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Determining key clinical predictors for chronic ankle instability and return to sports with cost of illness analysis: protocol of a prospective cohort study

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ABSTRACT

Introduction Ankle sprains are common in sports and the general population. Although considered innocuous, a large proportion has residual complaints such as recurrent ankle sprains and develop chronic ankle instability. Although some predicting factors are identified, there is no unequivocality regarding the development of chronic ankle instability, nor about the optimal rehabilitation for an acute ankle sprain. Alongside the biomechanical impairments, ankle sprains are a burden on society due to substantial economic costs. Therefore, we aim to identify key clinical predictors of chronic ankle instability or recovery after acute lateral ankle sprain. Additionally, we aim to determine cost-of-illness of patients who developed chronic ankle instability.

Methods and analysis This prospective cohort study (Clinicaltrials.gov: NCT05637008 - pre-results) aims to recruit adult (18–55 years) patients with an acute lateral ankle sprain who are active in sports. Clinical assessments and patient-reported outcome measures will be used to collect data at 7–14 days, 6 weeks, 12 weeks and 12 months after enrolment in the study. The primary outcome will be chronic ankle instability at 12-month follow-up. Salient outcomes will be analysed by logistic regression to determine association with the development of chronic ankle instability. Participants will fill in a cost diary containing direct and indirect costs related to their injury.

Ethics and disseminations The ethical committee of the Antwerp University Hospital (B3002022000138) has given approval of the protocol and consent forms on 10 October 2022. We perform this study according to the Helsinki Declaration. We will present results at conferences or webinars and publish in peer-reviewed articles.

TRIAL REGISTRATION NUMBER

NCT05637008.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ First known prospective cohort study with long-term follow-up that inquires about clinical predictors for the development of chronic ankle instability.
⇒ First known prospective cohort study that inquires about clinical predictors for return to sports.
⇒ First prospective cohort study to evaluate cost of illness of patients who develop chronic ankle instability.
⇒ We do not provide a rehabilitation programme, which can lead to variability in content of rehabilitation among participants. This may influence various outcome measures. However, content of rehabilitation will be assessed and included as outcome variable.
⇒ The comprehensive protocol can lead to drop-outs.

INTRODUCTION

Lateral ankle sprains (LAS) remain the most common musculoskeletal injury in athletic population.[1 2] Approximately 1 in 10 000 people suffer an ankle sprain everyday,[3] with 49.3% occurring during sporting activity.[4] Fifty-nine per cent of professional basketball players and football players have reported to have sustained LAS.[5] Indoor sports are most prone to incur LAS,[6] followed by field sports and outdoor sports.[7] Even though incidence and prevalence are high, LAS are still considered innocuous.[8] Yet, research in different sports report high reinjury rates and residual symptoms: 19% in football, 28% in basketball, 43% in American football and 46% in volleyball.[9] Furthermore, up to 73% develop chronic ankle instability (CAI)[10]; a heterogeneous condition characterised by reinjury at its epicentre.[11] Several aetiological models exist for CAI,[12–17] but these are mostly based on cross-sectional and case-controlled studies.[18] Only one prospective study has examined predictive factors for developing CAI after an acute LAS: lower postural control and the inability to perform a jump landing and a drop vertical jump.[19] Other factors contributing to CAI are delayed peroneal reaction time, decreased eversion muscle strength and impaired proprioception.[20]

The International Ankle Consortium developed a rehabilitation-oriented assessment (ROAST) 'guideline to evaluate common impairments associating with LAS: pain, swelling, ankle range of motion (ROM), arthrokinematics, muscle strength, static and dynamic postural balance, gait, physical activity level and patient-reported outcome measures (PROMS).[21] More recently, a consensus statement was published with a return-to-sports decision-making framework including assessments which aligning with ROAST: pain severity, ankle impairments, athlete perception, sensorimotor control, sport/functional performance.[22] This expert-recommended framework was compiled after a systematic review concluded that evidence-based criteria for return to sport after an acute ankle sprain are non-existent in the current published literature.[23]

LAS incur substantial economic costs.[2] A study in the Netherlands found that the mean cost per ankle sprain is around €820 (2010), based on healthcare consumption and direct costs.[24] Comparable numbers are found in the USA and United Kingdom (UK), $1000 (US dollars, 2019) and £940 (2007), respectively.[25 26] A nationwide cross-sectional study in the USA documented median healthcare costs of $1029 per ankle sprain (2010).[27] Indirect costs due to production loss are also pertinent[28]; an injury estimation model that included both direct and indirect costs, calculated mean comprehensive costs associated with LAS around $12.000 (US dollars, 2007).[29] Moreover, a comprehensive systematic review reveals an average production time loss of 7–29 days due to LAS, overall treatment cost of $1 809 to $5271 and a direct cost of illness of $292 to $2268 (US dollars, 2018) .[30 31] Given the high recurrence rates and subsequent development of CAI into account, there will also be significant long-term costs associated with LAS.[32 33]

Study objectives

Determining key prognostic markers will inform clinical decision-making and help highlight patients most at risk for recurrent ankle injury. This study aims to identify key clinical predictors of the development of CAI—as the primary outcome—or recovery after acute LAS. Participants presenting with acute LAS will be prospectively followed over a 12-month period. Candidate predictors will include personal, demographic, clinical outcomes and patient-reported outcomes. As a secondary objective, we will undertake a health economical study to evaluate the cost of illness of LAS patients who developed CAI.

