Title:

Rehabilitation of Watson-Jones proximal tibial avulsion injury in elite academy level football: A report of two separate cases in one season.

ABSTRACT

Objectives:

Watson-Jones proximal tibial avulsion injuries occur more frequently in athletic and muscular adolescent males. However, they are rare and therefore infrequently described in the medical literature. Two of these injuries occurred in a Category 1 football academy in the same season within a six-month period. We have described the cases with the hope of better informing other clinicians should they encounter this injury.

Methods:

This case report describes the injury mechanism, surgical management and rehabilitation for the two cases [Players A and B]. Outcomes measures including player speed, agility and power were compared with scores from players of the same age group at the time of injury in the Premier League academies. Risk factors are also discussed.

Results:

Both players were managed surgically, initially. Player B had the surgical fixation removed during rehabilitation. Player A still has the fixation in situ. Post-surgery, player A returned to full play at thirty-two weeks and thirty-eight weeks for player B. No critical incidents occurred during rehabilitation.

Conclusion:

Watson-Jones avulsion fractures, although rare, can be managed successfully. Athletes can achieve a successful return to play at their previous level.

Keywords:

Rehabilitation, tibial avulsion, academy football, Watson-Jones

INTRODUCTION

Avulsion type injuries of the proximal tibia are uncommon, with the incidence being from 0.6% to 2.1% of all physeal injuries[1]. It has been proposed that the anatomy of the proximal tibia reduces the risk of avulsion because the shape of the tubercle acts as a block, preventing posterior disarticulation[1]. A secondary ossification centre develops in the tibial tuberosity, -the tuberosity develops in traction, closure of the proximal tibial growth plate extends distally towards the tibial tubercle apophysis, which fuses lastly[2]. This may place greater mechanical strain on the tubercle; potentially predisposing it to injury[3].

It is reported that proximal tibial avulsion fractures occur more frequently in adolescent males, who are both athletic and muscular[4]. Physiologic physiodesis occurs at a later age in males, which can place the tubercle at greater risk of injury[5]. This, combined with males being larger, heavier with stronger quadriceps, places greater strain through the tibial tubercle, which may predispose to avulsion type injury[4].

Two main mechanisms of injury have been identified as causing acute displacement of the tibial tubercle[6]. The first is sudden concentric contraction of the knee's extensor mechanism, with significant force, .e.g. jumping. The second is due to flexion of the knee whilst the quadriceps eccentrically contract under force, .e.g. landing after a jump or sudden deceleration.

Whilst most injuries in elite academy soccer are non-contact, muscular, and occur in the U15 and U18 groups, in the anterior thigh and in training[7], the two cases described in this case study sustained a Watson-Jones proximal tibial avulsion injury[8], through quadriceps eccentric contraction with knee flexion, whilst decelerating, during match play. The two injuries occurred in a Category 1 football academy, in the same season, within a six-month period.

The aim of this report was to describe the injury mechanism, management and outcomes for two cases of Watson-Jones proximal tibial avulsion injuries with the hope of better informing clinicians should they encounter this type of injury. The report has been written using the CARE guidelines[9]. Written consent was ~~gained~~ obtained from the parents.

PATIENT INFORMATION

The two males in the case study are referred to as player A and player B.

Player A (Age: 15 yrs):

Past medical history:

No significant injury history to the injured knee. Prior arthroscopic removal of a loose body to the uninjured knee. Hypermobile score on the Beighton Scale[10], with bilateral genu recurvatum, both pre and post-surgery. Asymptomatic prior to injury.

