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Abstract

Background: Hundreds of thousands of anterior cruciate ligament (ACL) injuries occur every year, thousands of which are combination injuries with damage to multiple ligaments. Despite advances in surgical and rehabilitative interventions the rate of reinjury in this patient population remains high. While there is a growing amount of return to sport guidelines being published in the literature, there lacks a consensus on which is best. The purpose of this case study was to investigate the use of clinical movement screening tests to assess the return to sport readiness of a patient with a multi-ligament knee injury. **Case Description:** The patient was a 17-year-old male soccer player who sustained ACL, medial collateral ligament (MCL) and meniscus tears due to a contact injury while playing football. The patient underwent surgery for ACL reconstruction, MCL reconstruction and meniscal repair. The patient worked with therapy for over 12 months with an extended return to sport phase focused on functional strengthening, plyometrics, agility and neuromuscular training. **Outcome Assessments:** The move2perform tool was utilized, which combines the results of the Functional Movement Screen, the Lower Quarter Y Balance Test and Functional Hop Testing to assess risk of future injury. A checklist developed by the clinic to test neuromuscular control was also used. **Discussion:** This case report describes the effectiveness of using a combination of multiple movement screening tests to assist with guiding interventions and return to sport decision making. Research studies evaluating the validity of these movement screens to assess the risk of future injury show mixed results. Future research studies should investigate the validity of movement screens to specifically assess risk of reinjury in patients with multi-ligament knee injuries.

Background

An 'unhappy' or 'terrible' triad injury, originally termed by O'Donoghue in the 1950's, has traditionally been described as the combination of a ruptured anterior cruciate ligament (ACL), ruptured medical collateral ligament (MCL), and damage to the medial meniscus [1]. While it's debated whether the medial or lateral meniscus is more often damaged with this combination injury [2], it is evident that injuries to one or more of these structures are common and costly. The MCL is the most commonly injured ligament of the knee and 78% of grade III MCL injuries have a concomitant ACL injury [3]. The ACL is the most commonly injured ligament that causes pathological changes in knee function, with approximately 350,000 people estimated to have ACL reconstruction (ACLR) surgery each year in the United States [4]. It is likely that at least 40% of ACL injuries have concomitant meniscal damage [5]. These combination injuries are not only debilitating in the short term, but can lead to significant increases in osteoarthritis in the long term [6]. These injuries are also a burden on the healthcare system, with ACL injuries costing over $625 million annually [7].

Despite appropriate surgical and rehabilitation efforts, there are high rates of reinjury with ACL tears. In a meta-analysis and systematic review, Wiggins et al found a 15% ACL reinjury rate (7% in the ipsilateral leg, 8% in the contralateral) in the general population and a 21% reinjury rate (10% ipsilateral, 11% contralateral) in those under 25 [7]. For young athletes under the age of 25 returning to high-risk sports the reinjury rate is as high as 23%, which would be approximately 30-40 times greater risk than uninjured young athletes [7]. While there is a lack of data on the reinjury rate of multi-ligament injuries, one study found that only 70.8% of NFL players returned to sport after a combination ACL/MCL injury [8].

While there is a growing amount of return to sport (RTS) guidelines being published in the literature, there lacks a consensus on which is best. Many physicians continue to clear patients for sport based purely on time from surgery or personal experience [7]. A recent review found that out of 260 studies discussing RTS, 40% only had post-operative time as a RTS criteria and only 13% focused on objective criteria [9]. Recent research suggests that successful RTS relies on many different criteria including time, objective and subjective benchmarks. One category of objective benchmarks used to predict risk of injury that has gained popularity includes movement screens such as the Y-balance test, the Functional Movement Screen and hop testing. These movement screens are clinician friendly, cost-effective and can help detect neuromuscular deficits in patients. The reliability and effectiveness of such screens to predict sport injury has been debated. The purpose of this case study was to investigate the use of clinical movement screens to guide the RTS decision making in a patient with an ACL, MCL and meniscus repair.