METHODS

Design

We will conduct a prospective cohort study. Figure 1 shows an overview of the study outline. We have obtained approval from the local ethical committee (UZA – B3002022000138) and started recruitment as of 23 March 2023. The protocol of this trial is published at clinicaltrials.gov (NCT05637008). We followed the Strengthening the Reporting of Observational Studies in Epidemiology-guidelines for cohort studies (online supplemental file 1).[34]

Participants

We contacted emergency departments (EDs) of the Antwerp University Hospital and four other hospital surrounding Antwerp, participating sport physicians and sport associations to provide study information to athletes who sustained an acute ankle sprain for recruitment. Additionally, newsletters and internet advertisement (social media, posters, website: www.anklesprainresearch.be) are be distributed. Athletes who have sustained an acute LAS will be included. A more detailed overview of the eligibility criteria is displayed in table 1.

Sample size

It is difficult to calculate a precise sample size due to insufficient information regarding associations between presumed prognostic factors and the outcomes. The primary outcome will be CAI at 12-month follow-up. The definition of CAI will follow the consensus definition from the international ankle consortium.[10 35 36] After LAS, we can conservatively estimate that 33% of individuals develop CAI within the first year.[19] To identify at least 10 events per variable investigated[37] and allowing for a 20% dropout rate, we will require 318 recruited subjects to obtain 265 participants with full data when considering a margin of error of 5%.[38] We are not bound to any deadlines since we perform this study without funding. We estimate to recruit participants for a period of 4 years—based on the feasibility study mentioned below—and end the study in 2028.

Feasibility

We completed a feasibility study (ethical committee approval, University Hospital Antwerp (UZA)—BUN B3002021000199) to determine recruitment rate, eligibility criteria, adherence and dropout rates and duration of the assessment procedure; the criteria for success were established a priori and are detailed in table 2. We recruited participants from January 2022 to April 2022; we included eight participants (seven men, one woman; mean age: 20.00 years, range 18–21; mean height: 186.2 cm, range 165–196.5 cm; mean weight: 85.47 kg, range 74.2–99 kg). As we were unable to meet the criterion for eligibility, recruitment rate, recruitment time and equipment with the initial protocol, the following amendments were made: (1) time to first assessment was increased from 7 to 14 days, based on the feedback of collaborating physicians—they were unable to recruit participants within the week after their injury event. Recruitment rate went up from one per month to five per month after this disposition. (2) Some materials were insufficient: vacuum wall fixation broke down. We bought stronger wall fixators; everything worked henceforward. (3) Assessment duration at the 6-week time point was too time-consuming (>90 min). After having a consensus meeting with the