Injury mechanism and surgery:

The injury was sustained ~~The injury took place~~ within the first quarter of the season~~.~~ to the non-dominant leg during match play, whilst decelerating to control a pass. It was classed as a grade III Watson-Jones proximal left tibial avulsion injury, with two bony fragments avulsed from his tibial tuberosity (Fig. 1). No concomitant intra-articular injury occurred at the time. The knee was immobilised in a full leg plaster of paris, non-weight bearing, whilst awaiting surgery. Open reduction internal fixation was completed within one week of sustaining the injury, using cannulated screws. The metalwork remains in situ. ~~The injury took place within the first quarter of the season.~~

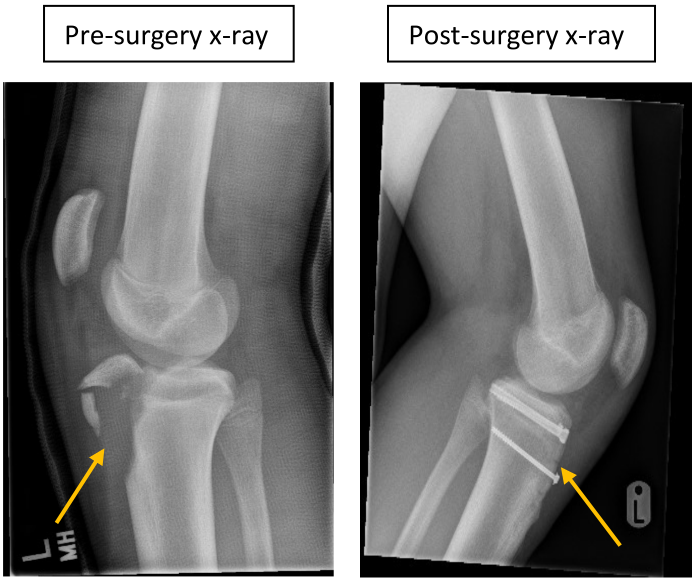

Figure 1. Player A pre- and post-surgery lateral x-rays of the left proximal tibial avulsion injury.

Player B (Age 14 yrs):

Past medical history:

Player B had a significant injury history, with previous patella dislocation bilaterally and Osgood-Schlatter disease in his injured knee. Hypermobile score on the Beighton Scale[10] with bilateral genu recurvatum, both pre and post-surgery.

Injury mechanism and surgery:

The injury was sustained ~~The injury took place with~~in the third quarter of the season~~.~~ to the non-dominant leg when decelerating to strike a ball. Two bony fragments avulsed and a grade IV Watson-Jones proximal right tibial avulsion injury was sustained[11]. One of the bony fragments had avulsed and rotated through his growth plate on the tibial plateau, the other avulsed fragment was completely detached along with his patellar tendon (Fig. 2). No concomitant intra-articular injuries were sustained at the time.

Player B was immobilised in a cricket pad splint and placed non-weight bearing prior to surgery. Surgery involved fixating the avulsed bony fragments with two Fixo screws and tension band K-wire. The two Fixo screws and tension band K-wire were removed fourteen weeks post-surgery in order to avoid premature closure of his tibial growth plate. ~~The injury took place within the third quarter of the season.~~

