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Return to Cycling After a Multiple Pelvic Fracture: A Case Report of a Strength and Conditioning Based Approach to Rehabilitation

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Abstract: This case report describes the integrated rehabilitation and strength and conditioning approach that was adopted after the diagnosis of a fracture of the inferior pubic ramus, as well as a fracture to the lateral aspect of the superior pubic ramus, in a semi-professional triathlete and cyclist. The male athlete also incurred a minimal displacement of the medial acetabular, fracture of the superolateral acetabular and a fracture of the left sacral ala. Bleeding into both adductor muscles, and sacroiliac joint dysfunction were also diagnosed. The athlete suffered these injuries within a standard field-based training routine. No surgery was performed on the athlete. He was prescribed a progressive, yet structured, rehabilitation and strength and conditioning program by an allied health team. The program was adhered to by the athlete for four months. The strength and conditioning program included adaptations in the execution of most of the prescribed exercises. It required the athlete to initially perform the exercises twice weekly. At seven weeks post fracture, the athlete's weight bearing capabilities were increased to partial weight bearing on the injured side. Over the following month a gradual increase in the athlete´s level of strength and conditioning, as he performed both upper and lower body isometric exercises, occurred. These exercises were subsequently followed up with various isotonic exercises. The athlete reported no pain when he returned to spin cycling. On clinical follow-up, three months post-accident, a healing fracture was confirmed via radiographs of the athlete´s pelvis. Bone healing was assumed, on review, when no evidence of a fracture gap was obtained.

Keywords: Pelvic Fracture, Master's Athlete, Cycling, Cycling Accident, Strength and Conditioning.

1. Introduction

Triathlon is raced at both the elite and age-group levels. Most of its participants, however, are amateur athletes [1]. The sport appears to be relatively safe for those of such athletes who are well trained and well prepared [2,3], assuming that high risk individuals have undertaken prior health screening. What we know thus far regarding the extent, severity, and risk factors for triathlon injury has been extensively reviewed [3,4,5]. A consistent finding across the studies to date is that less triathletes sustain traumatic injuries, *i.e.*, injuries that are caused by a hazard encounter such as falling and/or either being hit by or hitting an obstacle, than are affected by so-called overuse injuries (without a specific, identifiable cause). The outcomes of traumatic injuries may, however, be more severe.

In a race based one-month retrospective survey of 660 triathletes [5] most traumatic injuries were found to occur during cycling. The most cited contributing factors to said injury were collisions, falls, or slips or trips (accounting for 72.5% of cases). Weather and surface were major contributing factors in 45.5% and 40.9%, respectively, of such incidents. Injury to multiple anatomical sites, to the knee, the elbow and to the hip was usually the result, accounting for 25%, 20%, 10% and 10% of such cases. A separate retrospective study of 1159 long-distance triathletes [6, detailed in [5] reported that the traumatic injuries that had affected the largest proportions of (male and female) athletes, since they started triathlon training, were to the shoulder area (19.5–30.1% of which were to the clavicle) and to the hands (13.1–36.8% of which were to the wrist). These regions commonly support or catch the body during a bicycle fall [5]. Unfortunately, as has been stated, triathlon injury research shares the methodological problems of similar investigations in other Olympic sports [7, 8]. What the various reviews of the triathlon injury literature thus far conducted have not highlighted, however, is that it is also conspicuously lacking in reports of how athletes have successfully rehabilitated themselves from injury. This missing information is particularly unfortunate in this athlete group, because triathletes tend to continue to train whilst injured. They may do so either within the same or (paying insufficient attention to the effect of cross-training) in other disciplines to that in which the injury was first noted [6]. Such behaviour is likely to negatively impact both the time that it takes for the athlete to achieve "return to play," and the likelihood of injury recurrence [4]. Given the limitations of the existing literature, we cannot say with certainty what the impact of hip fractures- relative to that of the other most sustained traumatic, cycling related, injuries- is in triathletes. Nor can we do so for cyclists. But, hip fractures are clearly significant injuries. If a safe return to sport is to be ensured, resumption of function and mobility should be the priority.