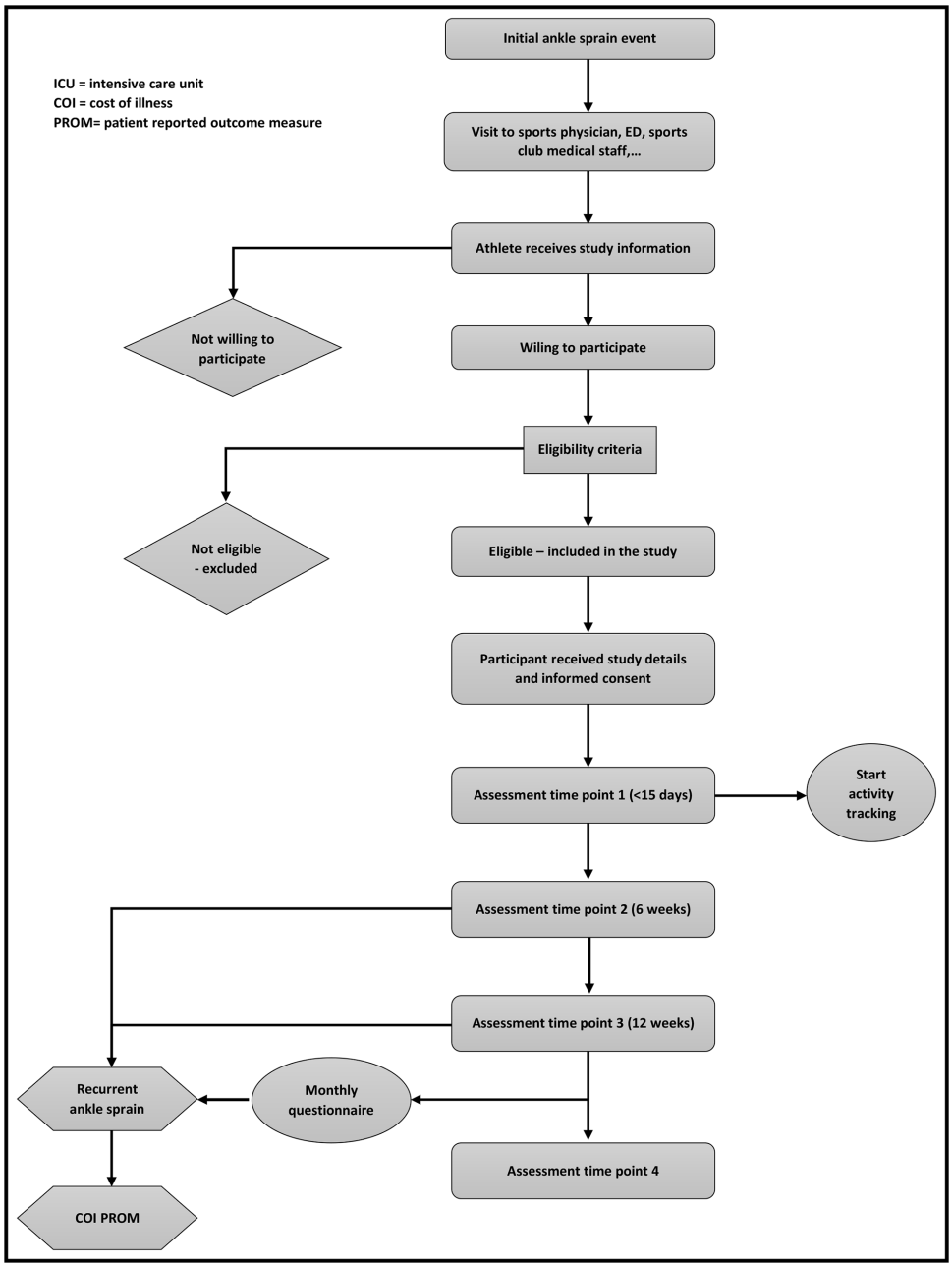

Figure 1 Study flow.

entire research group, the following adaptations were made: (a) knee muscle strength will be excluded entirely; (b) hip flexion, internal rotation and external rotation will be excluded; (c) joint position sense will be evaluated as of 7.5° and higher; (c) there will be only one target value for force sense: 50% of 1RM; (e) only ankle inversion and eversion force sense will be assessed. The target criterion of 90 min was fulfilled after these changes in the protocol.

Testing procedure and assessments

Participants will be assessed at the following time points postinjury: <15 days, 6 weeks, 12 weeks and 12 months after the initial ankle sprain event. Multiple randomised controlled trials, investigating the effect of physical therapy in the treatment of acute LAS,[39–43] showed significant improvements in various outcome measures 6 weeks postankle sprain. In the study of van Rijn *et al*.[44] Twenty-eight per cent of the study participants sustained a recurrent ankle sprain after 12 months of follow-up, with 83% of whom the resprain occurred prior to the 3-month assessment point. Additionally, the proliferation healing phase of ligament tissue merges into the remodelling phase between 6 and 12 weeks postinjury.[45] The 12-month time point is substantiated by a position statement of the International Ankle Consortium, recommending criteria for patients with CAI 12 months after sustaining the initial sprain.[10 35 36] Furthermore, studies have shown that risk of reinjury is similar to the risk of a first-time LAS after 12 months.[46 47]

Table 1 Eligibility criteria

Inclusion	Exclusion
Male or female	Recurrent ankle sprain <12 months
≥18 years of age	Ankle fracture
Acute ankle sprain: <15 days[19]	High ankle sprain (syndesmosis)
Athletes (recreational, semi-professional, professional)	Chronic ankle instability
Previous ankle sprain >12 months[10]	A history of ankle or foot operations
	Other lower limb injuries or complaints
	Severe ocular impairments
	Any neurologic, cardiac, vascular or metabolic disease

Additionally, there will be a monthly survey to inquire about presence of absence of reinjury. All participants will be assessed on location and all tests will be performed barefoot.

Online supplemental file 2 includes all patient-reported outcome measures.

Assessment time point 1: <15 days post ankle sprain event

Ligament injury severity grading

Diagnostic ultrasound (Telemed Ultrasound MicroUS PRO) will determine the severity of the ankle ligament injury and the ligaments involved. Diagnostic ultrasound has proven to have a high diagnostic value for ankle ligaments.[48] Afterwards ligaments will be clinically evaluated:

Integrity of the anterior talofibular ligament (ATFL) will be assessed by the anterior drawer test (ADT). Measurement properties of the ADT show sensitivity of 84% and specificity of 96% to detect ATFL injury in ankle sprain patients.[49] Participants are positioned supine on the table with a roll under their knees to obtain the least packed position of 30° of knee flexion, with the most distal part of the lower legs and the ankles over the edge of the table. The examiner stands at the end of the table, medially to the tested ankle. The homolateral hand of the examiner fixates the tibia and fibula by pressing the malleoli in the table. The contralateral hand holds the posterior side of the calcaneus, with the plantar side of the foot resting on the palmar side of the lower arm of the examiner. The examiner pulls the calcaneus anteriorly, while maintaining the tibia and fibula fixated on the table.[49]