Case Description

Patient History

The patient was a 17-year-old adolescent male who sustained ACL, MCL and meniscus tears due to a contact injury while playing football. The patient underwent surgery 21 days after injury for ACL reconstruction (bone patellar bone graft), MCL reconstruction and meniscal repair. The patient presented to physical therapy 4 days after surgery. The patient was required to wear knee brace for 6 weeks after surgery. The knee brace was locked in full extension with weight bearing and could be opened to 90 degrees of flexion during open chain exercises. Prior to injury, the patient played multiple sports including football and soccer. The patient was in good health and had no co-morbidities. The patient had a supportive family and social group. The patient had a previous partial PCL tear that is now more damaged after current injury. He was instructed to stay in knee immobilizer at 0-90 degrees for first 6 weeks after surgery. He had a long-term goal of returning to competitive soccer in one year in order to play in college.

Systems Review

The patient's musculoskeletal system was impaired due to gross range of motion (ROM) and strength impairment of R lower extremity (LE) post-surgery. The R quadriceps had atrophy and poor activation. The cardiovascular/pulmonary systems were not impaired. The neuromuscular system findings include mild decreased light touch around incision site and altered gait due to limited weight-bearing and crutches. Integumentary system impaired due to swelling and ecchymosis in R LE. The incision site had no signs of infection and appeared clean and dry. The patient was pleasant, cooperative and spoke English. The patient was alert, oriented, his cognition was intact and he had no learning barriers.

Clinical Impression 1

There were no differential diagnoses as the diagnosis was established prior to therapy and was consistent with the injury, imaging and surgical repair. His presentation of joint effusion, limited range of motion and reduced quadriceps strength was as expected for his surgical intervention. The patient was a good candidate for therapy because he was a healthy adolescent who was motivated. The patient was a good candidate for this case report and clinical movement screening because of his high risk of reinjury and his desire to return to a high risk competitive sport. Examination will focus on strength, balance and LE stability in order to determine when the patient will be safe to perform movement screens and if he has functional limitations that warrant their use.

Examination

During the initial examination, the patient completed a Lower Extremity Functional Scale (LEFS). The LEFS is a questionnaire containing 20 questions about a person's ability to perform everyday tasks. The LEFS evaluates the level of impairment in patients with lower extremity musculoskeletal conditions and is scored from 0-80 with lower scores representing higher disability levels. For ACLR patients the MCID is 9, the test has excellent interrater/intrarater reliability (ICC = .90) as well as test/retest reliability [10]. The patient's score was a 20. The patient reported moderate pain (4/10 on Numeric Rating Scale). The patient demonstrated a weak quad set and was unable to lift leg without assistance. The patient's knee ROM was evaluated using goniometry, which has been shown to be reliable for knee flexion/extension [11]. The patient lacked 5 degrees of extension and only had 30 degrees of flexion. The patient's presentation followed the pattern of most ACL-R cases, therefore it was assumed he would continue to demonstrate functional deficits that would warrant clinical movement screens in the later stages of his rehab.

Three months after surgery the patient was re-examined to see if movement screening was still appropriate. At this point the patient demonstrated no pain at rest, but the patient would still get soreness after activity that could raise his pain level to 2/10. The patient's LEFS score was a 62 (22.5% impaired). He was full weight bearing, but would still wear the brace during activity. The patient still lacked 1 degree of full active knee extension, but had 136 degrees of knee flexion. The patient still had low grade swelling in the R knee (2.5cm). The patient's hip and knee strength was evaluated using dynamometry. Dynamometry has been shown to have good-excellent reliability, but results can be affected by the tester's gender, body weight and grip strength [12-15]. Studies have suggested that less than a 10% difference in quadriceps strength should be the goal after ACLR [16]. The patient's R hip abductors were 5lbs weaker than his L and the patient's knee extensors were 25lbs weaker than L. The patient was safely able to perform single leg strengthening exercises and low level sagittal plyometric exercises with R leg.