This case report discusses the rehabilitation process for a male, semi-professional, triathlete who sustained multiple pelvic fractures in a bicycle fall. The report covers the four-month period from when the patient (hereafter referred to as X) sustained his traumatic injuries to when he resumed active cycle training. Firstly, we firstly describe the main functional deficits that the patient sustained because of his injuries. He did not, however, require surgery. We then detail his rehabilitation and strength program and describe how its phasing was matched to the patient´s progressive resumption of function and mobility back to pre-accident levels.

2. Subject and Injury Details

The data in this case report were approved for publication by the local University Ethics Committee (H21114). X was 45 years old and weighed 71 kg when the accident occurred in October 2022. He had been triathlon training, for approximately 10-16 hours per week, for 8 years. X attributed the fall from his bicycle to the combination of a badly replaced manhole cover, and inferior lighting conditions (early in the morning) on the bitumen surface on which he was cycling. No other individuals or vehicles were involved in the accident. When X fell, he had no problems in disengaging his shoes from his clipless pedals. X´s subsequent multiple pelvic fractures were located within the inferior public ramus, on the lateral aspect of the superior pelvic ramus, within the superolateral acetabular, and within the left sacral ala. They were insufficiently visible on an x-ray image that was obtained 48 hours post-accident for clinical diagnosis to be made at that time (Figure 1). The fractures were confirmed via magnetic resonance imagery (MRI), a week later. The same MRI scans showed that bleeding into the left adductor muscles, but no apparent tendon tear(s), had occurred (Figure 2). Displacement (although this was minimal) of the medial acetabular was visible.

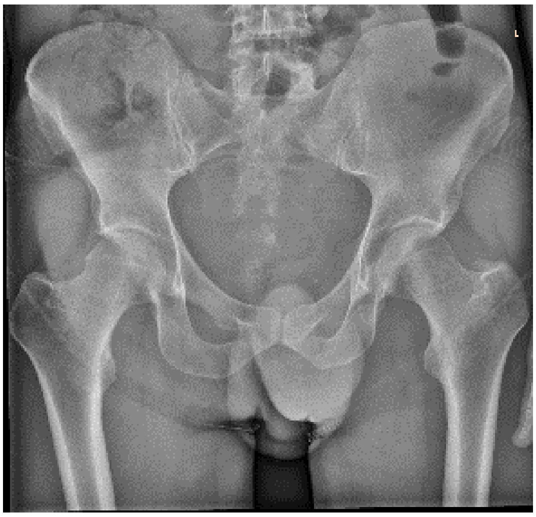

Figure 1. Patient x-ray that failed to show the multiple pelvic fractures that the patient sustained.

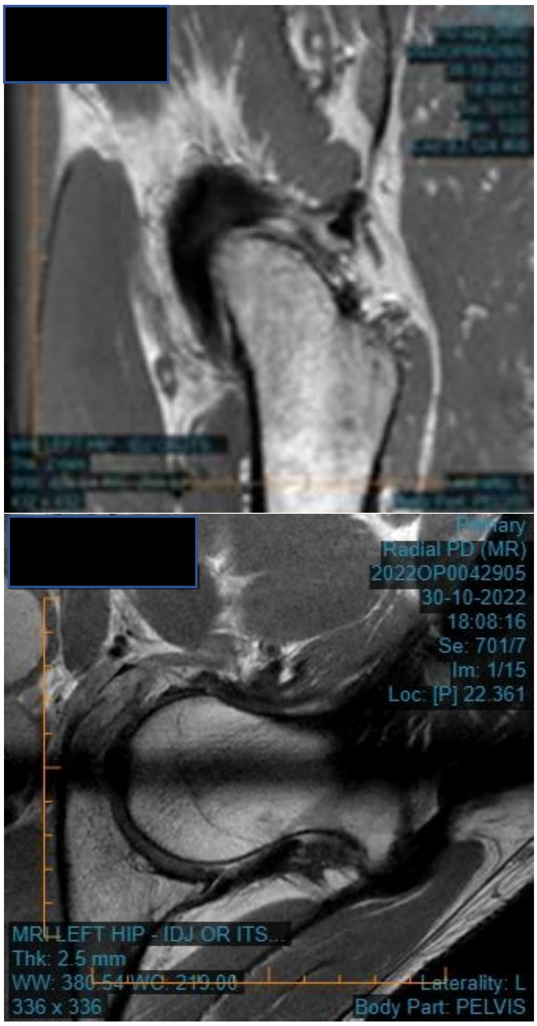

Figure 2. MRI data of the patient´s left hip.