To assess integrity of the posterior talofibular ligament (PTFL), calcaneofibular ligament (CFL) and deltoid ligament, the talar tilt test (TTT) will be performed. Measurement properties of the TTT show test–retest reliability with Intraclass correlation (ICC) =0.66,[50] sensitivity of 17.2%–31.7% and specificity of 89.6%–95.5%.[51] Similar to the ADT, the participant is positioned supine on the table with a roll under the knees and the distal part together with the ankles over the edge of the table. Positioned at the end of the table, medially to the tested foot, the examiner fixates both tibia and fibula in the table just proximal of the malleoli, while the contralateral hand holds the calcaneus. The examiner pulls the calcaneus to inversion and eversion while fixating the tibia and fibula.[51]

Additionally, we will inspect for presence or absence of discolouration due to haematoma and palpate to evaluate presence or absence of pain at the site of the above-mentioned ligaments. Research has displayed that sensitivity of ligament integrity assessment increased to 96% when performing additional inspection for bruising and pain palpation.[49] The participant's position is identical to the manual stress tests. The examiner closely

Table 2 Feasibility results

Outcome	Criterion for success	Achieved	Adaptation
Eligible participants	80%	70%	Prolong time period of recruitment
Recruitment rate	Three participants/week	Five participants/ month	Prolong time period of recruitment
Adherence	90% adherence	100% adherence	/
Dropout rate	10% dropout rate	0% dropout rate	/
Assessment time	Time point 1: 30 min Time point 2 and 3: 90 min	Time point 1: mean 17 min Time point 2: mean 122 min	/ Exclude knee, hip flexion, internal and external rotation muscle strength testing JPS: excluding 0–7.5 degrees, excluding 25% and 75% target values, excluding plantar flexion and dorsiflexion
Time to first assessment	7 days	Mean: 10 days	Time to first assessment 7–14 days
Equipment	All hardware and software works	Vacuum fixation broke	Stronger vacuum fixation
JPS: Joint position sense			

inspects both feet for bruising. Thereafter, the examiner palpates the ATFL, PTFL, CFL and deltoid ligament.[49]

We will also ask the participant's perspective on the severity grade of the ankle sprain. This will be evaluated by asking the participants to fill in a visual analogue scale (0–100).

Patient-reported outcome measures

The participant will be asked about personal information (eg, age and gender), sports-related information, injury-related information and status of rehabilitation (eg, content of rehabilitation, amount of sessions, duration of sessions).

Pain during weight bearing will be assessed through a numeric pain rating scale (NPRS) for pain intensity and digital pain drawing for area of pain. Test–retest reliability and validity for the NPRS as a measurement of pain intensity are r=0.95–0.96 and r=0.86–0.95, respectively.[52] We will use a 10 point rating scale, with 0 meaning 'no pain' and 10 meaning 'worst pain imaginable', which is considered applicable due to its high level of repeatability.[53] Also digital pain drawing as a measurement method for area of pain showed to have excellent validity (96.6%) and reliability (R^2= 0.87).[54]

To assess specific symptoms of instability, the Cumberland ankle instability tool (CAIT) will be used. Specifically, the Dutch version of the CAIT will be used, which is proven valid and reliable (test–retest reliability ICC=0.94), with high internal consistency (Cronbach's α=0.86) to assess ankle instability in the Dutch population. A cut-off value of >12 points (out of possible 30) as an indication for stable ankles is calculated, based on the Youden index (11.5 points).[55] SE of measurement is 0.82 (2.7%) and a minimal detectable change of 2.28 on individual level and 0.04 on group level, respectively.[55]

The short version of the foot and ankle ability measure (Quick-FAAM) will be used to evaluate region-specific functional abilities. This questionnaire contains 12 items scored across a 5-point Likert scale.[56] Measurement properties of the Quick-FAAM show excellent internal consistency (Cronbach's α=0.94), acceptable test–retest reliability (r=0.82), acceptable concurrent validity (r=0.76), excellent discriminative capabilities (sensitivity=0.96, specificity=0.85, area under the curve=0.95) with a cut-off value of 94.79% to make the distinguishment between patients with CAI and ankle sprain copers.[57 58]

The illness perception questionnaire (IPQ) quantitatively evaluates the five components of illness representation: illness identity, cause, timeline, consequences and management.[59] This questionnaire revealed to be reliable (ICC=0.53–0.85) with good internal consistency (Cronbach's α=0.51–0.87).[60] We will use the brief version of the IPQ, which has shown acceptable reliability (ICC=0.72; 95% CI 0.53 to 0.82).[60]

Fear avoidance beliefs pertinent to physical activities and work will be quantitatively evaluated by the fear avoidance beliefs questionnaire (FABQ), which has excellent test–retest reliability (ICC=0.97).[61]

The 11-questions version of Tampa Scale for Kinesiophobia (TSK-11) will be used to assess pain-related fear of physical movement and activity. This short version has shown similar measurement properties as the original TSK (test–retest reliability: ICC=0.81; internal consistency: Cronbach's α=0.79).[62]