Clinical Impression 2

Based on the examination data, the patient was a good candidate for clinical movement screens 3 months post-surgically. Since the patient had minimal pain, close to full range of motion, only small amounts of joint effusion, 70% strength symmetry and the ability to perform light plyometrics without pain the patient was deemed safe to initiate clinical movement screens. While the patient was demonstrating increased levels of control with his R LE, clinical movement screens were needed at this point to expose impairments in the patient's overall strength, neuromuscular control and balance. The results of the movement screens will demonstrate the patient's RTS readiness as well as demonstrate specific deficits that will need to be addressed in the plan of care.

Outcome Assessments

Move2perform

The move2perform software was used to assess the patient's limitations and risk of reinjury. The move2perform is an algorithm that places the patient into one of 4 risk categories (optimal, slight deficit, moderate deficit, substantial deficit). The algorithm combines the patient's scores from the Lower Quarter Y Balance Test (YBT-LQ) and the Functional Movement Screen (FMS) with demographic risk factors such as previous injury, age, gender, pain and sport. In a 2013 study, Lehr et al performed the algorithm on 183 collegiate athletes. 61% of the athletes in the substantial deficit category suffered an injury. The percentage of athletes injured in the moderate, slight and optimal categories were 30%, 16% and 0% respectively [17].

The first component of the move2perform is the YBT-LQ. The YBT-LQ tests the patient's stability and dynamic balance by having the patient maintain single-limb stance control while the other leg reaches as far as possible in the anterior, posteromedial or posterolateral direction. The patient must then return to the starting position without any loss of balance. The patient performs 6 practice trials and then performs 3 test trials. The longest test trial is recorded. Two outcomes can be taken from the YBT-LQ: a composite score and a right/left asymmetry score. The composite score is a percentage that is calculated by averaging the 3 reach directions and dividing by the limb length. Right/left asymmetry can be calculated for all three directions by calculating the difference between the distances achieved with the R and L LE. A composite score of less than 95% and an anterior reach asymmetry of more than 4cm is correlated with increased injury risk [18]. The YBT-LQ has been shown to have good inter-rater and intra-rater reliability [19]. The minimally clinical important difference for the YBT-LQ composite score is 3.5% [20].

The next component of the move2perform is the FMS. The FMS contains 7 fundamental movement patterns that requires the patient to have good mobility and stability to perform successfully. The movement patterns purposely place the patient into extreme positions that exposes any imbalances, asymmetries, strength deficits, motor control deficits or balance deficits the patient may have. The FMS then gives corrective exercises the patient can perform to normalize the patient's movement patterns. The 7 movement patterns are a deep squat, hurdle step, in-line lunge, supine active straight-leg raise, trunk stability push-up, quadruped rotary stability, and shoulder mobility (similar to Apley's Scratch Test). The 7 movements are scored from 0-3 points, giving a total score range of 0-21 points. A score of 3 points means the patient can perform the movement, 2 points means the patient can perform the movement with compensation, 1 point means the patient can't perform the movement, and 0 points means the patient had pain with the movement. A cut off score of 14 or less has been shown to be a predictor of serious injury [21]. Multiple studies have demonstrated good inter- and intra-rater reliability for the FMS [22]. An MCID of 1.25 has been established for total FMS score [22]. The YBT-LQ and FMS were first tested on the patient 3 months post-surgically and were retested periodically during the rest of the patient's rehab.

Functional hop testing is another measurement within the move2perform to assess asymmetries in motor control, strength and power between the patient's two LE's. The hop testing for distance includes a single leg single hop, a single leg triple hop, and a single leg crossover hop where the patient crosses over a tape measure with each consecutive hop. The patient performs 3 practice trials of each test and then 3 test trials are performed. The three trials are then averaged. A limb symmetry index (LSI) (percentage value of 1 limb vs. the other) is used to quantify any asymmetry between R and L LE. An LSI of >=90% has been suggested in literature as a cut-off score and is used in the move2perform software [23]. In the clinic, a goal of 95% LSI is used for patients. The test-retest reliability for the 3 tests are shown to be good (0.8-0.93 ICC) [23,24]. The minimal detectable change for single hop is 21.81% of leg length. For triple hop it is 47.59% of leg length and triple crossover hop is 58.65% [23].