The development timeline of X´s injury rehabilitation program is shown in Table 1.

Table 1. Timeline of events

Date	Description
8 October 2022	X´s cycle accident.
9 October 2022	X visited clinically registered osteopath for physical and functional evaluations. Medical management initiated. Patient requested to obtain an x-ray.
10 October 2022	X obtained referrals for x-ray and MRI´s within a consultation with MR. X obtained x-ray. MRI scan appointment booked for 14 October.
14 October	X obtained MRI and waited 48 hours for results.
17 October 2022	X saw MR, who confirmed that the X-rays were inconclusive whilst the MRI showed evidence of fracture(s). MR advised X to refrain from weight-bearing exercise for approximately four to six weeks. Deep water running was permitted. Patient advised to use crutches.
21 October 2022	X visited physiotherapist and ASCA coach. Exercises and strength and conditioning plan devised.
24 October 2022	X started rehabilitation program.
From 9 January 2023	"Return to play"

ASCA, Australian Strength and Conditioning Association; MR, medical registrar; MRI, magnetic resonance imaging.

The day after his accident, X´s physical and functional capacities were evaluated by an accredited qualified, clinically registered, osteopath. Given the severity of X´s injury, clinical muscle testing for strength and function was limited. This negated the osteopath from providing functional percentage deficits. Forty-eight hours post-accident, these findings were discussed with a sport and exercise medicine physician. The latter was both a registered member of the Australasian College of Sport and Exercise Physicians and a medical registrar (MR). MR recorded damage to the left sacroiliac joint

(SIJ) and referred X for x-rays and MRI scans of the affected area(s). His clinical diagnosis of multiple pelvic fractures was done a week later, on the basis of the MRI´s. At that point, MR advised X to refrain from all weight bearing exercise for approximately 4-6 weeks. He did not disallow deep water running,

Three days later, X was seen by both a sports physiotherapist and member of the Australian Physiotherapists Association (Physio), and a Level 2 accredited Australian Strength and Conditioning Association coach (Coach). They informed X that a structured "return to training" plan for him would, necessarily, be based around him being able to safely demonstrate the ability to perform the activity without pain, without compensation, and without apprehension. Moreover, their phased rehabilitation and strength and conditioning approach would be built around the combination of early phase movement screening and clinical clearance, followed by late phase athletic and field testing.

X's movement screening took place on the same occasion, ten days post-accident. Physio evaluated the strength of the muscle groups that were associated with the hip joint and pelvis (e.g., the abductors, adductors, iliacus, pectineus, psoas major, rectus femoris, and sartorius muscles). He also assessed the strength X´s gluteus maximus and hamstrings (*i.e.*, the long head of the biceps femoris, the semitendinosus, and the semimembranosus). By reason of X´s pre-accident levels of mobility and function, the Physio deemed it appropriate to use selected exercises that are recommended by the functional movement screening (FMS) tool for such purposes. The FMS is commonly used to identify limitations or asymmetries with respect to common, fundamental human movement patterns [8]. No additional exercises were incorporated into the test battery.

X was provided with, and started, his structured strength and conditioning program from the Coach three days later *i.e.*, two weeks post-accident. The 12-week program- which included a basic range of motion and strengthening exercises- was developed based on X´s likely rehabilitative progress and gradual improvements in strength and functionality. The program centred around the need for 1) pain management, 2) minimization of disuse related muscle atrophy and 3) an increase in X´s mobility over time back to his pre-accident levels. The program (see Table 2 for details) started with the combination of non-weight bearing water based aerobic exercises and isometric resistance exercises. From weeks 6-8, X then progressed to machine-assisted weight bearing exercise, free weight-based exercises, and spin cycle/cycle ergometer-based activity. The prescribed exercises were first performed twice a week. To put this into perspective, X was training six times per week (swimming on three days, running on four days, and cycling on three days) before his accident happened. His average indoor cycling-based training load, over weeks 8-12 of the program, equated to 40 km/week. Pre-accident, X was cycling approximately 200 km per week. He maintained fortnightly Physio consultations for two months post fracture diagnoses This was due to the Physio reviewing X's progress to help manage X's continued recovery.