To assesses quality of life by addressing five domains: mobility, self-care, usual activities, pain/discomfort and anxiety/depression, the EQ-5D-5L questionnaire will be employed. Each domain is scored across a 5-point Likert scale: 0=no problems, 1=slight problems, 2=moderate problems, 3=severe problems and 4=extreme problems. This version is an update of the EQ-5D-3L, showing superior measurement properties.[63]

Assessment time points 2 and 3: 6 weeks and 12 weeks postankle sprain event

Patient-reported outcome measures

Similar to assessment time point 1, we will inquire about rehabilitation status, pain, specific symptoms of ankle instability, ankle-specific functional abilities, illness representation, fear avoidance believes, pain-related fear of physical movement and activity and quality of life by the PROMS mentioned previously. Additionally, participants will be asked whether or not they returned to sports and if they sustained a recurrent ankle sprain or giving away episode.

Activity tracking

Participants will be asked to wear an activity monitoring device (wGT3X-BT Smart, ActiGraph, USA) 1 week after each assessment time point to capture and record continuous, high-quality information regarding sleep and physical activities. This activity monitor will both measure volume and intensity of physical activities. The wGT3X-BT Smart has shown excellent validity (91%) and intrasession reliability (ICC=0.95–0.98).[64]

Range of motion

We will apply a digital goniometer (K-Force Sens, KINVENT, France) and the weight-bearing lunge test to assess ROM. Digital goniometry has shown excellent intra-rater reliability (ICC=0.96–0.99) to assess ankle ROM.[65] Also the weight-bearing lunge test has conveyed excellent intra-rater (99%) as well as intra-rater reliability (99%).[66] For the digital goniometry ROM assessment, participants will be positioned in long sit on the table with the ankle over the edge of the table in 10–15° of plantarflexion. The examiner will place the digital goniometer just proximal of the metatarsal heads, in the direction of the respective movement. Test subjects will actively perform ankle dorsiflexion, plantarflexion, inversion and eversion.[67] For the functional assessment of dorsiflexion by utilising the weight-bearing lunge test, participants will be standing in split stance facing a wall with the tested foot in front. A measurement tape will be laid out on the floor to measure distance from the wall to the first toe. Participants will be instructed to perform dorsiflexion by pushing the knee

forwards over the toes while maintaining their heels flat on the ground.[68]

Isometric muscle strength

Hip and ankle muscle strength will be evaluated by the use of a fixed handheld dynamometer (HHD) (K-Force Sens, KINVENT, France). Fixed HHD has shown to have good to excellent reliability to assess isometric muscle strength (ankle muscle strength: inter-rater reliability ICC=0.78–0.94; intra-rater reliability ICC=0.77–0.88; hip muscle strength: inter-tester reliability ICC=0.76–0.95).[69 70] Test subjects will be able to hold on to the sides of the table for fixation during the isometric muscle strength tests.

For ankle muscle strength,[71] the participants will be positioned in long sit on the table with the ankles over the edge of the table in 10–15° of plantarflexion. The lower leg will be fixated to the table with a fixation belt, just proximal of the malleoli, to exclude compensations by adjacent joint movements. The HHD will be placed perpendicular to the foot in each respective direction: (1) plantarflexion: the HHD will be placed at the plantar side of the foot, at the level of the metatarsals with the wall as fixation of the HHD; (2) dorsiflexion: the HHD will be placed at the dorsum of the foot, at the level of the metatarsals with belt fixation of the HHD; (3) inversion: the HHD will be placed at the medial side of the foot, at the level of metatarsal I with belt fixation of the HHD; (4) eversion: the HHD will be placed at the lateral side of the foot, at the level of metatarsal V with belt fixation of the HHD.

Hip muscle strength[70] will be evaluated by assessing hip extension, abduction and external rotation. For hip extension and external rotation, participants will be positioned prone on the table with the hip in neutral position and the knee flexed 90°. To evaluate hip extension, the patients will be placed perpendicular to the posterior aspect of the upper leg, as distally as possible to the knee joint with belt fixation attached to the examiner as fixation of the HHD. For external rotation, the HHD will be placed on the medial aspect of the lower leg, 5 cm proximal to the proximal edge of the malleolus medialis with belt fixation as fixation of the HHD. For hip abduction, the participants will also be positioned prone on the table but with the knee extended with the distal part of the lower leg and the ankle placed over the end of the table. The HHD will be placed on the lateral aspect of the lower leg, 5 cm proximal to the proximal edge of the malleolus lateralis with belt fixation of the HDD.

For the execution of the isometric muscle strength tests, participant will first be asked to perform a guided, submaximal contraction during the above-mentioned movements, then the test subjects will perform a 5 s maximal isometric contraction.