Neuromuscular Control Checklist

The final movement screen performed was a checklist developed in the clinic to test the patient's neuromuscular control while performing a variety of movements. The checklist is based off a clinical commentary done by Stasi et al detailing 11 neuromuscular training exercise progressions that target 4 specific deficits often seen in patients post ACL-R [25,32]. The exercises have 4 phases that progress from simpler, unidirectional exercises with a wide base of support to more complex, multidirectional, explosive movements with narrow base of support and added perturbations. These exercises were turned into an outcome measure in the clinic by creating a checklist listing all 4 phases of all 11 exercises. Once the patient successfully completed an exercise it was marked off and dated on the checklist, at which point the patient would then progress to the next phase of the exercise. Since risk of reinjury is high in the contralateral leg as well as ipsilateral leg, these progressions should be done on for both lower extremities. For more specific information on the exercise progressions reference Stasi et al [25].

The first 4 exercises in the checklist tests the ability of the patient to prevent hip internal rotator moments often seen upon landing in post ACLR patients. The exercises require large hip extension/abduction/external rotation moments by requiring the patient to maintain large hip/knee flexion angles while avoiding frontal plane hip movement. Exercise 1 is a single-leg anterior jumping progression that begins with a double leg take off to single leg landing and progresses to multiple single leg hops while controlling the landing in a deep knee/hip flexion position. Exercise 2 is a single-leg lateral jumping progression which starts with lateral hops onto an airex pad progressing to multiple medial-lateral hops onto a BOSU with ball catches. Exercise 3 is a lunge progression starting with a single forward lunge progressing to repeated forward lunges with added weight and trunk twists. Exercise 4 is a tuck jump progression starting with a single tuck jump progressing to multiple consecutive tuck jumps over an object.

The next set of exercises tests the patient's ability to limit frontal plane knee motion often seen to be excessive during landing in post ACLR patients. Exercise 5 is a lateral jump progression that tests this directly by beginning with double leg lateral jumps over an obstacle and progressing to repeated single leg lateral jumps over an obstacle. Exercises 6-8 tests the trunk stability and proprioception needed to control frontal plane movement. Exercise 6 is a lateral trunk stability progression starting with lateral crunches on top of progressively more unstable surfaces with the therapist stabilizing the pelvis and lower extremities. Exercise 7 is a prone trunk stability progression that begins with a swimming motion on a BOSU and progresses to bird-dog and plank exercises. Exercise 8 is a kneeling trunk stability progression starting with kneeling on a BOSU and progressing to the patient kneeling on an exercise ball while performing trunk rotations. The next 2 exercises test hamstring strength and control, which has been seen to assist with frontal plane control. Exercise 9 is a posterior chain progression beginning with bridges with both feet on a BOSU and progresses to straight leg bridges on an exercise ball with hamstring curls. Exercise 10 is a Romanian dead lift (RDL) progression that begins with a single leg RDL on stable ground and progresses to single leg RDL's on a BOSU while holding weight. Exercises 1-4 listed previously also help to assess frontal plane knee control.

The third set of exercises tests the patient's ability to maintain symmetrical sagittal plane knee moments/angles during dynamic activity. This is important because ACL injuries are associated with low knee flexion angles and athletes post ACLR often have asymmetrical knee joint moments. Exercise 11 is a lunge jump progression that tests the ability of the patient to perform dynamic movements with large knee flexion motion and good stability while also requiring functional upright trunk posture and strong knee extensor moments at contact. The progression begins with a single lunge jump and progresses to repeated alternating lunge jumps while holding weights. The tuck jump progression (exercise 4) also tests sagittal plane control. Hamstring strength/activation is also crucial to control sagittal anterior tibial translation motion, which is tested by exercise 9 and 10.