3. Results

At seven weeks post fracture, X's weight bearing capability had been increased from zero to partial weight bearing on the injured site of his pelvis. Then, for the next four weeks, as X performed both upper and lower body isometric exercises, he was gradually able to increase the frequency, intensity, and duration of the related strength and conditioning exercises and activities. These exercises were subsequently followed by a variety of isotonic exercises. Upon return to spin cycling in a gymnasium, X reported experiencing no pain. Although X stated that he still experienced weakness of the left gluteal and surrounding SI region, he was able to cycle without impairment.

Table 2. A summary of the rehabilitation and strength and conditioning training program.

Week post diagnosis	Prescribed exercise	Sets, repetitions, and loading	Duration	Frequency	Rationale
Start: 24 October 2022	Non-weight bearing flexibility exercise		< 30 minutes	Maximum three times per week	
Weeks: 1-6	**Aquatic** Water aerobics/deep water running isometric exercises: ***Lower limbs*** • Supine quadriceps contraction • Supine ankle circles • Supine inner range quadriceps contraction (with towel/pillow placed under knee) • Supine hip adduction/abduction • Heel slides (performed seated while feet remain in contact with the ground) **Isometric exercises:** ***Upper limbs*** • Supine shoulder press • Supine shoulder flexion • Supine elbow flexion Core exercises • Pelvic floor exercises (e.g., isometric abdominal brace)	3 sets, 12-15 repetitions with 90 seconds recovery 3 sets, 12-15 repetitions with 90 seconds recovery 10 repetitions	3 x 30 second isometric contraction Performed daily		Attention paid to ensure that X can perform the isometric exercises without pain

Table 2. A summary of the rehabilitation and strength and conditioning training program. (continued)

Weeks: 6-8	**Aquatic** Water aerobics/deep water running/or assisted swimming (the latter using upper body only).	-	30-45 minutes		Assisted swimming with pool buoy (no fins, paddles or kicking, only upper body)
	Partial weight bearing on the affected side. ***Isotonic and isometric exercises: Lower limbs*** • One legged gluteal bridge (supine with one foot off the floor and extended to approximately 45°) • Standing hip flexion (with chair) • Standing hip abduction • Standing hip extension • Assisted squat (holding onto chair) • Lateral sideways shuffle (with band) • Clam shells (side-lying lower body activation and strengthening exercise with band)	3 sets, 12-15 repetitions with 90 seconds recovery		Maximum duration three times per week	
	Isotonic and isometric exercises: Upper limbs • Machine assisted latissimus dorsi pull down (seated) • Machine assisted chest press (seated) • Machine assisted posterior deltoid fly (seated) • Seated front raise (with dumbbells)	3 sets, 12-15 repetitions with 90 seconds recovery	As needed		Partial weight bearing on left side as tolerated without pain followed by progressive weight bearing (25% increase per week)
Weeks: 8-10	**Aquatic** Water aerobics/deep water running/or assisted swimming		< 45-60 minutes		With pull buoy (no fins, paddles or kicking, only upper body).
	Spin/ergometer cycle Stationary cycling		30 minutes		X can perform cyclic rotations and passive, active and resistance exercises.
	Isotonic and isometric exercises: ***Lower and lower limbs*** • Repeat from weeks 6-8	3 sets, 12-15 repetitions with 60 seconds recovery.			X to increase gradually the duration of the walk.
	Assisted walking (walking support provided by the therapist)				
	Step ups	10 repetitions			General aerobic step up and step-down exercise variations.

