Outcome evaluation after Achilles tendon ruptures. A Review of the literature

Running title: " Achilles Tendon Function: evaluation tools"

Abstract

The optimal treatment and the best rehabilitation protocol after an acute Achilles tendon rupture (ATR) remain a matter of controversy in orthopedic and sports medicine. The use of validated injury-specific outcome instruments is the only way to clarify these aspects, in order to ensure our patients the best possible treatment.

This article describes the most commonly reported evaluations instruments useful to assess patients treated for a ruptured Achilles tendon. Based on the available evidence, the Achilles Tendon Total Rupture Score (ATRS) is the most appropriate outcome measure for evaluating the management of acute ATR.

Keyword: Achilles tendon; surgical treatment; conservative treatment; outcome evaluation.

Introduction

In recent years, the demand for validated, reliable and responsive outcome measures has been growing. Proper evaluation tools are of utmost importance both in the scientific settings, to evaluate and compare research studies, and in the clinical settings, to guide therapeutic decisions and assess the progression of treatment.

Acute Achilles tendon rupture (ATR) is one of the most common tendon injuries in the adult population, especially in men in their third and fourth decades of life [1].

Despite the improvement of knowledge about Achilles tendon pathology, the optimal treatment and the best rehabilitation protocol after an acute rupture remain a matter of controversy in orthopedic and sports medicine. The knowledge and the use of validated injury-specific outcome instruments is the only way to clarify these aspects, in order to ensure our patients the best possible treatment.

This article describes the outcome measures reported in the literature for the assessment of patients following ATR. The aim is to provide clinicians and researchers with the available evidence regarding what evaluation tools should be used for this specific injury.

Outcome measures following ATR

The outcome instruments to evaluate the functional results following an Achilles tendon rupture can be broadly divided in two types: objective measures and patient-reported measures.

The former are parameters directly taken by the clinician, such as ankle range of motion (ROM) or calf muscle strength measurements. These objective data, arising from the patient's physical examination, have traditionally formed the basis of the functional assessment following an ATR.

However, over the past two decades, it has become increasingly recognized that the patients' perspective of outcome is of utmost importance in judging the results of a treatment [2].

At this regard none of the traditional objective parameters has been convincingly correlated with patient satisfaction [3,4].

Therefore, it is now well accepted that traditional defined outcomes need to be complemented by measures that focus on the patient's feeling toward a given treatment. This assumption is well demonstrated through the explosion in the literature of the patient reported outcome measures, namely questionnaires completed by patients to measure their perceptions of their own functional status and wellbeing.[5-7].

Objective and subjective parameters used to evaluate treatment modalities for ATR are variably reported in the literature, whether as isolated measures or grouped in different multi-items scoring systems (**Table 1**).

Validity, reliability and responsiveness are the clinimetric properties that define the clinical relevance of each outcome measure [8]. At this regard, It is worthy to remember that the **e**stablishment of the usefulness of an outcome instrument is never completed. It is an ongoing process whereby evidence is collected to support its use under various conditions [9].

Objective measures

After ATR patients have been reported to show a lengthening of the healed tendon along with impairments in the joint ROM, strength, endurance and calf muscle trophism. Therefore, when evaluating the final outcome of treatment, it is important to include these clinician-generated measurements [10]. Each of these parameters is usually compared in the injured and healthy side, to establish the limb symmetry index expressed as a percentage [11].

Achilles tendon lengthening

Some thirty years ago Nystrom showed a postoperative separation of the tendon ends after suturing a ruptured Achilles tendon, in patients immobilized for 3 weeks in a position of

slight plantar flexion [12]. Schepull et al confirmed more recently these observations, describing a biphasic lengthening of the tendon in the recovery period after an ATR, regardless the type of treatment [13].

Despite the improvements in therapeutic strategies, Achilles tendon lengthening following rupture remains a frequent undesired complication, assumed to cause functional modifications in ankle range of motion, strength deficits and gait abnormalities [14-16].

A proposed relation between elongation and functional impairments is that the lengthening of the tendon reduces the tension of the whole muscolotendinous unit. As a consequences the power produced by the calf muscle contraction decreases because the muscle is potentially acting at a different position of its force-length curve[16]. The tension of the unit is also necessary for the hypertrophic process of the muscle fibers. Therefore the slack of the tendon can also affect the potential for strength recovery through physical therapy [17]. Schepull et al could not find any correlation between tendon elongation and others functional outcomes after ATR [13], suggesting that, probably, a variation in elongation within reasonable limits might not influence the end result.