The final deficit to be tested by the checklist is lack of postural stability, which is a risk factor for second ACL injury [25]. The anterior and lateral jumping progressions test postural stability by requiring the patient to hold their deep flexion, single-leg posture once they land. The prone trunk stability progression, kneeling trunk stability progression, and RDL progression tests postural stability by requiring the patient to maintain body position while performing dynamic tasks. The neuromuscular checklist was first used on the patient 8 months post-surgically. It would have been initiated earlier, but the clinic hadn't adopted the assessment yet. Once the assessment was initiated with the patient it was used within most sessions to continually evaluate that patient's progress.

Outcomes

The patient's outcomes from the clinical movement screens performed are seen in Tables 1-4. The tables do not contain data from every session in which the movement screens were preformed due to problems retrieving the data from the software. Table 1 shows results from three times the YBT-LQ was performed. Initially the patient demonstrated significant asymmetries between R and L LE's and the patient had a low R leg composite score, which would be expected at 3 months post-op. At the 8 months post-op mark the patient's R LE was within 4cm of the L LE in all direction, which put the patient above the cut off score for increased injury risk. It wasn't until 10 months post-op, however, that both LE's had a composite score above the 95% cut off score. The patient's composite score increased 23.3% in the RLE and 12% in the LLE, both of which were well above the MCID (3.5%).

Table 1: YBT-LQ Results

Month Post-operative	Composite Score (L/R)	Anterior Reach (L/R); L/R difference	Posteromedial Reach (L/R); L/R difference	Posterolateral Reach (L/R); L/R difference
3 month	89.7%/75%	69cm/56.5cm; 12.5cm	103.5cm/84.5cm; 19cm	97cm/85cm; 12cm
8 month	86.7%/86.4%	**67cm/65cm; 2cm**	**99.5cm/102cm; 2.5cm**	**89cm/87cm; 2cm**
10 month	**98%/98.3%**	76cm/77cm; 1cm	115cm/112cm; 3cm	106cm/109cm; 3cm

Table 2 shows the results of two instances the FMS was performed. At 3 months post-op the patient's total FMS score was below the 14-point cut-off score, indicating he was still at an elevated injury risk. The screen demonstrated the patient's difficulty with LE strength and stability tasks such as squatting and lunging. The patient received a 0 for rotatory stability because of pain experienced with quadruped rocking, which forces the knees into end range flexion. This pain persisted in the 10 month post-op FMS testing, but he was able to score a 15 due to improvements in squatting, lunging and the hurdle step. The score of 15 was above the 14-point cut-off score and demonstrated a clinically important change from month 3 post-op (MCID=1.25).

Table 2: FMS Results

Movement	Score	Movement	Score
Deep Squat	Month 3 PO: 1 Month 10 PO: 2	Active SLR	Month 3 PO: R: 3; L: 3 Month 10 PO: R: 3; L: 3
Hurdle Step	Month 3 PO: L: 2; R: 1 Month 10 PO: L: 3; R: 3	Pushup	Month 3 PO: 3 Month 10 PO: 2
Inline Lunge	Month 3 PO: L: 2; R: 2 Month 10 PO: L: 3; R: 3	Rotary Stability	Month 3 PO: 0 Month 10 PO: 0
Shoulder Mobility	Month 3 PO: L: 2; R: 3 Month 10 PO: L: 2; R: 2	Total	Month 3 PO: 12 **Month 10 PO: 15**

*PO = post-operative

Table 3 shows the results of hop testing, which was the most consistently performed movement screen during the patient's rehab. The patient initially demonstrated lack of power in the R LE as shown by LSI's in the mid 80's through 6 months post-op. By 8 months post-op the patient had achieved the

90% LSI cut-off score for single and triple hop tests. The patient achieved our long term goal of 95% LSI in the triple hop conditions at 8 month post-op and at 9 month post-op in the single hop condition. Despite the general trend of improvements in his LSI scores, there were fluctuations seen in his raw hopping distances. For instance, his single hop distances decreased in the last two sessions measured even though his LSI improved. These fluctuations could be due to a variety of reasons (measurement errors, patient fatigue, etc.) The patient's single hop distance improved by 33% of limb length from initial testing date to final test date, which is above the MDC of 21%. The triple hop improved by 118% of leg length, far exceeding the MDC (48%). The crossover triple hop improved 56% of leg length, just short of the MDC (58%).