Table 2. A summary of the rehabilitation and strength and conditioning training program. (continued)

Weeks: 8-12	**Aquatic** Water aerobics/deep water running/or assisted swimming.			With pull buoy (no fins, but gentle kicking from week 10 permitted). Maximum duration three times per week. Can use pool buoy to kick from week 10.
	Isotonic and isometric exercise • Free-weight exercises included the squat, straight leg deadlift. • Pulley machine exercises for the chest, back, and triceps included the Smith machine, bench press.	3 sets, 12-15 repetitions with 60 seconds recovery.	Maximum duration three times per week (not to be performed on consecutive days	X can include use of Smith machine.
	Stair walks with walking aid • Unaffected leg goes up first, followed by the affected leg and finally the walking aid. • Going down: The walking aid goes down first, followed by the affected leg and then the unaffected leg.			
	Walking • Full weight bearing, unassisted.			
	Spin/ergometer cycle			Can increase intensity. X can rise out of the saddle from week 10. Moderate to high intensity aerobic exercise.
Week 12	Return to outdoor/ cycling (for which X self-selected the use of a road cycle bicycle).			

All exercises performed by X were unsupervised and were inclusive of weight bearing, aerobic exercise, flexibility, balance and mobility which followed the practice of progressively greater distances and less supportive mobility aids.

In week 8 (continuing through to week 12) X commenced weight-bearing upper and lower body exercises. He also did isotonic exercises, using weighted pulley machines. For weeks 8-12, resistance was set at approximately 40% of X's estimated one repetition max (1RM). His 1RM was estimated as 1RM = weight / (1.0278 – 0.0278 × reps [9]. The Coach advised X to do three sets of 12-15 repetitions, with an initial 90 second recovery period between sets. From week 12 onwards, X was instructed to increase resistance, that is– the load increased to approximately 42-44% of his 1RM. His spin cycling exercise intensity progressively increased throughout the program. X′s initial maximum spin cycle session duration was 60 minutes. This had increased to 90 minutes by week 12. From then, X slowly increased intensity and flywheel resistance during cycling. Intensity and resistance was self-selected by X.

Within his follow-up appointment with MR, three months post the fracture diagnosis, updated MRI scans of X′s pelvis revealed a healing fracture. Bone healing was assumed at approximately 13 weeks post- accident and when there was no evidence of a fracture gap on review. There was a good clinical evolution in the gluteal and left SIJ inclusive of asymmetry evaluation between limbs. The SIJ range of motion in flexion-extension was almost 3°, followed by an axial rotation of approximately 1.5° and lateral bending of 0.7° as measured by the Physio.

Following the 12- week return to training program, X then self-selected the frequency, intensity, time, and type of exercises that were performed to enable a gradual return to competition. He then reported that approximately eight months' post-accident, he had returned to national level triathlon/cycling competition. There has been no recurrence of pain between then and the submission date of this article. Clinical signs of a satisfactory outcome include pain free range of movement and a return to pre-injury baseline fitness and physical activity levels. X has self-reportedly performed at the same level of ability as he did prior to incurring his traumatic injuries.

Discussion

In this case report, we first describe injuries pertaining to multiple pelvic fractures, involving the inferior and superior pelvic rami, the acetabular and the left sacral ala along with SI joint dysfunction, in a semi-professional triathlete. This allowed for a structured and cohesive strength and conditioning plan to assist X in safe return to competitive triathlon.

The location of the stress fracture in this patient necessitated the production of a slow and methodically developed rehabilitation and return to training plan. The plan first included isometric exercises. Repetitive eccentric and concentric tensile loading by the gluteal muscle group and the adductors and abductors were introduced to help build endurance by applying constant tension to the muscles without causing a high tensile or sheering impact.

In our case report, the main factors influencing the recovery are the absence of pain, the athletic level of X, and the fear of a new injury and/or stresses placed on the injured site. While X obtained an x-ray and an MRI scan to confirm the fracture diagnosis, the structured strength, conditioning, and rehabilitation plan followed the literature in that athletes should also not compete if pain persists until other imaging studies have been obtained and an accurate diagnosis made [i.e., 9]. Even with the knee and hip providing most of the joint moment power, a muscle coordination along the kinetic chain, that is, at the hip, knee and ankle, is needed to transfer the mechanical energy between joints [11]. This kinetic chain is likely to be broken, or muscular activation may be threatened, if muscles are inferior or weakened due to the likely muscle atrophy sustained around the fractured area. Here, strength deficits were evident post X's fracture diagnosis.