Proprioception

Force sense

A HHD will be used to assess ankle inversion and eversion force strength as a measure of ankle proprioception.[72] Participants will be positioned in long sit on the table with the ankles over the edge of the table in 10–15° of plantarflexion. The lower leg will be fixated to the table with a fixation belt, just proximal of the malleoli, to exclude compensations by adjacent joint movements. HHD positioning is similar to ankle isometric muscle strength testing: (1) inversion: the HHD will be placed at the medial side of the foot, at the level of metatarsal I with belt fixation of the HHD; (2) eversion: the HHD will be placed at the lateral side of the foot, at the level of metatarsal V with belt fixation of the HHD. First, participants will perform two maximal voluntary contractions. The mean will be used as 1 repetition maximum (1RM). Participants will then be asked to build up force until target value is reached (50% of 1RM). The achieved target value will be maintained and mentally visualised for 5 s to determine criterion force for the participants. After 10 s of rest, participants will try to reproduce the criterion force and hold for 5 s when they confirm that they have achieved the confirmed force.

Joint position sense

To evaluate joint position sense as a measure proprioception, the slope-box test will be used.[73] This test has an excellent test–retest reliability (ICC=0.92–0.93).[74 75] The slope box is a 30 cm by 30 cm wooden box with an adjustable slip proof cover. The cover can be inclined at angles varying by 2.5° between 0° and 25° in the four applicable directions (anterior, posterior, lateral and medial). Because mean estimate errors are larger in the 7.5–25° range,[75] we will perform the test from 7.5° to 25° in the four directions, yielding a total of 32 test positions. Patients will be blinded and positioned facing a wall on a normal box of equal height of the slop box, which will be positioned adjacently. They can use the wall for stability when necessary. Test subjects will be asked to step on the slope box with the tested foot and to place their entire weight on that foot. Patients will be asked to estimate the direction and degree of incline onto which they stand. Degree of incline will be represented by a scale from 0 to 15 (0° to 37.5°, table 3), which enables possible overestimation by 12.5°. Order of direction and degree of incline will be determined randomly and all 32 positions will be performed. Participants have the opportunity to test trial the platforms at 0°, 12.5° and 25° of the four directions as a reference.

Sensorimotor control

The foot-lift test will be used to assess static balance. This test has good test–retest reliability (r=0.78; ICC: 0.73; 95% CI 0.40 to 0.89).[76] Test subjects will be instructed to initiate the test in single stance position with both hands placed on the iliac cristae. Participants will close both eyes when the examiner gives the signal to do so, after which participants have to remain stable for 30 s. The amount of foot lifts, foot shifts and touches on the ground with the contralateral foot will be counted as errors. Each error counts as 1. When the contralateral side remains on the

Table 3 Degrees of incline scale

Scale	Degrees of incline
0	0°
1	2.5°
2	5°
3	7.5°
4	10°
5	12.5°
6	15°
7	17.5°
8	20°
9	22.5°
10	25°
11	27.5°
12	30°
13	32.5°
14	35°
15	37.5°

ground, the amount of seconds will be counted as additional errors to the final score.[76 77]

To evaluate functional balance, the Y-balance will be employed. This test has shown good to excellent reliability (inter-rater reliability: ICC=0.85–0.93; Standard Error of Measurement (SEM): 2.0–3.5 cm) to assess functional stability in ankle sprain patients.[78] The starting position for this test is a single-leg stance on the firm centre footplate of the Y-balance testing apparatus, with both hands placed on the iliac cristae. Prior to testing, lower limb length will be measured from the distal aspect of the malleolus lateralis to the proximal aspect of the trochanter major. The participant will be instructed to reach in the thee directions (anterior, posterolateral and posteromedial) and to try to push the indicator as far as possible with the free leg while maintaining balance. The reach distance evaluated by the indicator will be analysed in proportion to the lower limb length of each test subject.

The side-hop test will be used to assess dynamic balance. This test has a significant correlation with the presence of functional ankle instability (r=0.35; p<0.01).[76] Similar to both sensory motor function tests above, participants start in single-leg stance with the hands on the iliac cristae. There will be a 30 cm width embarkment with white elastic tape. Participants will take the starting position lateral to the embarkment. Test subjects will hop laterally 30 cm and back 30 cm over the embarked zone for 10 repetitions as fast as possible and perform a stable landing after the tenth hop, which needs to be maintained for 5 s.[76 77]

Performance

The performance tasks included in this study will be evaluated on completion. Additionally, standing long jump performances will be evaluated on jump distance and drop vertical jump performance will be evaluated by measuring reactive strength index (RSI), contact time and jump height as measures of lower limb power.[79] This will be recorded and evaluated by the My Jump 2 app, which has acceptable to excellent reliability (67%–98%) and validity (r=0.66–0.98) for the assessment of RSI, jump height and contact time.[80]

Single-leg drop landings will be evaluated. Participants will start in a single-leg stance position on a 30 cm box, from which they will have to drop forward and perform a stable landing. Subsequently, subjects need to maintain the stable landing position for 5 s.[19]

For the standing long jump, test subjects will be instructed to take place in a single-leg stance position at an indicated take-off line. Participants will have to jump as far as possible in a horizontal direction. Swinging of the arms and bending the knees to provide forward drive are permitted.