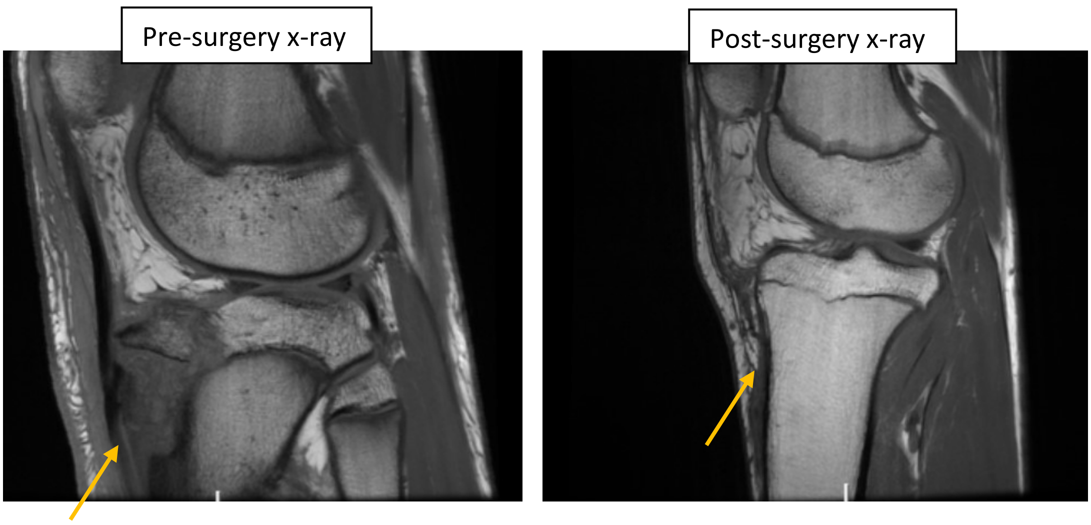

Figure 2. Player B pre- and post-surgery lateral MRI scans of the right proximal tibial avulsion injury

Post-surgical management and rehabilitation:

Due to the rarity of Watson-Jones proximal tibial avulsion injuries, objective markers were taken from the more abundant, high quality anterior cruciate ligament reconstruction (ACLR) literature [12-14]. This literature was chosen as both injuries involve the same joint and testing. In line with ACLR literature, for each objective criterion, rehabilitation was progressed when the limb symmetry index was within 10% [12-154, Logerstedt et al 2014].

Player A:

Immediately post-surgery:

Player A remained non-weight bearing for the first five weeks post-surgery and then progressed to full weight bearing in line with the surgeon's protocol (Table 1). A hinged knee brace was worn for nine weeks to protect the knee. The brace was initially fixed at zero degrees, and increased by thirty degrees at each review with the treating surgeon. Reviews took place at weeks four, five and seven post-surgery.

4 weeks post-surgery:

Rehabilitation commenced under guidance from the surgeon from four weeks post-surgery. Rehabilitation started with isometric co-contraction of the quadriceps and hamstring muscles. Range of motion (ROM) 0-30 degrees.

7 weeks post-surgery:

Body weight bilateral loading was started from seven weeks post-surgery. Knee brace ROM 0-90 degrees, which enabled retraining of squat movements.

10 weeks post-surgery:

Knee brace removed and resistance work started. The treating surgeon deemed that sufficient physiological healing had taken place. Player A had achieved full active knee ROM. Unilateral loading patterns were achieved by week 12 post-surgery.

13 weeks post-surgery:

From week thirteen post-surgery, player A was discharged by the surgeon and could progress loading as able. Rehabilitation was progressed from unilateral closed kinetic chain exercises to open chain exercises and plyometric preparation. Resistance training allowed a progression between body weight and plyometric type exercise, it is a safe and effective means of improving motor performance, such as running and jumping, in youth athletes [(16 Behringer et al 2011]). It has also shown to increase bone mineral density, particularly during adolescence, along with potentially assisting in injury reduction when incorporated into a multifaceted training programme ([17-19Lloyd et al 2014, Faigenbaum and Myer 2009, Lloyd and Oliver 2012)].

Plyometric exercises were supplemented through the VertiMax vertical jump and speed training system (VertiMax Inc, Tampa, Florida, USA). VertiMax facilitated particularly eccentric loading of the quadriceps complex and force dissipation during landing mechanics [(20-22Rhea et al 2008, Yuksel et al 2019, Rhea et al 2008)]. This was particularly pertinent due the mechanism of injury and seeking to address injury reduction strategies during rehabilitation.

Through an integrated training programme, Player A was then able to progress to pitch based rehabilitation. Alter-G (Alter-G, Fremont, California, USA) anti-gravity running was employed prior to running on grass. This enabled running load to be below full body weight and effective graduation of load and progression to outdoor running.

19 weeks post-surgery:

Pitch based rehabilitation commenced at week 19 as sufficient objective markers had been reached in the gym. The setting of objective markers limited any strength deficits and enabled player A to return to play as safely as possible.