As was expected due to the initial bleeding in X's left adductor muscle, a significant deficit in adductor strength were observed in the FMS assessment. From week 6, and after X had regularly performed isometric adductor exercises, strength gains were more evident (Table 2). This confirms that improved functionality and early return to strength training may have reduced residual deficits [12, 13]. However, strength gains are individualistic and include factors such as age, gender, body mass index (BMI), and level of physical activity and training prior to injury [14], all of which are factors that are strongly correlated to the return to sport [15]. In this regard, interventions to retain bilateral muscle strength during the early to middle stages of rehabilitation and strength and conditioning are warranted.

Our study has limitations, such as the fact that it is a case report, which restricts its application to other populations. We also note that use of the FMS is limited. The FMS attempts to identify fundamental movement patterns that simultaneously measure range of motion, stability, and balance [16]. Although there is moderate evidence for acceptable reliability when deriving a composite FSM score [17], the test continues to be subjected to strong challenges. Portable uniaxial force plates are a valid and reliable alternative to laboratory-based force plates for assessing strength, balance, and movement.

Isokinetic assessment of shoulder internal and external rotators is commonly used by clinicians to assess muscle performance and to guide rehabilitation. The reliability of isokinetic assessment is fundamental to track small but clinically relevant changes.

It was not possible to follow X's physical training before the rehabilitation protocol was implemented, so such information comes from X's self-report and is subject to memory bias. While the affected left adductor and gluteal along with the sacroiliac joint were analysed, the same location on the contralateral limb was evaluated based on the FMS criteria. This evaluation can be subjective, and the interpretation is based on the practitioner's level of the expertise.

5. Practical Applications

This clinical case report of multiple pelvic fractures sustained in a bicycle accident by a semi-professional triathlete highlights the necessity of both a multifaceted and a structured approach to X's movements and mechanical stress. Furthermore, the report highlights the additional use of concepts derived from sport, exercise, rehabilitation, and health sciences. Thus, this case report illustrates the advantage of using a comprehensive rehabilitative strength and conditioning program for the management of athlete recovery. For proper treatment of cycling injuries, an appropriate care program should integrate several approaches, such as biomechanics and physiology related work, in order to adapt management, training work and eventually rehabilitation to avoid injury and its recurrence. It is also prudent to note that the patient in this case study was not an elite (professional) triathlete and did not have a multidisciplinary allied health team managing his injury and rehabilitation. While X's medical diagnoses and return to play strategy was well considered and planned, the lack of cycling-specific rehabilitation knowledge of his support team will likely differ from that of professional triathletes. For instance, identification, treatment and ongoing management of probable asymmetries and symmetries when spin cycling would, in such athletes, be likely to occur in the early stages of return to play. This contrasts whit the general strength and conditioning approach that was taken with X. Therefore, the approaches listed in this case study should not be considered appropriate for professional triathletes.

Return-to-play decision making should be based on all the advantages and disadvantages of return to play for individual athletes, and not just the probability of recurrence of injury. This includes the effect of early versus delayed return to cycling and the other disciplines of triathlon on performance. Using a formal approach guided by expert personnel should help provide the valid approach.

In the present case, no other factor was considered harmful to the maintenance and progression of training and gradual improvement of sports performance.

6. Conclusions

Despite the severity of X's nondisplaced pelvic fractures, conservative management of them attained excellent results in this semi-professional triathlete. Correct early diagnosis with the aid of proper imaging is essential. Early return to non-weight bearing training followed by a combination of isometric and isotonic exercises that were followed by training on a stationary bike enables the triathlete to maintain fitness whilst protecting the process of bone healing. Moreover, this permits a gradual progression to competition. In addition, a more concise outcomes-based approach to treatment, and rehabilitation strength and conditioning protocols needs to be developed. Considering the lengthy recovery time of injuries that have been reported here, effective rehabilitation and accurate prognosis are fundamental to a timely and safe return to play.