Starting position for the drop vertical jump is a single-leg standing position on a 30 cm box with the hands on the iliac cristae. Participants will have to drop forward off of the box with the test foot, land with the same foot and immediately perform a maximal jump as high as possible, followed by a landing on the ground in a stable single-leg stance position.[19 81]

The t-test will be used to assess quickness.[82] Participants will have to take place at an indicated starting line. On the signal, they will have to run forward to the centre cone, sidestep 5 m to the right cone, sidestep 10 m to the far left cone and then sidestep back 5 m to the centre cone. Conclusively, participants have to run backward back to the starting line. This test is performed as quickly as possible.[82]

Assessment time point 4: 12-month post ankle sprain event

Similar to the previous time points, we will ask participants about return to sports, recurrent ankle sprain or the ankle giving away, rehabilitation status, pain, specific symptoms of ankle instability, ankle-specific functional abilities, illness representation, fear avoidance beliefs, pain-related fear of physical movement and activity and quality of life by the previously discussed PROMS.

Monthly assessment

From assessment time point 3 (12 weeks post ankle sprain event) up to assessment time point 4 (12 months postankle sprain event), we will contact participants monthly via e-mail, short message service or telephone call to inquire whether or not—if yes, when—they returned to sports and if—and if yes, when—they sustained a recurrent ankle sprain or giving away episode.

Data processing and analysis

All clinical assessments will be performed two times. The mean of the two measurements will be calculated per outcome measure and used for further statistical analysis. Data from PROMS will be acquired through a

secure web application for online surveys and databases (REDCap, Research Electronic Data Capture, USA). Data from ROM and isometric muscle strength will be recorded in the K-Force app (KINVENT, France), from which excel data reports can be extracted for further analysis. The My Jump 2 app will be used to evaluate jump distance of the standing long jump and RSI, contact time and jump height as measures of lower limb power for the drop vertical jump. Excel data reports can be extracted from the K-Force app (K-INVENT, Montpellier, France) and the My Jump 2 app (Carlos Balsalobre, Spain) for further analysis. Participants' information will be pseudonymised.

Predictor variables

The primary outcome will be CAI at 12-month follow-up. The definition of CAI will follow the consensus definition from the international ankle consortium.[10 35 36] After LASs, we can conservatively estimate that 33% of individuals develop CAI within the first year.[19] To identify at least 10 events per variable investigated,[37] we will require 265 participants with full data. Individuals with missing data will be included within the analysis and assumed to be missing at random, with checks on the plausibility of the assumption.

We will use logistic regression to examine the association between the salient predictors and the primary outcome (CAI). Initially, we will conduct a series of univariate analyses to determine whether any predictor variables are associated with the binary variable of CAI. Correlations among predictor variables will be calculated to screen for any strong colinearity (r>0.8). Predictors demonstrating a p value less than 0.10 on univariate testing will be entered into a multiple logistic regression analysis. The strength of the predictive model will be determined using R2, p values, ORs, with 95% CI.

Secondary outcomes will be time to return to sports and time to reinjury. The relationship between predictors and secondary outcomes will be examined using survival analyses, continuous covariates (predictors) will be categorised using 50th centiles. The time (in days) from the index injury, to a participants' first event (eg, return to sport/recurrent injury) or the end of their 12-month follow-up period, will be the main end point. Initially, Kaplan-Meier survival curves will be generated and log-rank tests were used to explore survival differences between levels of each covariate. Univariable and multivariable Cox proportional hazard models will be used to evaluate associations between covariates and hazard of injury. Variables with p<0.1 in the univariable model will then be analysed within a multivariate Cox proportional hazard model. HRs will be presented with their 95% CI and we will consider p<0.05 to be statistically significant. Non-proportionality will be checked graphically by assessing Kaplan-Meier survival distribution for each level of the covariate; and stratum-specific log minus-log plots.

Exploratory analysis

All other clinical and patient-reported outcomes will be recorded at 7–14 days, 6 weeks and 12 weeks postinjury. We will use factor analysis, latent class analysis and item response models to examine the psychometric properties of the various constructs. Latent growth curve models will be used to examine individual trajectories of recovery since the data are nested (level 1) with individuals (level 2). The derived models will then be further tested as a clinically useful predictor of the course of functional recovery.

COST OF ILLNESS EVALUATION ALONGSIDE PROSPECTIVE STUDY

Aim of the economic evaluation

Athletic patients with an acute ankle sprain receive a prescription for physiotherapeutic rehabilitation after visiting a physician. The maximum amount of sessions prescribed for rehabilitation is by law determined at 18 sessions. This can be a high economic burden for the patient, health insurance agencies and other healthcare policymaking agencies. To the best of our knowledge, it has not yet been researched what the cost of illness is in a Flemish context for patients who sustained an acute ankle sprain. Therefore, this study will be the first to evaluate long-term costs after an acute ankle sprain, with regard of long-term repercussions, such as CAI. In this section, we describe the protocol of a cost-of-illness (COI) analysis alongside the prospective cohort study.

