the sciatic nerve by the avulsed bony fragment and/or hypertrophic bony callus formation or heterotopic ossification[5].

1-4. ASIS avulsion injury in adolescent athletes

The ASIS represents the origin of the sartorius muscle and the tensor muscle of the fascia latae. The suture muscles stop on the medial side of the tibial coarse surface. The tensor muscle acts in hip flexion, abduction, and external rotation, and in knee flexion and internal rotation. The tensor muscle of the fascia latae terminates at Gerdy's tubercle of the lateral tibial condyle via the iliotibial ligament.

The tensor muscles of the fascia latae and the long tibial ligament work in conjunction with other muscle groups to assist and stabilize hip and knee joint motion. Sprinters or jumpers are typical athletes at risk for ASIS avulsion injury.

With regard to rehabilitation, both conservative and surgical treatments have a guideline of 6 weeks of exercise restriction. No weight restriction is required during that time. After 6 weeks of exercise restriction, the patient can return to his or her original sport[7], but no information is given regarding phased or specific rehabilitation.

In both the acute and subacute phases, there is a risk of lateral femoral cutaneous neuropathy[7][21][22][23]. Lateral femoral cutaneous neuropathy presenting with proximal lateral thigh pain is called meralgia paraesthetica. It can be caused by compression associated with a muscle or hematoma, or by pressure from an avulsed bone fragment. Some reports have mentioned that avulsion fractures were relieved by conservative treatment[7][21], and others mentioned that avulsion fractures were quickly relieved by fixation of the bone fragments[22][23]. Hayashi et al. stated that acute-onset meralgia paresthetica is a target for conservative treatment, while delayed-onset meralgia paresthetica is a target for surgery. The authors further stated that surgical therapy can speed up the time to return to sports (RTS)[23].

1-5. Adductor longus muscle avulsion injury in adult athletes

The long adductor muscle originates in front of the pubic symphysis and below the pubic tubercle. The adductor longus muscle inserts into the middle third of the linea aspera of the femoral shaft. It acts on the internal rotation and flexion of the hip joint.

With regard to the rehabilitation of adult patients with avulsion injuries of the long adductor pollicis longus, both surgical and conservative treatments have been reported to have a positive turnaround to RTS. A previous small case series[24] in athletes indicated that the use of an exercise-based approach resulted in a faster RTS time compared with surgical reattachment (RTS times of 6–13 weeks compared with 12–21 weeks).

Meanwhile, Serner et al. found that a supervised standardized criterion-based rehabilitation protocol without surgery was successful in 16 adult male competitive athletes with acute complete avulsion injuries of the adductor pollicis longus muscle[2]. The supervised standardized criterion-based rehabilitation protocol[2][25] included nine groin exercises that were performed three times per week on alternate days. The athletes also followed a criteria-based running and sport function progression, including sprinting and changing direction with and without a ball. When athletes participated in the three weekly sessions, non-groin exercises were added on an alternating basis. The selection of additional exercises was not standardized but focused primarily on the posterior kinetic chain muscle groups (hip abductors, extensors, hamstrings, and calves). Additional exercises were determined by the individual athlete's needs, including the type of sport and injury history[2].

Three different milestones were used to assess RTS continuity. The number of days from injury was calculated until (1) the individual was clinically pain-free, (2) controlled sports training was completed, and (3) full team training resumed, regardless of meeting all the protocol criteria[2][25]. Dutton et al. found that with managed rehabilitation using the above protocol, athletes with MRI grade 0 to

2 (grade 2, fluid-equivalent intramuscular collection, indicating structural disruption) adductor muscle injuries reported that they were pain-free and returned to full team training within 3 months. Moreover, most athletes with MRI grade 3 (avulsion or complete musculotendinous disruption) adductor muscle injuries were pain-free within 3 months and returned to full team training[25]. With regard to late complications, the authors reported that 8% of cases of reinjury within 1 year occurred in patients who underwent strictly controlled rehabilitation[25]. Since most cases had reinjury within 2 months of joining the team's overall practice[25], it may be necessary to consider this period as a risk period for reinjury and to observe patients more closely.

2. Pelvic Bone Stress Injuries

2-1. Prevalent sites and epidemiology of pelvic bone stress injuries

Stress fractures account for 15% of injuries experienced by running athletes, and 4% of these involve the pelvis[26]. They represent a spectrum of bone disorders from early injury (stress reaction) to catastrophic failure of the bone fracture[12]. In an epidemiological study of athletes affiliated with the National Collegiate Athletic Association (NCAA) [13], the most common site was the metatarsals (37.9%), followed by the tibia (21.9%). The frequency of fatigue fractures in the lower back/lumbar spine/pelvic area was 12.1%, although the value for the pelvis was not described. Overall, 21.5% of stress fractures were recurrent injuries, and 20.7% were season-ending injuries[13].

