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CrossFit-related hip and groin injuries: a case series

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ABSTRACT

To provide descriptive data on injury presentation and treatment and to identify risk factors for requiring surgical treatment for athletes presenting with CrossFit-related hip and groin injuries. CrossFit-related injuries ($n = 982$) were identified within a single hospital system from 2010 to 2017, with 83 (8.5% of total) identified hip or groin injuries. Patient demographics, injury diagnosis, surgical procedure and rehabilitation were assessed. Independent predictors of requiring surgery were analyzed via multivariate logistic regression analysis. Patients with hip or groin injuries were more often female (hip injuries: 63%; all injuries: 50%; $P < 0.001$) with mean age 34.3 years (standard deviation 10.9). Median symptom duration was 4 months with 70% reporting insidious onset. Most common diagnoses were femoral-acetabular impingement syndrome (34%), hamstring strain (11%), non-specific hip/groin pain (imaging non-diagnostic) (11%), hernia (7%) and iliotibial band syndrome (6%). Most (90%) required physical therapy (median 2 months). Surgery occurred in 24% ($n = 12$ hip arthroscopy, $n = 5$ inguinal hernia repair, $n = 3$ total hip arthroplasty), with 100% return to sport after arthroscopy or hernia repair. The only predictor of surgery was complaint of primarily anterior hip/groin pain (82% surgical patients, 46% non-surgical) (odds ratio 5.78, 95% confidence interval 1.44–23.1; $P = 0.005$); age, sex, body mass index, symptom duration and symptom onset (insidious versus acute) were non-significant ($P > 0.25$). CrossFit athletes with hip and groin injuries often present with prolonged symptoms with insidious onset. Most patients require several months of physical therapy and approximately one quarter require surgery. Patients presenting with primarily anterior hip/groin pain are at increased risk for requiring surgery.

Level of Evidence: IV, case series.

INTRODUCTION

CrossFit is a popular fitness activity that is considered a type of high intensity interval training (HIIT) or extreme conditioning program [1, 2]. Although the popularity of CrossFit has grown among both sexes and many age groups, rates of CrossFit Open enrollment have increased particularly rapidly among women and in athletes over the age of 40 years [3]. This exercise regimen is characterized by circuit training that incorporates ballistic gymnastics and Olympic weightlifting, as well as high-volume aggressive training workouts with short rest periods [1, 4, 5]. These types of HIIT programs have increased in popularity in recent years due to evidence showing both cardiovascular and metabolic benefits, as well as less time commitment compared to traditional exercise [6, 7]. Luc *et al.* [8] argue that HIIT offers the same exercise benefits as steady state exercise in a shorter time period.

Though injury rates and patterns in gymnastics [9] and weightlifting sports [10] are well documented, it is currently unclear how performance of these movements in the setting of CrossFit training affects injury risk. The estimated incidence of injuries related to CrossFit activities ranges from 0.74 injuries per 1000 training hours [11] to 3.1 per 1000 training hours [12], though prior research of CrossFit -related injuries are largely based on athlete self-report in surveys [4, 12–16]. The clinical utility of self-report CrossFit injury rates is questionable; Feito and Paul [17] report 84% of self-reported injuries did not require medical attention, and Hak *et al.* [12] report only 7% of self-reported injuries required surgery.

The majority of CrossFit injuries are localized to the shoulder, knee or spine [4, 12, 14, 18, 19]. It has been postulated that loss of proper form due to fatigue at the extremes of exercise can create abnormal stress on joints, causing injury [12]. Hip and groin injuries, although reported less often than shoulder or knee injuries, represent 4.0% [1]–7.1% [14] of all injuries in certain studies. CrossFit athletes may be at risk for hip-related injuries due to the high intensity activity and frequency of hyperflexion activities [20]. Hip injuries can be treated with a variety of techniques ranging from more conservative rest and physical therapy to arthroscopic surgery [1, 20–22].

The type and severity of CrossFit hip and groin injuries have not been well studied. With the continued popularity of CrossFit and the prevalence of high intensity activities requiring full motion of the hip (squats, dead lifts, box jumps), further inquiry into the outcome of CrossFit hip and groin injuries is needed to appropriately treat and counsel athletes. The purpose of this study is to provide descriptive data on injury presentation and treatment and to identify risk factors for requiring surgical treatment for athletes presenting with CrossFit-related hip and groin injuries. We hypothesize that the majority of injuries would be musculotendinous in nature, would not require surgical intervention, and that time away from sport would be limited on average to 2 weeks or less.