Endurance markers, i.e. specific movements to failure, were measured using capacity tests. Calf raises, bridge and leg press (10 repetition maximum, targeting twice body weight) were utilised in order to assess capacity and strength[12]. Muscle bulk, quadriceps circumference 20cm proximal to the tibial tuberosity and calf circumference 10cm distal to the tibial tuberosity was measured throughout rehabilitation. Hop tests were used to determine progressions of outdoor rehabilitation[13]. Player A achieved a 90% limb-symmetry index compared to his non-injured limb in all measures taken[14]; enabling a safe return (Table 2).

Pitch-based drills were progressed from straight line, through to predictable change of direction. Agility drills and position specific fatigue drills were completed prior to return to training. Care was taken to ensure that player A did not have an adverse reaction to load during rehabilitation; through ensuring player A's objective markers of swelling, ROM and strength did not regress.

24 -32 weeks post-surgery

A phased return to training was completed at 24 weeks and full return to play at 32 weeks. This was achieved through progressing training from non-contact to full contact and increasing training time; return to play was increased in increments of twenty minutes of playing time until player A completed a full match.

Player B:

Immediately post-surgery:

In line with the post-surgery protocol set by the surgeon, player B employed reduced weight bearing for eight weeks; initially non-weight bearing for two weeks, toe touch weight bearing from week two post-surgery, partial weight bearing from seven weeks, and then full weight bearing at eight weeks after surgery (Table 1). Player B used a hinged knee brace for 14 weeks post-surgery, initially set at zero degrees for the first seven weeks post-surgery.

7 weeks post-surgery:

The brace was set at 30 to 40 degrees of flexion only from week seven, limiting player B's knee movement to ten degrees only. At weekly intervals, knee brace ROM increased by ten degrees. It was initially increased into flexion one week, then extension the following week. For example, at week eight, the knee brace was set at 30 to 50 degrees, then increased at week nine to 20 to 50 degrees. Initial co-contraction work began from week seven.

14 weeks post-surgery:

At week 14 post-surgery the knee brace was set at zero to 80 degrees. The two inferior Fixo screws and a tension band K-wire were removed to reduce the chance of growth plate disruption in the proximal tibia. From this point there was unrestricted weight bearing and ROM. Isometric body weight exercises were started at week 14, once player B could weight bear fully. Loaded bilateral exercises were completed at week 15, followed by loaded unilateral exercises at week 16. Full active knee ROM was achieved by week 17.

21 weeks post-surgery:

Early plyometric preparation was achieved by week 21, supplemented by the VertiMax and enabled progression to Alter-G anti-gravity treadmill at week 23 in order to graduate and progress running load.

25 weeks post-surgery:

Outdoor running drills began at week 25. Objective markers were taken prior to running outdoors to enable safe transition to pitch based rehabilitation. Markers took the form of capacity tests, leg press ten-repetition maximum and hop tests[13]. Muscle bulk was also measured periodically throughout rehabilitation. Objective markers (Table 2) were achieved within a 90% limb symmetry index, which facilitated a progression to pitch based rehabilitation for player B[14].

Running drills began with straight line, followed by predictable change of direction with gradual increases in angles of directional change. Agility drills and position specific fatigue drills were utilised prior to phasing player B back into training. Again, the player was closely monitored in case of any adverse events following completion of each rehabilitation stage.

30-38 weeks post-surgery:

Player B completed a phased return to training at thirty weeks and full return to play at thirty-eight weeks post-surgery. Player B achieved this through increasing training time and progressing training from non-contact to full contact; return to play was increased in increments of twenty minutes of playing time until player B completed a full match.

Table 1. Rehabilitation timelines for player A and player B with milestones.

Milestone	Player A	Player B

	Weeks post injury	Weeks post injury
Surgery	1	1
Protected weight bearing	0-5	0-8
Full weight bearing	5	8
Discontinued use of hinged knee brace	9	15
Removal of metal work	Not applicable	15
Alter-G anti-gravity treadmill	16	23
Pitch based rehabilitation	19	25
Phased return to training	24	30
Full return to play	32	38

Table 2. Objective markers for players A & B, with final scores achieved prior to return to training and match play.