Table 3: Hop Testing Results

Month Post-operative	SL Single Hop (L/R); LSI	SL Triple Hop (L/R); LSI	SL Crossover Triple Hop (L/R); LSI
4	67/56.3; 84%	Not performed	Not performed
5	71.2/59; 83%	212/175; 82%	Not performed
6	72.3/62.7; 86.7%	228.3/204; 89.4%	203.4/190.7; 93.7%
8	68/64; 94.1%	**220.5/215; 97.5%**	**214/203; 94.9%**
9	**77/74; 96.1%**	224/218; 97.3%	206/205; 99.5%
10	74.3/67; 90.2%	230.3/230.7; 98.2%	207/202.8; 98%
12	69/69; 100%	229/221; 96.5%	Not performed

*****Jump distances measured in inches

Table 4 shows the results of the neuromuscular control checklist. The table demonstrates at which point during rehab the patient could complete the neuromuscular control exercises. The checklist was first introduced in the clinic when the patient was already 36 weeks post-op, at which point the patient had already demonstrated the ability to perform many of the movements within the checklist. For this reason, many of the movements were checked off 36 weeks post-op. Since the checklist was developed in the clinic, the test doesn't have any normative data or minimum benchmarks to target. The checklist does, however, demonstrate what movement patterns were challenging for the patient. The patient had difficulty with trunk stability tasks. He wasn't able to perform higher level core exercises until the end of his rehab. The patient also struggled with single leg lateral hopping, demonstrating difficulty with frontal plane stability. The patient did not demonstrate competency in all neuromuscular control exercises until 12 months post-op.

Table 4: Neuromuscular Control Checklist

Exercise	Phase 1	Phase 2	Phase 3	Phase 4
Single Leg Anterior Progression	R:36w; L: 36w	R:36w; L: 36w	R:36w; L: 36w	R:39w; L: 36w
Single Leg Lateral Progression	R:36w; L: 36w	R:49w; L: 49w	R:49w; L: 49w	R:55w; L: 55w
Lunge Progression	36w	36w	36w	38w
Tuck Jump Progression	36w	36w	38w	39w
Lateral Jump Progression	R:36w; L: 36w	R:36w; L: 36w	R:39w; L: 37w	R:39w; L: 39w
Lateral Trunk Progression	Not performed	Not performed	49w	55w
Prone Trunk Progression	Not performed	Not performed	49w	55w
Kneeling Trunk Progression	39w	39w	39w	41w
Posterior Chain Progression	39w	42w	39w	47w
Romanian Dead Lift Progression	R:36w; L: 36w	R:36w; L: 36w	R:39w; L: 36w	R:39w; L: 39w
Lunge Jump Progression	R:36w; L: 36w	R:40w; L: 39w	R:41w; L: 41w	R:47w; L: 47w

* w=weeks post-op

In addition to the movement screens, strength testing and the LEFS was still administered throughout rehab and was used to assist the RTS decision making. Table 5 shows the data from strength testing using dynamometry. LSI numbers are given for knee extension strength. Through the first 5 months the patient's R quadriceps, hip abductors and hamstrings were significantly weaker than the L leg. The goal of 90% LSI for knee extension wasn't achieved until 12 months post-op, at which point the R leg demonstrated a stronger rating than the L leg. By discharge the R hip abductors, extensors and hamstrings were also within 10% of the L leg. Table 6 shows the data from the LEFS administered. The patient self-reported LEFS score improved 57 points from initial evaluation to discharge date, which far exceeds the MCID (9). At discharge the patient score reflected only a 3.75% impairment.