METHODS

Data source

A convenience sample was utilized of all patients who were evaluated within a single hospital system in the Midwestern United States from 1 January 2010, until 7 February 2017. The year 2010 was the year the first CrossFit affiliate gym opened within the surrounding metropolitan area. A free text-based query was submitted of all clinical documentation within the hospital system electronic medical records during this time period. Any patient clinical encounter in which CrossFit or a related term (listed in Table I) appeared within the patient's clinical documentation was flagged for manual review. The clinical encounters were then manually reviewed to confirm that the injury was related to CrossFit participation. A total of 1203 patient encounters were identified, 982 of which CrossFit-related injuries were identified. Of the 221 excluded patient encounters, 144 (65.2%) were for a musculoskeletal complaint (acute or chronic) unrelated to CrossFit activity, and 77 (34.8%) were for a medical issue unrelated to athletic activity. The most common anatomic sites of injury were the knee (26.4%) followed by the shoulder (21.0%) and spine (20.4%). Inclusion and exclusion criteria specific to this study (Table I) were applied to these 982 patients. Hip and groin injuries that met the current study criteria were identified in 83/982 of cases (8.5%).

Among the 83 included CrossFit-related hip and groin injuries, clinical data including patient demographics and injury diagnosis were documented. Treatments including injections, physical therapy and surgery were reviewed. Use of advanced diagnostic imaging including computed tomography and/or magnetic resonance imaging (MRI) were recorded. The primarily location of pain (anterior hip/groin, lateral hip or posterior hip) were recorded. Data on injury mechanism and symptom chronicity were recorded. Time away from sport was determined for all patients.

Statistical analysis

Statistics were performed with a standard software package (JMP 13.1, SAS Institute, Cary, NC, USA). Descriptive statistics were first generated for the entire sample. Comparisons in age, sex and body mass index (BMI) were made between hip/groin injury patients and CrossFit-related injuries overall (regardless of anatomic location). Comparisons were then made between athletes and non-athletes regarding demographics, symptom duration and location, injury treatment and time away from sport. For continuous data, Student's tests were utilized for normally distributed data and Wilcoxon rank sum for non-normally distributed data, respectively. Comparisons of categorical data were performed via Fischer's exact test. Finally, a multivariate logistic regression analysis was performed on the hip/groin patient cohort to identify independent risk factors for requiring surgical treatment. Potential covariates included age, sex, BMI, primary location of pain (anterior, lateral or posterior hip), duration of pain and symptom onset (insidious versus acute). Statistical significance was set at alpha <0.05.

RESULTS

Descriptive statistics

In comparison to all patients with CrossFit injuries, patients with hip or groin injuries were more likely to be female (hip injuries: 63% female; all injuries: 50% female; $P < 0.001$) but had a similar mean age [34.3 years standard deviation (SD) 10.9] ($P = 0.43$) and BMI (mean 25.3 SD 3.8) ($P = 0.52$). There was a trend toward higher rates of surgical treatment ($n = 20/83$; 24.1%) for hip/groin injuries compared to musculoskeletal injuries overall (16.6%) ($P = 0.09$).

Table I. Study inclusion and exclusion criteria

Search terms
1. CrossFit, cross fit, cross-fit, HIIT and high intensity interval training
Inclusion criteria
1. No age or sex restrictions
2. Patient must have a clinical encounter within OSU health systems for an injury related to CrossFit participation
3. Pathology involving the hip or surrounding musculature, including femoral or abdominal hernias presenting as hip or groin pain
4. Acute injury or exacerbation of underlying condition
Exclusion criteria
1. Acute injury due to non-CrossFit activity in a patient that participates in CrossFit
2. Evaluation or surveillance of chronic condition with stable symptoms. Example: maintenance therapy for hip osteoarthritis

Median time away from sport due to injury was 0.75 months (25th percentile 0, 75th percentile 4, max 7 months) with a higher time away from sport for surgically treated patients (median 5 months) versus injuries that did not require surgery (median 0 months) ($P < 0.001$) (Table II). All hip arthroscopy and inguinal repair patients returned to sport ($n = 17$, 100%); the 3 total hip arthroplasty patients were advised not to return to high impact activities such as CrossFit. The majority of injuries required physical therapy (90%) with a median duration of 2 months (25th percentile 1.5 months, 75th percentile 3.25 months). The primary site of pain was anterior hip/groin in 54%, posterior hip in 37% and lateral hip in 7%.