	Player A			**Player B**		
Objective Marker	Left	Right	Limb Symmetry Index	Left	Right	Limb Symmetry Index
Bridge capacity*	30	31	97%	49	55	112%
Calf capacity*	25	25	100%	34	35	103%
Leg press [ten repetition maximum]	150kg	160kg	94%	150kg	150kg	100%
Triple crossover hop test	5.5m	5.8m	95%	6.1m	6.0m	98%
Quadriceps bulk post injury						
3 months	43.5	47.5	92%	52.5	46.5	89%
4 months	45.5	47.5	96%	53	50	94%
5 months	48.5	49.5	98%	53.5	52.5	98%

Comparison of Injured Players Versus Premier League Academy Average and Best Scores

Measures of speed, agility and power were collected and compared with average and best scores for other Premier League academies. Both players scored equal to, or higher, on all average test scores when assessing speed, agility and power. Data were obtained from the Premier League Performance Management Application[23~~15~~].

Growth and Maturation

Player growth and maturation was measured at regular intervals; every three to four months. Peak height velocity (PHV) is defined as the period of maximal rate of growth during puberty [24~~16~~]. It was used to determine growth and maturation measured in years from PHV. Injury risk is reported to increase as an athlete approaches, reaches and then surpasses their PHV[24~~16~~].

Player A was 1.3 years past his PHV, but still deemed to be in a maturation status, which needed to be monitored following injury. Player B was 0.2 years past PHV following injury, close monitoring of growth, maturation and load was required (Table 3).

Table 3. Maturation status in the months pre and post injury.

Months pre and post injury	Player A Years from PHV	Player B Years from PHV
-7	+0.9	-0.2
-5	+1.1	-0.1
-2	+1.2	+0.2
+1	+1.6	+0.4
+4		+0.7
+7		+1.0

+10		+1.4
+14	+1.8	+1.5

Key:

= Growth spurt anytime

= Monitor

DISCUSSION

This case series described the management and outcome of two elite academy footballers who sustained a Watson-Jones proximal tibial avulsion injury to better inform practice, enhancing the current literature base, and acting as a platform for enabling further studies to be completed in the future[25~~17~~].

Injury incidence is reported as higher during PHV~~-~~[4, 26~~18~~, 27~~19~~, 28~~0~~], especially compared to pre-PHV[29~~1~~]. Some state the effects of maturity status and timing on injury risk is unclear and requires further research[26~~18~~]. Both players in this study were early maturers, with above average physical qualities. Player A had surpassed his PHV at time of injury, but was deemed to be in a maturation period where close monitoring was required. Player B was within one year of PHV and therefore going through a growth spurt at his time of injury.

Reported risk factors of injury in football include ≥ 0.6 centimetre growth per month, ≥ 0.3 kg/m2 increase of body mass index value per month, and < 7% low fat percentage for players aged 11–16[27~~19~~]. During maturation, there is also a temporary vulnerability of bodily tissues including muscle-tendon junctions, bone-tendon junctions[25~~17~~] and decreased bone density~~-~~[30~~22~~, 31~~23~~]. Another possible risk factor identified from the cases include Osgood-Schlatter disease[2]. Only player B had a history of Osgood-Schlatter disease and due to the rarity of the injury, data to support this hypothesis are not available.

Both players showed generalised hypermobility using the Beighton Scale measure[10], demonstrating hypermobility in knee joints bilaterally with genu recurvatum. Hypermobility is a risk factor particularly for knee injuries and in contact sports[(32Pacey et al 2010)]. Elite soccer players with hypermobility have an increased incidence of injury, and consequently, increased lost playing time [(33Konopinski et al 2012])). Within footballing populations, rates of hypermobility are comparable to the general population; despite this, footballers with generalised hypermobility require more time to rehabilitate to reduce the risk of reinjury [(34] Collinge and Simmonds 2009). However, without sufficient surveillance data for this type of injury, it is not possible to infer causation between hypermobility and tibial avulsion fracture.