Table 5: Strength Testing Dynamometry

	3 month PO	**5 month PO**	**6 month PO**	**8 Month PO**	**12 Month PO**
Knee Extensors	L:130.4, R:100; LSI: 77%	L:145.4, R:114; LSI: 78.6%	Not performed	L:162.6, R:135.4; LSI: 83.3%	L:167.2, R:172.8; **LSI: 103.2%**
Hip Abductors	L:25.3, R:20.2	L:31.6, R:30.9	L:32, R:24.1	L:35.1, R:31.5	Not performed
Knee Flexors	Not performed	L:89.7, R:65.7	L:90.5, R:85.5	Not performed	L:87.3, R:82.7
Hip Extensors	Not performed	Not performed	L:48.5, R:50.1	L:51.2,R:51.2	Not performed

*Strength given in pounds

Table 6: LEFS

Month Post-op	**0**	**2**	**3**	**5**	**12**
LEFS Score (raw score; % impaired)	20; 75%	43; 46%	62; 22.5%	71; 11.3%	77; 3.75%

At 6 months post-op, despite still demonstrating deficits in strength, power and neuromuscular control in the R LE as seen during the movement screens and strength testing, the patient began performing light sport specific activities such as shooting soccer balls on goal. At this point the patient had demonstrated he could run and perform plyometrics without pain. At 8 months post-op, the YBT-LQ and hop testing indicated the patient was very close to being no longer at an elevated risk for reinjury. While his quadriceps strength was still asymmetrical at this point, he had significant gains in quadriceps strength in the R LE and his hip strength was close to symmetrical. He had also passed a large portion of the neuromuscular control checklist. This data was enough to give the patient permission to start non-contact soccer scrimmaging. Over the next couple of months the patient continued being seen in order to work on functional/neuromuscular limitations exposed by the neuromuscular control checklist and to work towards symmetrical strength between both legs. Soccer specific training was also worked on as the patient progressed to full contact sport participation approximately 9 months post-op. At discharge the patient had accomplished all long term goals concerning functional movement screens and strength. The patient was playing competitive soccer without any issues. Despite the successful transition back into competitive sport, the move2perform algorithm still put the patient at a moderate risk for injury, most likely due to his previous injury and the nature of the sport he was returning to.

Discussion

The purpose of this case report was to investigate how clinical movement screens could be used to assess the RTS readiness of a young athlete after a multi-ligament knee injury and to review current literature on the effectiveness of these movement screens to predict future injury. Movement screening was initially performed on the patient 3 months post-op and was continued throughout his rehab. Based on the results of the movement screens, the patient was released to play non-contact soccer at 8 months and full contact by 9 months. The patient successfully returned to competitive soccer without any major setbacks. While the transition to playing competitive soccer was successful, it is hard to know how successful the clinical screens were in predicting future injury since it is still unknown whether the patient will be reinjured or not. However, since a large portion of reinjuries happen within the first month of returning to sport the patient had a good outlook [7]. The patient's results were superior to what has been seen in literature for athletes attempting to return to sport after an ACLR. One study found that within the first year after ACLR only one third of athletes cleared for participation actually returned to their competitive sport [26]. Another study found that only 44% of athletes returned to sport successfully after ACLR and it took an average of 41.5 months to return [27]. One the reasons the patient succeeded was the length of the patient's rehab. Being able to follow up with the patient over an entire year allowed for the patient to purse higher level long term goals, which often isn't possible for patients. This case study shows that patients may demonstrate large improvements objectively and subjectively by 6 months post-op, but the use of clinical movement screens can reveal lasting neuromuscular deficits that still puts the patient at risk for reinjury and therefore requires continued intervention.