Currently there is no clear definition and no validated outcome measure for tendon elongation at all. Nystrom described the placement of thin steel wires on each tendon ends during the surgical repair and subsequent direct measures of the position of the marker on postoperative standardized X-ray [12]. Silbernagel evaluated Achilles tendon length as the distance between calcaneal osteotendinous junction and musculotendinous junction, by means of non invasive ultrasound imaging [15]. Selvik et al reported the use of Roentgen Stereophotogrammetric Analysis (RSA) to measure the distance between implanted tantalum beads in three dimensions with high accuracy [18].

In conclusion, given its potential influence on functional recovery, an important treatment goal appears to be to minimize tendon elongation.

Strength

Calf muscle strength is significantly deteriorated following ATR. The majority of the reports on the functional outcome after an ATR show a permanent strength deficit, up to 30% compared to the uninjured side [19,20].

The treatment of Achilles tendon ruptures should not only restore Achilles tendon length but the original strength of the whole muscle–tendon unit, because of the detrimental effects related to persistent calf muscle strength deficit [17]. Several studies report strength measurements through dynamometry as an evaluation outcome after surgical and conservative treatment of ATR. [21-23]. Currently, there is no consensus regarding the best method to determine strength. Both isokinetic and isometric measurements of ankle dorsiflexion and plantar flexion power are reported, as well as eccentric and concentric surveys. The position used in the clinical setting to measure these parameters also varies between studies [17,21-24]

The reliability of the isokinetic and isometric dynamometry is generally high, and the various testing positions for plantarflexion and dorsiflexion have good test-retest reliability [25,26]. Strength deficits following an acute ATR seem to be related to anatomical and structural changes of the healed tendon, namely elongation, as the ability of the calf muscle to contract does not reduce after the injury [16].

However, it is important to remember that although strength tests are valid for measuring improvements in strength, they are only moderately correlated to functional performance and they need to be complemented with other type of functional assessment [17,27].

Endurance/heel rise test

The muscular endurance evaluation is another type of muscle function measurement. The heel rise test is the most commonly used test for measuring the muscular endurance of the calf musculature [28] (Fig1).

The testing position for the subject is standing on one leg, while maintaining a straight knee, support with the fingertips for balance and avoiding body sway forward. It is important to instruct

the patient to go as high as possible for every heel-rise. Heel rise can be measured both in term of number of repetitions and height of each heel-rise [29]. This test has been shown to be reliable, valid and responsive in patients with ATR [30,31].

Following an ATR there is a significant deficit in heel-rise height and repetition between injured and uninjured side [14,15,29]. Silbernagel et al showed a correlation between the degree of tendon elongation and the side to side deficit in heel rise height [15]. The test also correlated well with isokinetic measurements in several research studies [4,19,30].

Due to these observations, along with the ease of execution, the heel rise test is recommended as a measure of functional recovery after ATR.

Calf muscle size

Calf muscle circumference is measured to determine muscular trophic modifications after rupture and during the recovery phase. It is important to remember that some aspects, as swelling and body composition – relative presence of fat tissue versus muscle tissue – avoid unambiguous interpretations of circumference values.

Different techniques are described to measure this parameter. Some authors propose CT or MRI measurements techniques [13,22,23], while others report circumference values detected by hand at predetermined positions related to bony landmarks [33] (Fig 2). Regardless the technique the calf circumference is described as a reliable parameter [30,32]. Nevertheless its correlation with other important outcomes, such as calf muscle endurance and strength, is debated [17,19,33].

Leppilahti et al reported muscle size recovery in only 30% of patients surgically treated for an ATR, in spite of excellent isokinetic strength results in 73% of the patients [33].

Conversely, Valderrabano recently reported that the muscle calf circumference is an easy-to-measure parameter that correlate well with the force that can be exerted by the muscle [17]. Moller et al [19] showed that when calf muscle size is evaluated by means of CT derived cross sectional area, it correlates well with the muscle ability to perform repeated heel rise tests.

These apparently conflicting data suggest that probably the assessment technique is an important factor for the validity of the calf muscle size as an outcome to evaluate recovery after ATR.