Injury mechanism and diagnosis

The most common diagnoses (>5% each) were femoral-acetabular impingement syndrome (FAIS) (34%), hamstring strain (11%), non-specific hip or groin pain (imaging non-diagnostic) (11%), hernia (7%) and iliotibial band syndrome (6%) (Table III). The majority of patients reported an insidious symptom onset with inability to identify a specific causative workout (70%); a further 10% could recall a specific workout but not a specific moment or movement after which they became symptomatic. A minority of patients could recall a specific movement that initiated symptoms, including deep squatting (6%), running or sprinting (6%), deadlift (4%), fall (2%), lunging (1%) and rapid hip flexion (1%).

Hip arthroscopy was primarily indicated for patients who had history, physical exam, as well as imaging findings consistent with FAIS. The patients had failed conservative management with a combination of rest, activity modification, medications, injections and formal physical therapy. Surgery was utilized to treat the FAIS with rim resection, cam resection, labral repair and capsule repair or plication where indicated. A minority of surgical patients were treated for hip flexor origin avulsion injuries. All hip surgery was performed by two high-volume fellowship trained hip preservation surgery specialists. Hernia repair surgeries are performed by one general surgeon as the primary consultant from the orthopedic hip team for core muscle injuries/hernia/adductor procedures. The non-specific hip and groin pain with non-diagnostic imaging was felt to primarily include hip flexor strain injuries, the majority of which resolved with non-surgical management. Specialized physical therapists were provided for all patients in this cohort. Length of formal physical therapy was variable dependent on the nature of the injury, as well as the recovery profile for each patient involved.

Risk factors for requiring surgery

Presentation with primarily anterior hip or groin pain (82% surgical patients and 46% non-surgically treated patients) was the only identified risk factor for requiring surgery in the multivariate logistic regression analysis [odds ratio 5.78, 95% confidence interval (CI) 1.44–23.1; $P = 0.005$]; age, sex, BMI, symptom duration and symptom onset (insidious versus acute) were all non-significant predictors of requiring surgery ($P > 0.25$) (Table IV).

DISCUSSION

The most important findings of the current study are that 24% of hip and groin injuries related to CrossFit activity required surgical treatment and that presentation with primarily anterior hip/groin pain is a risk factor for requiring surgery. Additionally, several months of physical therapy are typically required to adequately rehabilitate from a CrossFit-related hip or groin injury (regardless of surgical treatment), and median time away from sport is less than 1 month for non-surgical injuries and 5 months for surgically treated injuries. To our knowledge, this is the first study to present data related to CrossFit injured patients surgical intervention rates among athletes who sought medical attention for hip and groin injuries. The severity of injury among patients who seek medical attention is likely higher than injuries self-reported by athletes in survey

Table II. Descriptive statistics

	All patients (n = 83)	*Non-surgical patients (n = 63)*	*Surgically treated patients (n = 20)*	P-*value*
Age	34.3 SD 10.9	34.2 SD 11.2	34.8 SD 10.4	0.84
Male	37%	35%	45%	0.42
Female	63%	65%	55%	
Body mass index (kg/m^2)	25.3 SD 3.8	25.8 SD 3.8	23.3 SD 3.8	0.12
Symptom duration (months)	Median: 4	Median: 3	Median: 6	0.09
	25th percentile: 1	25th percentile: 0.75	25th percentile: 1.25	
	75th percentile: 8.5	75th percentile: 8.25	74th percentile: 12	
Primary symptom location				0.01
Anterior/groin	54%	46%	82%	
Posterior	37%	42%	18%	
Lateral	7%	12%	0%	
Time away from sport (months)	Median: 0.75	Median: 0	Median: 5	<0.001
	25th percentile: 0	25th percentile: 0	25th percentile: 4.25	
	75th percentile: 4	75th percentile: 1	75th percentile: 5	
	Max: 7	Max: 7	Max: 6	
Physical therapy	90%	92%	85%	0.39
Physical therapy duration (months)	Median: 2	Median: 2	Median: 3	0.68
	25th percentile: 1.5	25th percentile: 1.5	25th percentile: 1.25	
	75th percentile: 3.25	75th percentile: 4	75th percentile: 4	
	Max: 6	Max: 6	Max: 5	
Corticosteroid injection	31%	17%	75%	<0.001
MRI scan obtained	41%	30%	75%	<0.001
Surgery performed	24%	0%	100%	N/A

studies. Feito and Paul [17] report that 84% of self-reported injuries did not require medical attention. Similarly, Hak *et al.* [12] report a lower rate of surgery than the current study, as only 7% of self-reported CrossFit injuries required surgery in their study.