Timing of injury within the season could present as a risk factor. Injuries took place in the first and third quarter of the season. Football injuries in elite players occur more frequently during match play[(35Wong and Hong 2005)] and during periods of increased load and fixture congestion[(36Dellal et al 2015])). Both injuries were sustained during match play. Player A would have experienced a period of increased load during preseason, prior to the first quarter, but for player B, there was no significant change in load prior to injury. Again, there are no data to support increased risk of Watson-Jones proximal tibial avulsion injuries and time of season.

A lack of guiding literature for tibial avulsion fractures meant that rehabilitation was adapted from ACLR protocols found in high quality literature~~-~~[13, -14]~~].~~. This enabled players to safely progress through objective markers to prevent strain on their surgery sites whilst achieving the goal of a limb symmetry index of ≥90 percent[12-14]. Between limb asymmetries of more than 10 to 15% are considered significant in knee injuries [15]; thus in the elite environment players were only progressed once the objective criterion of <10% between limb asymmetry was achieved[13, 14], enabling safe and progressive rehabilitation. Post-surgery advice was strictly followed and neither player had a critical incident during their rehabilitation.

Knee ROM, pain and swelling was able to be monitored daily to detect any adverse reactions to the rehabilitation. Swelling was initially monitored through the patellar tap test, followed by the sweep test for the duration of rehabilitation. Both effusion measures have been shown to be reliable for a variety of knee pathologies[~~(~~37, 38~~Lee, Khan and Anand 2014, Sturgill et al 200~~]~~9)~~. ROM and reported pain are also known to be reliable measures in knee injuries [~~(~~37, 39~~Lamb and Guy 2016, Lee, Khan and Anand 2014)~~]. ~~Players were progressed once objective criteria were achieved[13, 14], enabling safe and progressive rehabilitation. Between limb asymmetries of more than 10 to 15% are considered significant in knee injuries (Logerstedt et al 2015).~~ Daily monitoring to determine if recovery was progressing, unchanged, or regressing was key; consequently, rehabilitation could be modified if required. Recovery of both players followed similar timescales to previously published literature on the same injury[2, 4].

These two cases have demonstrated that elite adolescent footballers can successfully return to play and compete at their pre-injury level after sustaining a Watson-Jones proximal tibial avulsion injury. Following rehabilitation, both players equalled or bettered their pre-injury test scores in relation to speed~~,~~ and power, and player A bettered pre-injury agility scores. ~~Furthermore~~Subsequently, both players were ~~subsequently~~ offered professional contracts, thus validating the objective markers of physical qualities and reinforcing their technical qualities on the football pitch.

The strengths of this case study are: daily monitoring and rehabilitation of the players due to injury occurrence whilst in a Category 1 football academy; joined up record keeping as the physiotherapist was present throughout both cases from injury through to return to match play. Finally, this is a unique case report, whilst Watson-Jones tibial avulsions are rare; it is even rarer to experience two injuries in the same season.

A limitation of the case report is that training and match play exposure was~~is~~ not available for the two players. These~~is~~ data were~~as~~ not routinely recorded at the time of injury.

Future case studies for this type of injury and management would be beneficial to add to the current body of evidence. Specific areas for development are risk factors for injury and effect of specific modes of rehabilitation such as blood flow restriction therapy.

CONCLUSION

For elite academy football players, sustaining a Watson-Jones proximal tibial avulsion injury, whilst rare and serious, is not career ending. Through applying the fundamental principles of healing and graduated load, recovery can take up to 38 weeks. No two injuries are the same, especially when they occur during periods of physical growth, which is non-uniform. The injured growth plates may be at differing points of maturation, which possibly require different surgical and rehabilitative management. Clinicians are encouraged to publish case reports of similar injuries to increase the evidence base.

Highlights

- Watson-Jones proximal tibial avulsion injuries are rare and atypical.
- Elite academy footballers can successfully return to match fitness following this injury.
- Clinicians are encouraged to publish case reports of similar injuries to increase the evidence base and understanding.

PPI STATEMENT

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

REFERENCES

1. Mubarak SJ, Kim JR, Edmonds EW, Pring ME and Bastrom TP. Classification of proximal tibial fractures in children. J Child Orthop2009:3:191-197.