Ankle Range of Motion

Measurements of joints range of motion are common both in clinical and research setting. Ankle ROM is usually used as an indirect measurement of tendon elongation: an increased dorsiflexion after an ATR is assumed to result from a tendon lengthening.
Goniometric measurements, both active and passive, in different positions are described [34]. Goniometric measurements have been shown to have higher intra-tester reliability than inter-tester reliability [11]

Other parameters

In an attempt to propose increasingly valid outcomes, some authors described specific mechanical parameters to evaluate different treatment regimens for ATR. Selvik et al first used Roentgen stereophotogrammetric analysis (RSA) to describe the mechanical properties of a healing Achilles tendon [18].
By means of RSA technique Schepull et al calculated early modulus of elasticity of the healing tendon finding a correlation with late functional outcome [13, 35]. Interestingly the authors reported no difference in early mechanical properties between operative and non-operative treatment for ATR.
Valderrabano et al [17] recently first used the pedobarographic analysis of plantar pressure distribution as an outcome to evaluate results of different operative techniques for ATR, finding a significant correlation between the push-off force and calf muscle volume measurements. Dynamic pedobarography is an easy-to-measure examination that seems to be a suitable tool to evaluate functional changes following an ATR [36].

Multi-Items Scoring Scales

These rating systems are important measures of subjective and objective criteria, useful to compare patient's function and different treatment modalities. They may combine subjective (patient's perception of pain and function) or objective (physical examination) data or both.

Generally, outcome scales are characterized as global, regional, or disease-specific. Each type of instrument has a unique purpose and has advantages and disadvantages that affect the instrument's potential usefulness.

A global scale like the Short Form-36 [37] is designed to be a general assessment tool for health-status; it may be used for different patients and conditions, but it might not capture important aspects of a specific disease. Conversely, disease-specific measures are designed to assess function, pain and disability for specific conditions, with the important advantage of a greater responsiveness when capturing changes of the targeted disease. A region-specific instrument contains items specific to only one body part (i.e. foot and ankle) and can be used with several different disease states affecting this specific region [9,38]

Kearney et al [39] performed in 2011 a systematic review of the literature in order to recommend the most suitable outcome scales for the assessment of patients after an ATR. The authors reported 21 different multi-item patient outcomes, with the AOFAS hindfoot score being the most frequently used. Of all cited tools, the Achilles tendon Total Rupture Score (ATRS) was the only developed using recognized methodology for outcome measure development [5].

A description of some outcome scales commonly used in research studies about ATR treatment is here reported.

The American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale (Table 2)

The AOFAS ankle-hindfoot scale has been described by the American Orthopaedic Foot and Ankle society in 1994, in order to provide a universally accepted outcome measure, to compare different methods of treatment in patients with hindfoot problems [40].

This clinician-based outcome scale incorporate both subjective and objective factors into numerical scales with a maximum score of 100 points. The subjective portion has been shown to have satisfactory reliability and responsiveness [41].

As region-specific system, the AOFAS Ankle-Hindfoot Scale is intended to be used in several hindfoot problems affecting ankle, subtalar, talonavicular and calcaneocuboid joints [40].

Then this score is commonly used to evaluate conditions very different from Achilles Tendon Rupture treatment, as ankle arthroplasty, talonavicular arthrodesis or ankle instability [42].

Although routinely reported as an outcome measure in studies on patients with Achilles tendon rupture [39, 43], validity and responsiveness have never been evaluated in this specific population [24, 39]. Therefore some authors question its clinical relevance and on the basis of the available evidence this scale cannot be recommended for use in research studies about ATR [11,44].

The Achilles Tendon Total Rupture Score ATRS (Table 3)

The ATRS is a patient-reported injury-specific instrument developed in 2007, to specifically evaluate outcome after treatment in patients with ATR [45]. This questionnaire is a self-administered instrument, filled out by the patient and scored by the clinician. The score consists of ten items evaluating aspects of symptoms and function. Each item ranges between 0 and 10 on a Likert scale, with a maximal score of 100 indicating no symptoms and full function.

Thanks to its injury-specific nature the ATRS has demonstrated multiple facets of validity for use in the specific ATR patient population [39].

The reliability, validity and responsiveness of the ATRS have been evaluated and confirmed outside the developing centre and for languages different from the original version [24,46,47].

At present, the best available evidence suggests that the ATRS is the most appropriate outcome measure for evaluating the management of acute Achilles tendon ruptures [11,39].

The Leppilahti Score (Table 4)

Described by Leppilahti et al in 1998, this is the first report of a disease-specific standardized protocol for evaluation of outcome after ATR [48]. This scoring system combines both subjective assessments of the symptoms and objective measures, such as the ankle range of motion and isokinetic calf strength, with a total of seven items giving a sum of 100 points as best possible score.

The Leppilahti score is currently reported in several research studies about ATR treatment [21,49,50]. However, a potential limitation for comparison among different studies is the presence in the final score of parameters for the detection of which no consensus has been established, such as strength measurement. [24]

The Foot and Ankle Ability Measure (FAAM) (Table 5 and 6)

This is a self-reported outcome instrument, in the form of questionnaire filled out by the patient, described by Martin et al in 2005 [51].