Athletes can have high rates of return to sport after hip arthroscopy [23–25] regardless of sex [26]; high rates of return to sport are also observed after hernia repair [27, 28]. In a study of patients performing frequent squatting activities, Polesello *et al.* [29] report a 71.5% rate of return to sport. A higher rate of return to sport following arthroscopic hip surgery was reported by Riff *et al.* [20] for athletes participating in HIIT programs. They noted that out of the 32 patients they included in the study, 88% were able to return to HIIT post-operatively and 44% noted improvement in their HIIT performance [20]. Subgroup analysis in our study showed similar results. All patients who underwent arthroscopic hip surgery or hernia repair were able to return to CrossFit in our study, although the time away from sport due following surgery was significantly

Table III. Injury characteristics

	Percentage
Mechanism	70% insidious/no specific event
	10% symptomatic after a specific workout, cannot pinpoint exact movement
	6% deep squat
	6% running/sprinting
	4% deadlift
	2% fall
	1% lunging
	1% rapid hip flexion
Diagnosis	34% femoral-acetabular impingement syndrome (FAIS)
	11% hamstring strain
	11% non-specific pain, imaging non-diagnostic
	7% hernia
	6% iliotibial band syndrome
	5% adductor strain
	5% hip osteoarthritis
	5% hip flexor strain
	5% stress fracture ($n = 2$ femoral neck, $n = 1$ pubic ramus, $n = 1$ sacrum)
	5% SI joint pain
	5% hip external rotator strain
	2% quadriceps strain

Table IV. Independent risk factors for requiring surgery

	Odd ratio, 95% CI	P-*value*
Anterior hip/groin symptoms?	5.78, 1.44–23.1	0.005
Sex	N/S	0.70
Age	N/S	0.75
Body mass index (kg/m^2)	N/S	0.88
Symptom duration (months)	N/S	0.42
Symptom onset: insidious versus acute	N/S	0.70

N/S: non-significant.

longer (median 5 months) than injuries that did not require surgical treatment (median 0 months, 75th percentile 1 month).

There are many potential causes of hip and groin pain, which may make accurate identification of the specific anatomic pain generator difficult [30, 31]. There are multiple anatomic layers and structures involved [32], and certain structures can have either static (pain at rest) or dynamic (pain with specific movements) contributions to hip or groin pain [31]. Primarily anterior hip and groin symptoms are concerning for abdominal wall or intra-articular pathology [28, 31] and accordingly this was found to be the only independent risk factor for requiring surgical treatment in the current study. Posterior hip pain in this group rarely requires surgery. This type of pain, although it has the potential to be significantly impactful for patients, can be caused by referred lumbar spine and sacroiliac joint pathology, or be associated with diagnosis such as piriformis syndrome or deep gluteal nerve syndrome [31–33]. This was a less frequent pain presentation in this patient population. Lateral hip pain is frequently indicative of greater trochanteric pain syndrome, which can often be treated successfully with non-surgical modalities [34–36].

Injury risk assessment is an important component of injury prevention; several non-demographic risk factors for injury have been identified in CrossFit athletes. Chachula *et al.* [37] and Moran *et al.* [11] both found higher risk of subsequent injury in the 6 months following an initial injury. This increased risk window has been documented in prior recreational adult fitness activities [38]. Moran *et al.* [11] also noted that previous injury was an independent risk factor for injury among CrossFit athletes, and correspondingly, left–right asymmetries on functional movement screening [39] were associated with higher injury risk. Prior reports have also suggested that strength/flexibility imbalances increase injury risk in athletic setting [40]. Furthermore, in a recent study of 449 CrossFit athletes in the Netherlands, duration of training less than 6 months was the only identified predictor of increased injury risk [16]. In the opinion of the respondents, the mostly likely causes of injury were use of bad/incorrect form (20.5%), fatigue (20.2%), use of too heavy of weight (16.1%), unknown (10.1%), relapse of an old injury (10.1%) and too little or bad coaching (1.6%) [16]. Conversely, high training load in more competitive athletes may also increase injury risk, as a survey of 191 athletes from CrossFit affiliate gyms in southern Florida found that greater training hours and level of competition were both associated with higher injury rates [15].