2. Frey S, Hosalkar H, Cameron DB, Heath A, Horn BD. and Ganley TJ. Tibial tuberosity fractures in adolescents. J Child Orthop2008;2:469-474.

3. Stavrakakis IM, Katsoulis PE and Katsafarou M. Proximal tibial epiphysis fracture in a 13-year-old male athlete. Case Rep Orthop2017;6:1-4.

4. Hamilton SW. and Gibson PH. Simultaneous bilateral avulsion fractures of the tibial tuberosity in adolescence: a case report and review of over 50 years of literature. Knee2006;13:404-407.

5. Chitkara P, Anne R, Lavianlivi S, Lehto S. and Kolla S. Imaging review of adolescent tibial tuberosity fractures. Open J Med Imaging2013;3:90-96.

6. Mosier SM and Stanitski CL. (2004) Acute tibial tubercle avulsion fractures. J Pediatr Orthop2004;24:2:181-184.

7. Renshaw A. and Goodwin PC. Injury incidence in a Premier League youth soccer academy using the consensus statement: a prospective cohort study. BMJ Open Sport Exerc Med2016;26:2:1-6.

8. Watson-Jones R. Fractures and Joint Injuries 4th Ed, Baltimore MD: Williams & Williams 1955.

9. Gagnier JJ, Kienle G, Altman DG, Moher D, Sox H and Riley D. The CARE Guidelines: consensus-based clinical case reporting guideline development. J Med Case Rep,2013;7:1:223.

10. Smits-Eng B, Klerks M, Kirby A. Beighton Score: A Valid Measure for Generalized Hypermobility in Children. J Pediatr2010;158:1:119-23.

11. Ryu RK and Debenham JO. An unusual avulsion fracture of the proximal tibial epiphysis. Case report and proposed addition to the Watson-Jones classification. Clin Orthop Relat Res1985;194:181-184.

12. Neeter C, Gustavsson A, Thomee A, Augustsson J, Thomee R and Karlsson J. Development of a strength battery for evaluating leg muscle power after anterior cruciate ligament injury and reconstruction. Knee Surg Sport Traumatol Arthrosc2006;14:6:571-580.

13. Reid A, Birmingham TB, Stratford PW, Alcock GK. and Giffin RJ. Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. Phys Ther2007:87:337-349.

14. Rohman E, Steubs JT and Tompkins M. Changes in involved and uninvolved limb function during rehabilitation during rehabilitation after anterior cruciate ligament reconstruction: implications for limb symmetry index measures. Am J Sport Med2015;43:6:1391-1398.

15. Logerstedt D, Arundale A, Lynch A, Snyder-Mackler L. A conceptual framework for a sports knee injury performance profile (SKIPP) and return to activity criteria (RTAC). Braz J Phys Ther. http://dx.doi.org/10.1590/bjpt-rbf.2014.0116

16. Behringer M, vom Heede A, Matthews M, and Mester J. Effects of strength training on motor performance skills in children and adolescents: a meta-analysis. Pediatric Exercise Sci2011:23;186-206.

17. Lloyd RS, Faigenbaum AD, Stone MH, Oliver JL, Jeffreys I, Moody JA, Brewer C, Pierce KC, McCambridge TM, Howard R, Herrington L, Hainline B, Micheli LJ, Jaques R, Kraemer WJ, McBride MG, Best TM, Chu DA, Alvar BA, and Myer GD. Position statement on youth resistance training: the 2014 International Consensus. Br J Sports Med2014:48;498-505.

18. Faigenbaum A, and Myer G. Resistance training among young athletes: safety, efficacy and injury prevention effects. Br J Sports Med2009:44;56-63.

19. Lloyd RS, and Oliver JL. The youth physical development model: a new approach to long-term athletic development. Strength Cond J2012:34;3;61-72.

20. Rhea MR, Peterson MD, Lunt KT, and Ayllon FN. The effectiveness of resisted jump training on the VertiMax in high school athletes. J Strength Cond Res2008a:3;731-734.