2-2. Risk factors of pelvic stress injuries

Several risk factors for the development of stress injuries have been identified. Endogenous risk factors include female sex, amenorrhea, low bone density, low lean body mass, low aerobic fitness at the start of exercise, genu valgum, and leg length discrepancy[26][27][28]. Exogenous factors include a rapid progression of training programs, running on uneven or angled surfaces, running and jumping sports, deteriorated shoes, smoking, and poor nutrition[26][27][28].

2-3. MRI findings and timing of Return To Sports

A systematic review found that MRI findings were correlated with the return-to-work time[9]. A total of 16 studies involving 560 bone stress injuries met the inclusion criteria[9]. The MRI findings indicated a faster return to work for less severe injuries (stress reactions) and a slower return to work for more severe injuries (stress fractures). Moreover, trabecular-rich injury sites (e.g., the pelvis, femoral neck, and calcaneus) took longer to heal than cortical-rich injury sites (e.g., the tibia, metatarsal, and other long-bone injury sites)[9].

2-4. Rehabilitation for pelvic bone stress injuries

Pelvic bone stress injuries are generally considered to be easily treated with appropriate rehabilitation and do not require surgical intervention. In particular, the sacrum and pubic ramus reflect lower-risk sites of injury and are typically managed with activity modification to a pain-free level[11].

During rehabilitation, it is important to maintain cardiopulmonary function, muscle strength, and neuromuscular control, while avoiding aggravation or stress to the injured area. Non-weight-bearing/low-impact exercises like water jogging and cycling are often used to maintain physical fitness. A 4-week underwater running program can maintain leg strength, VO2 max, and running performance. Muscle strength and leg length imbalances related to neuromuscular control deficits identified on initial physical examination need to be corrected.

Leg length imbalances can be treated with heel lifts and custom shoe inserts. Through patient education, efforts should be made to prevent future stress injuries. Proper progression of the training program is necessary to reduce musculoskeletal overload.

The U.S. Army training program was reported to have reduced fatigue fractures in military personnel[10]. The Army Physical Readiness Training Program[10] standardizes the intensity, duration, amount, frequency, and balance of exercise for U.S. military personnel. It was thought that the ability to train moderately without overloading led to the prevention of fatigue fractures.

The effect of osteopathic manipulative treatment on the prevention of fatigue fractures was investigated in student cross-country athletes affiliated with the NCAA[14]. Osteopathic-trained medical students regularly assessed the musculoskeletal status of the athletes and intervened when necessary on an ongoing basis, and in male athletes, it was suggested that fatigue fractures were reduced[14]. While many internal factors are involved in fatigue fractures in female athletes, external factors are the main causes of fatigue fractures in male athletes, suggesting that regular observation of musculoskeletal status may provide an early response to the risk factors for fatigue fractures. Future follow-up studies are desirable owing to the small number of subjects involved and the fact that this was an observational study rather than a comparative study.

2-5. Other treatments for pelvic bone stress injuries (medication, etc.)

In female athletes, each additional daily serving of skim milk reduced the incidence of stress fractures by 62%[29]. In female Navy basic training recruits, the incidence of stress fractures was reduced by 20% for every 2000 mg of calcium and 800 IU of vitamin D per day for 8 weeks[30]. Based on the above reports, we believe it is also important to try to prevent this problem, especially from the perspective of endocrine nutrition, regarding emotional athletes.

In addition, a case report showed that teriparatide (parathyroid hormone [PTH] preparation) was effective in improving sciatic fatigue fractures[15]. PTH activates osteoblasts, stimulating bone remodeling and an overall increased trabecular bone volume and cortical thickness. After 16 weeks of conservative treatment from the onset of symptoms, the patient’s symptoms did not improve, and drug therapy was initiated. The findings in this case report[15] suggest that PTH preparations may be effective in fatigue fractures. A protocol for, in this case, RCT in Army recruits (136 men and women aged 18–40 years) with MRI-diagnosed lower body fractures (pelvic girdle, sacrum, coccyx, or lower limb) has now been approved[31], and the results are currently in the analysis phase. Further results on the effect of PTH on fatigue fractures are awaited.

Competing interests

None to declare.

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Author Contributions

YY, MY conceived the study. YY drafted the manuscript, and MY revised it. All the authors approved the final version of the manuscript.

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