Limitations

The present study has several limitations. Prior CrossFit injury studies are largely limited to patient-reported surveys that lack evaluation by a medical professional [4, 12–16]. Injury assessments were made in this dataset by medical professionals and, in contrast to self-report of injuries in surveys, are not prone to recall bias [41]. However, an athlete's competitive level and athlete contact hours can influence injury risk and injury severity but are not available in the current study. The demographics and injury patterns of patients seen within our medical center may not be representative of injured CrossFit athletes seeking medical care in other regions. Additionally, treatment patterns including rates of surgery are potentially influenced by multiple factors including medical provider recommendations, patient resources and the goals of treatment including the desire to return to high level athletic activities. Location of hip pain may not be an accurate reflection of risk for surgical intervention given the dominance of anterior hip and groin pain in this group. Although this may introduce bias, it is addressed indirectly and mitigated via regression analytics. The increased surgery in this group may reflect that the pathology indicated in this anterior hip/groin pain group is more amenable to surgical treatment.

CONCLUSIONS

CrossFit athletes with hip and groin injuries often present with prolonged symptoms with insidious onset. Most patients require several months of physical therapy and approximately one quarter require surgery. Patients presenting with primarily anterior hip/groin pain are at increased risk for requiring surgery.

CONFLICT OF INTEREST STATEMENT

The authors received no funding for this study and report no conflicts of interest.

REFERENCES

1. Aune KT, Powers JM. Injuries in an extreme conditioning program. *Sports Health* 2016; **9**: 52–58.
2. Biddle SJ, Batterham AM. High-intensity interval exercise training for public health: a big HIT or shall we HIT it on the head? *Int J Behav Nutr Phys Act* 2015; **12**: 95.
3. Henderson S. *CrossFit's Explosive Affiliate Growth by the Numbers*. 2018. Available at: https://morningchalkup.com/2018/10/23/crossfits-explosive-affilaite-growth-by-the-numbers/. Accessed: 8 January 2020.
4. Summitt RJ, Cotton RA, Kays AC *et al*. Shoulder injuries in individuals who participate in CrossFit training. *Sports Health* 2016; **8**: 541–6.
5. Bergeron MF, Nindl BC, Deuster PA *et al*. Consortium for Health and Military Performance and American College of Sports Medicine consensus paper on extreme conditioning programs in military personnel. *Curr Sports Med Rep* 2011; **10**: 383–9.
6. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: part I: cardiopulmonary emphasis. *Sports Med* 2013; **43**: 313–38.
7. Gibala MJ, McGee SL. Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain? *Exerc Sport Sci Rev* 2008; **36**: 58–63.
8. Gosselin LE, Kozlowski KF, DeVinney-Boymel L *et al*. Metabolic response of different high-intensity aerobic interval exercise protocols. *J Strength Cond Res* 2012; **26**: 2866–71.
9. Kolt GS, Kirkby RJ. Epidemiology of injury in elite and subelite female gymnasts: a comparison of retrospective and prospective findings. *Br J Sports Med* 1999; **33**: 312–8.
10. Keogh JW, Winwood PW. The epidemiology of injuries across the weight-training sports. *Sports Med* 2017; **47**: 479–501.
11. Moran S, Booker H, Staines J *et al*. Rates and risk factors of injury in CrossFitTM: a prospective cohort study. *J Sports Med Phys Fitness* 2017; **57**: 1147–53.
12. Hak PT, Hodzovic E, Hickey B. The nature and prevalence of injury during CrossFit training. *J Strength Cond Res* 2013; [Epub ahead of print].
13. Owen AL, Forsyth JJ, Wong DP *et al*. Heart rate-based training intensity and its impact on injury incidence among elite-level professional soccer players. *J Strength Cond Res* 2015; **29**: 1705–12.
14. Weisenthal BM *et al*. Injury rate and patterns among CrossFit athletes. *Orthop J Sports Med* 2014; **2**: 2325967114531177.
15. Montalvo AM, Shaefer H, Rodriguez B *et al*. Retrospective injury epidemiology and risk factors for injury in CrossFit. *J Sports Sci Med* 2017; **16**: 53–9.
16. Mehrab M *et al*. Injury incidence and patterns among Dutch CrossFit athletes. *Orthop J Sports Med* 2017; **5**:2325967117745263.
17. Feito Y, Paul A. Prevalence of injury among CrossFit participants. *Med Sci Sports Exerc* 2014; **46**: 762.
18. Everhart JS, Kirven JC, France TJ *et al*. Rates and treatments of CrossFit-related injuries at a single hospital system. *Current Orthopaedic Practice* 2019; **30**: 347–52.
19. Klimek C, Ashbeck C, Brook AJ *et al*. Are injuries more common with CrossFit training than other forms of exercise? *J Sport Rehabil* 2018; **27**: 295–9.
20. Riff AJ, Ukwuani G, Clapp I *et al*. High rate of return to high-intensity interval training after arthroscopic management of femoroacetabular impingement syndrome. *Am J Sports Med* 2018; **46**: 2594–600.
21. Sochacki KR *et al*. Performance and return to sport after hip arthroscopy for femoracetabular impingement syndrome in National Hockey League players. *J Hip Preserv Surg* 2019; **6**: 234–40.
22. Ishoi L *et al*. The association between specific sports activities and sport performance following hip arthroscopy for femoroacetabular impingement syndrome: a secondary analysis of a cross-sectional cohort study including 184 athletes. *J Hip Preserv Surg* 2019; **6**: 124–33.
23. O'Connor M, Minkara AA, Westermann RW *et al*. Return to play after hip arthroscopy: a systematic review and meta-analysis. *Am J Sports Med* 2018; **46**: 2780–8.
24. Memon M *et al*. Athletes experience a high rate of return to sport following hip arthroscopy. *Knee Surg Sports Traumatol Arthrosc* 2018; **10**: 3066–104.