21. Rhea MR, Peterson MD, Oliverson JR, Ayllon FN, and Potenziano BJ. An examination of training on the VertiMax resisted jumping device for improvements in lower body power in highly trained college athletes. J Strength Cond Res2008b:22;3;735-740.

22. Yuksel O, Erzeybek MS, Kaya F, and Kirazci S. Investigation of the effect of VertiMax V8 elastic resistance platform and classic strength training on dynamic balance in basketball players. J Educ Learning2019:8;2;188-197.

23. English Premier League, Elite Player Performance Plan (https://www.premierleague.com/youth/elite-performance) (Accessed December 2019).

24. Malina RM, Bouchard C, and Bar-Or O. Growth, maturation, and physical activity. Champaign, IL: Human Kinetics2004.

25. van der Sluis A, Elferink-Gemser MT, Brink MS and Visscher C. Importance of Peak Height Velocity Timing in Terms of Injuries in Talented Soccer Players. Int J Sport Med2015;36:4:327-332.

26. Swain M, Kamper SJ, Maher CG, Broderick C, McKay D, and Henschke N. Relationship between growth, maturation and musculoskeletal conditions in adolescents: A systematic review. Br J Sport Med2018;doi: 10.1136/bjsports-2017-098418

27. Spriestersbach A, Rohrig B, du Prel JP, Gerhold-Ay A. and Blettner M. ‘Descriptive Statistics. The specification of statistical measures and their presentation in tables and graphs. Deutsch Arzteblatt Int2009;106:36: 578-583.

28. Kemper GLJ, van der Sluis A, Brink MS, Visscher C, Frencken WGP and Elferink-Gemser MT. Anthropometric injury risk factors in elite-standard youth soccer. Int J Sport Med2015;36:13:1112-1117.

29. Johnson DM, Williams S, Bradley S, Sayer, Murray Fisher J, Cummings S. Growing pains: Maturity associated variation in injury risk in academy football. Eur J Sport Sci2019:doi.org/10.1080/17461391.2019.1633416.

30. Faulkner RA, Davison KS, Bailey DA, Mirwald RL, and Baxter-Jones AD. Size-corrected BMD decreases during peak linear growth: Implications for fracture incidence during adolescence. J Bone Mineral Res2006:21;12;1864–1870. doi: 10.1359/jbmr.060907

31. Blimkie C, Lefevre J, Beunen GP, Renson R, Dequeker J, and Van PD. Fractures, physical activity, and growth velocity in adolescent Belgian boys. Med Sci Sport Exercise1993:25;7;801–808.

32. Pacey V, Nicholson LL, Adams RD, Munn J, and Munns CF. Generalized joint hypermobility and risk of lower limb joint injury during sport: a systematic review with meta-analysis. Am J of Sp Med2010:38;7;1487-1497.

33. Konopinski MD, Jones GJ, and Johnson MI. The effect of hypermobility on the incidence of injuries in elite-level professional soccer players: a cohort study. Am J Sp Med2012:40;4;763-769.

34. Collinge R, and Simmonds JV. Hypermobility, injury rate and rehabilitation in a professional football squad – a preliminary study. Phys Ther Sport2009:10;3;91-96.

35. Wong P, and Hong Y. Soccer injury in the lower extremities. Br J Sports Med2005:39;473-482.

36. Dellal A, Lago-Penas C, Rey, E, Chamari K, and Orhant E. The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. Br J Sports Med2015:49;390-394.

37. Lee LH, Khan MNB, and Anand, S. Acute soft tissue knee injuries. InnovAiT2014:7;7;428-436.

38. Sturgill LP, Snyder-Mackler L, Manal TJ, and Axe MJ. Interrater reliability of a clinical scale to assess knee joint effusion. J Orthop Sports Phys Ther2009:39;12;845-849.

39. Lamb JN, and Guy SP. Soft tissue knee injuries. Surgery2016:34;9;453-459.