The FAAM is a region-specific instrument divided in two separate subscales, namely activities of daily living and sports activities, divided in 21 and 8 items respectively. The two subscales are scored separately, then summed: a higher score represents a higher level of physical function [51]. This scale has been validated for individuals with a broad range of musculoskeletal disorders of the lower leg, foot and ankle, with reported evidence for validity, reliability and responsiveness [28]. In a recent systematic review about clinimetric properties of the outcome scales used to measure lower leg conditions, Shultz et al. reported the FAAM to be one of the most frequently assessed in terms of evidence for responsiveness [38]. Nevertheless FAAM has not been until now evaluated for use in the specific patient population who suffered an ATR.

Conclusions

A proper outcome evaluation following Achilles tendon rupture is essential to thoroughly understand the effectiveness of available treatment modalities. Actually the use of validated, responsive and reliable rating systems is the only way to allow comparison across practice, helping to draw conclusions about the optimal treatment.

The best choice of outcomes tools to report the results of treatment of patients with foot and ankle disorders remains uncertain. Nevertheless, on the basis of the available evidence, the patient treated for an ATR should be assessed with a disease-specific measure, such as the ATRS score, in combination with a generic measure, such as the SF-36. These patient-reported outcome scales focus on the patient's perception of his health status, that has to be considered as the most important indicator of the success of a treatment. Patient-reported outcome scales should also be completed by objective indicators of function, such as strength, endurance and return to previous activity level, to provide a complete picture of the effect of the treatment.

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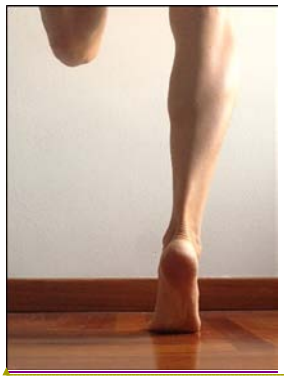

Fig 1. The Heel Rise Test - The subject is standing on one leg, maintaining a straight knee; support with the fingertips for balance.

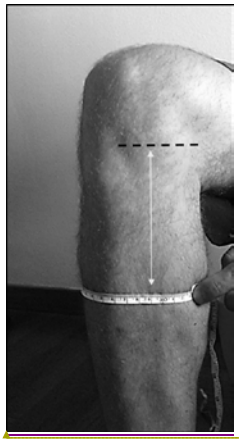

Fig 2. Calf muscle circumference - The maximal calf circumference is measured relative to fixed identifiable bony landmarks, e.g. the medial joint line

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394 **Tab 1.** Common reported evaluation instruments following Achilles tendon rupture.

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Objective Measures	***Multi-items Scoring Scales***	
	Clinician-Based	Patient-reported
- achilles tendon elongation - calf muscle size - calf muscle strenght - calf muscle endurance - ankle range of motion - AT mechanical properties	- AOFAS Ankle-Hindfoot Scale - Leppilahti Score	- Achilles Tendon Rupture Score (ATRS) *disease specific* - The Foot and Ankle Outcome Score (FAOS) *region specific* - The Foot and Ankle Ability Measure (FAAM) *region specific* - Short Form-36 (SF-36) *generic*

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398 **Tab 2.** The AOFAS Ankle-Hindfoot Scale

AOFAS Ankle-Hindfoot Scale

Pain (40 points)	
None	40
Mild, occasional	30
Moderate, daily	20
Severe, almost always present	0
Function (50 points)	
Activity limitations, support requirement	
No limitations, no support	10
No limitation of daily activities, limitation of recreational activities, no support	7
Limited daily and recreational activities, cane	4
Severe limitation of daily and recreational activities, walker, crutches, wheelchair, brace	0
Maximum walking distance, blocks	
Greater than 6	5
4-6	4
1-3	2
Less than 1	0
Walking surfaces	
No difficulty on any surface	5
Some difficulty on uneven terrain, stairs, inclines, ladders	3
Severe difficulty on uneven terrain, stairs, inclines, ladders	0
Gait abnormality	
None, slight	8
Obvious	4
Marked	0
Sagittal motion (flexion plus extension)	
Normal or mild restriction (30° or more)	8
Moderate restriction (15°-29°)	4
Severe restriction (less than 150)	0
Hindfoot motion (inversion plus eversion)	
Normal or mild restriction (75%-100% normal)	6
Moderate restriction (25%-74% normal)	3
Marked restriction (less than 25% normal)	0
Ankle-hindfoot stability (anteroposterior,varus-valgus)	
Stable	8
Definitely unstable	0
Alignment (10 points)	
Good, plantigrade foot, midfoot well aligned	10
Fair, plantigrade foot, some degree of midfoot malalignment observed, no symptoms	5
Poor, nonplantigrade foot, severe malalignment, symptoms	0