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References

1. Rios, L. (2017). 2016 USA Triathlon membership survey report. Colorado Springs, Colorado. USA Triathlon. https://www.teamusa.org/USA-Triathlon/News/Articles-and-Releases/2017/December/18/USA-Triathlon-Membership-Sur- 1046 vey-Report
2. Dallam, G.M., Jonas, S., & Miller, TK. (2005). Medical considerations in triathlon. Sports Medicine, 35(2), 143–161
3. Vleck, V.E. (2010). Triathlon. In: Caine DJ, Harmer P, Schiff M, editors. Epidemiology of injury in Olympic sports. International Olympic Committee Encyclopaedia of Sports Medicine Series West Sussex: Wiley-Blackwell 2010, 294-320.
4. Vleck, V., Millet, G.P., & Alves, F.B. (2014). The impact of triathlon training and racing on athletes' general health. Sports Med, 2014, *44*, 1659–1692.
5. Vleck, V., & Hoeden, D. (2019). Epidemiological aspects of illness and injury. In Triathlon Medicine; Springer Nature: Basel, Switzerland, pp. 19–41.
6. Hoeden D. (2017). Verletzungen und Schmerzen im Langdistanztriathlon: Zusammenhänge zwischen trainingsbezogenen Risikofaktoren und häufigen Beschwerdebildern bei Langdistanztriathleten und -athletinnen [Injuries and pain in long-distance triathlon: correlation between training related risk factors and frequent discomforts among long distance triathletes]. Unpublished Ph.D. thesis. Karl-Franzens University, Graz.
7. Caine, D.J., Harmer, P.A., & Schiff M.A. (2010). Epidemiology of injury in Olympic sports. Oxford: Wiley Blackwell.
8. Gosling, C.M., Forbes, A.B., McGivern, J., & Gabbe, B.J. (2010). A profile of injuries in athletes seeking treatment during a triathlon race series. American Journal of Sports Medicine, 38(5):1007-14.
9. Cook, G., Burton, L., Hoogenboom, B.J., & Voight, M. (2014). Functional movement screening: the use of fundamental movements as an assessment of function-part 2. International Journal of Sports Physical Therapy, *9*(4), 549-63.
10. Brzycki, M. (1993). Strength testing – predicting a one-rep max from reps to fatigue. Journal of Physical Education, Recreation & Dance, 64, 88–90.
11. Cerynik, D.L., Roshon, M., Abzug, J.M., Harding, S.P., Tom, & J.A. (2009). Pelvic fractures in professional cyclists: a report of 3 cases. Sports Health, 1(3), 265-70. doi: 10.1177/1941738108326704
12. Anhalt, R., Löbell, R., Pereira, F., & Saccol, M.F. (2021). Return to cycling after hip arthroplasty: a case report of femoroacetabular impingement. Journal of Science in Cycling, *10*(1), 31-39. doi: 10.28985/1221.jsc.04
13. Friesenbichler, B., Casartelli, N.C., Wellauer, V., Item-Glatthorn, J.F., Ferguson, S.J., Leunig, M., & Maffiuletti, N. A. (2017). Explosive and maximal strength before and 6 months after total hip arthroplasty. Journal of Orthopaedic Research. 10.1002/jor.23626

14. Winther, S. B., Foss, O. A., Husby, O. S., Wik, T. S., Klaksvik, J., & Husby, V.S. (2019). Muscular strength and function after total hip arthroplasty performed with three different surgical approaches: one-year follow-up study. HIP International, 29(4), 405–411.

15. Williams, D.H., Greidanus, N.v., Masri, B. A., Duncan, C.P., & Garbuz, D.S. (2012). Predictors of participation in sports after hip and knee arthroplasty. Clinical Orthopaedics and Related Research, 470(2), 555–561. doi: 10.1007/s11999-011-2198-y

16. Kiesel K, Plisky P.J., Voight, M.L. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? North American Journal of Sports Physical Therapy, 2, 147–5816. Moran, R.W., Schneiders, A.G., Major, K.M., et al (2015). How reliable are Functional Movement Screening scores? A systematic review of rater reliability. British Journal of Sports Medicine.

17. Beardsley, C., Contreras, B. (2014). The Functional Movement Screen: A Review. Strength and Conditioning Journal *36*(5):p 72-80, October 2014. doi: 10.1519/SSC.0000000000000074