25. Perets I, Craig MJ, Mu BH *et al*. Midterm outcomes and return to sports among athletes undergoing hip arthroscopy. *Am J Sports Med* 2018; **46**: 1661–7.
26. Shibata KR, Matsuda S, Safran MR. Arthroscopic hip surgery in the elite athlete: comparison of female and male competitive athletes. *Am J Sports Med* 2017; **45**: 1730–9.
27. Kumar A, Doran J, Batt ME *et al*. Results of inguinal canal repair in athletes with sports hernia. *J R Coll Surg Edinb* 2002; **47**: 561–5.
28. Meyers WC, McKechnie A, Philippon MJ *et al*. Experience with "sports hernia" spanning two decades. *Ann Surg* 2008; **248**: 656–65.
29. Polesello GC, Cinagawa EHT, Cruz PDSS *et al*. Surgical treatment for femoroacetabular impingement in a group that performs squats. *Rev Bras Ortop* 2012; **47**: 488–92.
30. Tibor LM, Sekiya JK. Differential diagnosis of pain around the hip joint. *Arthroscopy* 2008; **24**: 1407–21.
31. Bedi A, Dolan M, Leunig M *et al*. Static and dynamic mechanical causes of hip pain. *Arthroscopy* 2011; **27**: 235–51.
32. Draovitch P, Edelstein J, Kelly BT. The layer concept: utilization in determining the pain generators, pathology and how structure determines treatment. *Curr Rev Musculoskelet Med* 2012; **5**: 1–8.
33. Hernando MF, Cerezal L, Pérez-Carro L *et al*. Deep gluteal syndrome: anatomy, imaging, and management of sciatic nerve entrapments in the subgluteal space. *Skeletal Radiol* 2015; **44**: 919–34.
34. Strauss EJ, Nho SJ, Kelly BT. Greater trochanteric pain syndrome. *Sports Med Arthrosc Rev* 2010; **18**: 113–9.
35. Redmond JM, Chen AW, Domb BG. Greater trochanteric pain syndrome. *J Am Acad Orthop Surg* 2016; **24**: 231–40.
36. Lustenberger DP, Ng VY, Best TM *et al*. Efficacy of treatment of trochanteric bursitis: a systematic review. *Clin J Sport Med* 2011; **21**: 447–53.
37. Chachula LA, Cameron KL, Svoboda SJ. Association of prior injury with the report of new injuries sustained during CrossFit training. *Athletic Train Sports Health Care* 2016; **8**: 28–34.
38. Requa RK, DeAvilla LN, Garrick JG. Injuries in recreational adult fitness activities. *Am J Sports Med* 1993; **21**: 461–7.
39. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function—Part 1. *N Am J Sports Phys Ther* 2006; **1**: 62–72.
40. Knapik JJ, Bauman CL, Jones BH *et al*. Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *Am J Sports Med* 1991; **19**: 76–81.
41. Coughlin SS. Recall bias in epidemiologic studies. *J Clin Epidemiol* 1990; **43**: 87–91.