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401 **Tab 3.** The *The Achilles Tendon Total Rupture Score (ATRS* **)**
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Achilles Tendon Total Rupture Score

All questions refer to your limitations/difficulties related to your injured Achilles tendon.	
Mark with an X the number which matches your level of limitation!	
1. Are you limited due to decreased strength in the calf/Achilles tendon/foot?	0 1 2 3 4 5 6 7 8 9 10
2. Are you limited due to fatigue in the calf/Achilles tendon/foot?	0 1 2 3 4 5 6 7 8 9 10
3. Are you limited due to stiffness in the calf/Achilles tendon/foot?	0 1 2 3 4 5 6 7 8 9 10
4. Are you limited due to pain in the calf/Achilles tendon/foot?	0 1 2 3 4 5 6 7 8 9 10
5. Are you limited during activities of daily living?	0 1 2 3 4 5 6 7 8 9 10
All questions refer to your limitations/difficulties related to your injured Achilles tendon	
Mark with an X the number which matches your level of limitation!	
6. Are you limited when walking on uneven surfaces?	0 1 2 3 4 5 6 7 8 9 10
7. Are you limited when walking quickly up the stairs or up a hill?	0 1 2 3 4 5 6 7 8 9 10
8. Are you limited during activities that include running?	0 1 2 3 4 5 6 7 8 9 10
9. Are you limited during activities that include jumping?	0 1 2 3 4 5 6 7 8 9 10
10. Are you limited in performing hard physical labor?	0 1 2 3 4 5 6 7 8 9 10

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405 **Tab 4.** *The Leppilahti Score*
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The Leppilahti Score

Pain	
None	15
Mild, no limitations on recreational activities	10
Moderate, limitations on recreational, but not daily activities	5
Severe, limitations on recreational and daily activities	0
Stiffness	
None	15
Mild, occasional, no limitations on recreational activities	10
Moderate, limitations on recreational, but not daily activities	5
Severe, limitations on recreational and daily activities	0
Calf muscle weakness (subjective)	
None	15
Mild, no limitations on recreational activities	10
Moderate, limitations on recreational, but not daily activities	5
Severe, limitations on recreational and daily activities	0
Footwear restrictions	
None	10
Mild, most shoes tolerated	5
Moderate, unable to tolerate fashionable shoes, modified shoes tolerated	0
Active range of motion (ROM) difference between ankles	
Normal (<6°)	15
Mild (6°–10°)	0
Moderate (11°–15°)	5
Severe (>15°)	0
Subjective result	
Very satisfied	15
Satisfied with minor reservations	10
Satisfied with major reservations	5
dissatisfied	0
Isokinetic muscle strength (score)	
Excellent	15
Good	10
Fair	5
Poor	0

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409 **Tab 5.** *The Foot and Ankle Ability Measure (FAAM)* - Activities of Daily Living subscale

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living subscale

Please answer every question with one response that most closely describes to your condition within the past week. *If the activity in question is limited by something other than your foot or ankle mark not applicable (N/A).*						
Activities						
Standing	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking on even ground	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking on even group without shoes	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking up hills	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking down hills	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Going up stairs	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Going down stairs	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking on uneven ground	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Stepping up and down curbs	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Squatting	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Coming up on your toes	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking initially	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking 5 minutes or less	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking approximately 10 minutes	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Walking 15 minutes or greater	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Because of your foot and ankle, how much difficulty do you have with: *If the activity in question is limited by something other than your foot or ankle mark not applicable (N/A).*						
Activities						
Home responsibilities	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Activities of daily life	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Personal care	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Light to moderate work (standing, walking)	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Heavy work (pushing/pulling, climbing, carrying)	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Recreational activities	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
How would you rate your current level of function during your usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?						

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Foot and Ankle Ability Measure (FAAM)
Sports subscale

Because of your foot and ankle, how much difficulty do you have with:						
If the activity in question is limited by something other than your foot or ankle mark not applicable (N/A).						
Activities						
Running	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Jumping	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Landing	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Starting and stopping quickly	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Cutting/lateral movements	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Low impact activities	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Ability to perform activity with your normal technique	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Ability to participate in you desired sport as long as you would like	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
How would you rate your current level of function during your sports related activities from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?						
Overall, how would you rate your current level of function?	Normal	Nearly normal	Abnormal	Severely abnormal		

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