As clinical movement screening tests have gained popularity in recent years, more research has been published evaluating their effectiveness. Research on the validity of the YBT has shown conflicted results. Multiple studies have shown that a cut-off score of 4cm for anterior reach asymmetry indicates higher risk of future injury [22]. For the YBT composite score, however, studies conflicted on the ideal cut off number. Two studies in the past year performed the YBT on collegiate athletes from multiple sports and found that the YBT alone was not able to predict LE injury [28,29]. Furthermore, it is difficult to simply associate YBT scores with dynamic balance because research has shown that many factors influence YBT scores. These factors include dorsiflexion ROM, sex, previous injury, and hip strength [22,30]. Because of the conflicting evidence and multiple variables, clinicians should be cautious when drawing firm conclusions on YBT results. The YBT should not be solely used to predict future injury.

The FMS, like the YBT, has conflicting evidence supporting its use for injury prediction. Recent reviews have shown the FMS to have moderate-excellent reliability [22, 31]. One current limitation of the test's validity is the lack of data on its content validity. While the deep squat movement has been tested biomechanically, none of the other movements have been tested [22]. The single value scoring of the screen has been questioned, where all movements are weighted the same despite some movements being more complex and incorporating multiple joints. A single score might not be appropriate due to the 7 movements testing different variables that don't correlate with each other. The sensitivity and specificity of the single score cut-off has a large range within the literature, which could be partially due to different populations tested and different definitions used for an injury [22]. A recent review by Moran et al concluded there isn't enough evidence to support the FMS composite score as an injury prediction tool [33]. Current evidence is also conflicted on using only specific movements within the FMS to predict future injury [22]. While clinicians can be confident about the reliability of the FMS, caution should be used in using it as an injury prediction tool.

Less data is available concerning the validity of hop testing in predicting future injury. While some studies suggest it can be a valid tool [24], a recent review by Harrison et al showed that none of the hop tests were able to predict knee injury in athletes [34]. Since evidence revolving around YBT, FMS and hop testing are conflicted, caution must be used when using the move2perform software to evaluate risk of future injury. While one study demonstrates the move2perform algorithm is effective in assessing the general injury risk of athletes [17], more data is needed in order for clinicians to be confident in it's formula. Because the neuromuscular control checklist was developed in the clinic, there is no normative data for the outcome measure. However, there is evidence demonstrating that the exercises within the checklist can reduce factors related to ACL injuries [35,36]. Furthermore, the movements within the checklist closely relate to other objective clinical movement screens, such as tuck jump assessment and drop vertical jumps. Future research is needed to show whether assessing competency in this set of exercise progressions or in a similar collection of neuromuscular control exercises could help assess risk of future injury. Overall, the role of clinical movement screens within the RTS criteria needs to be further evaluated. While there is lack of conclusive evidence on their ability to predict future injury, they could still have a role in identifying functional impairments and guiding interventions. Future research should specifically focus on testing the validity of the movement screens with patients post ACLR to assess their effectiveness in predicting reinjuries.

Return to sport decision making can be difficult and requires a team approach between physicians, therapists, trainers and coaches. Recent literature has suggested that a broad array of criteria should be tested to assess RTS readiness. Davies et al suggests RTS criteria should include testing strength, power, performance, function, proactive and reactive activities, fatigue, psychological aspects (kinesiophobia) and patient-reported outcomes [37]. While the patient in this case report underwent several components of the suggested criteria, more could've been evaluated to ensure safe return to sport. For instance more specific patient-reported outcomes could've be utilized, such as the International Knee Documentation Scale or the Knee Orthopedic Outcome Scale. Psychological aspects could've been testing, such as administering a Tampa Kinesiophobia Index. The clinical movement screens that were used could've been performed on a more regular basis. More screens could've been used, such as the Drop Jump Test, the Landing Error Scoring System, the Tuck Jump Assessment, and the Athletic Ability Assessment. Despite being thorough by using extensive amounts of RTS criteria, the rate of injury in competitive sports is still high even in athletes with no prior injury. Future research could focus on creating an algorithm similar to the move2perform, but with an increased amount of variables included. Such an algorithm could help athletes more clearly understand what level of risk they are taking by participating in their given sport.

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