Methods of the health economic evaluation

This health economic evaluation will be conducted for patients with and without a recurrent ankle sprain. All data will be gathered by asking the participants to fill in a PROM containing questions about the economic cost related to the ankle sprain. Patients who reinjured their ankle will be asked to fill in the PROM again. Duration of the trial is 12 months: we will ask participants every month to fill in the questionnaire. The COI analysis will follow an incidence approach, that is, from diagnosis until the disorder has been dissolved. Health services consumed (eg, physician consult, physiotherapy session, ED visit) will be recorded using diaries. Costs will be calculated as units consumed × unit price. Hence, costs will be presented in a non-aggregated form. Direct and indirect costs will be calculated while intangible costs—costs that represent impaired quality of life because of the injury, which exceed the monetary value of tangible effects and services[83]—will be omitted. Direct costs include costs about diagnosis, treatment, rehabilitation (eg, consultation with physician, physiotherapist session) and non-medical expenditures occasioned by injury (eg, purchase of braces, purchase of wheelchair). Indirect costs include costs regarding travel, productivity loss and other expenses (eg, absenteeism, presenteeism, bus ticket). All costs will be expressed in 2028 Euro's. This COI study will be conducted from a healthcare and a

societal perspective. All results will be presented as means or medians and their corresponding 95% CI or IQR, respectively. A sensitivity analysis will be performed to test robustness of the results against uncertainty on the precision of several input parameters.[84]

ETHICS AND DESSIMINATIONS

The ethical committee of the Antwerp University Hospital (B3002022000138) has given approval of the protocol and consent forms on 10 October 2022. All participants will be informed of the study, after which they will have an opportunity to ask questions. Thereafter, we will ask to fill in an informed consent form. The principal investigator will have access to, and control over the final data set. We perform this study according to the Helsinki Declaration. We will present results at conferences or webinars and publish in peer-reviewed articles.

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Contributors All authors—JW, JT, KK, HB, CB and DV—contributed to the design of this protocol. CB did the sample size calculation and designed the plan for the statistical analysis. JT and DV Implemented the cost of illness evaluation. JW, HB and KK described the assessments. All authors gave critical feedback for revisions of this manuscript and approved the final version of this manuscript.

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REFERENCES

1 Canata GL, d'Hooghe P, Hunt KJ, *et al*. Sports injuries of the foot and ankle. In: *Sports injuries of the foot and ankle: a focus on advanced surgical techniques*. 1st edn. Berlin, Heidelberg: Springer, 2019.
2 Bleakley CM, Taylor JB, Dischiavi SL, *et al*. Rehabilitation exercises reduce reinjury post ankle sprain, but the content and parameters of an optimal exercise program have yet to be established: a systematic review and meta-analysis. *Arch Phys Med Rehabil* 2019;100:1367–75.
3 Struijs PA, Kerkhoffs GM. Ankle sprain. *BMJ Clin Evid* 2010;2010:1115.
4 Waterman BR, Owens BD, Davey S, *et al*. The epidemiology of ankle sprains in the United States. *J Bone Joint Surg Am* 2010;92:2279–84.
5 Halabchi F, Angoorani H, Mirshahi M, *et al*. The prevalence of selected intrinsic risk factors for ankle sprain among elite football and basketball players. *Asian J Sports Med* 2016;7:e35287.
6 Vuurberg G, Hoorntje A, Wink LM, *et al*. Diagnosis, treatment and prevention of ankle sprains: update of an evidence-based clinical guideline. *Br J Sports Med* 2018;52:956.
7 Doherty C, Delahunt E, Caulfield B, *et al*. The incidence and prevalence of ankle sprain injury: a systematic review and meta-analysis of prospective epidemiological studies. *Sports Med* 2014;44:123–40.
8 Hiller CE, Nightingale EJ, Raymond J, *et al*. Prevalence and impact of chronic musculoskeletal ankle disorders in the community. *Arch Phys Med Rehabil* 2012;93:1801–7.
9 Herzog MM, Kerr ZY, Marshall SW, *et al*. Epidemiology of ankle sprains and chronic ankle instability. *J Athl Train* 2019;54:603–10.
10 Gribble PA, Delahunt E, Bleakley C, *et al*. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International ankle Consortium. *Br J Sports Med* 2014;48:1014–8.
11 Doherty C, Bleakley C, Delahunt E, *et al*. Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis. *Br J Sports Med* 2017;51:113–25.
12 Hertel J, Corbett RO. An updated model of chronic ankle instability. *J Athl Train* 2019;54:572–88.
13 Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *J Athl Train* 2002;37:364–75.
14 Hiller CE, Kilbreath SL, Refshauge KM. Chronic ankle instability: evolution of the model. *J Athl Train* 2011;46:133–41.
15 Freeman MAR, Dean MRE, Hanham IWF. The etiology and prevention of functional instability of the foot. *The Journal of Bone and Joint Surgery British Volume* 1965;47-B:678–85.
16 Donovan L, Hertel J. A new paradigm for rehabilitation of patients with chronic ankle instability. *Phys Sportsmed* 2012;40:41–51.
17 Gribble PA. Evaluating and differentiating ankle instability. *J Athl Train* 2019;54:617–27.
18 Bleakley C, Wagemans J, Netterström-Wedin F. Understanding chronic ankle instability: model rich, data poor. *Br J Sports Med* 2021;55:463–4.
19 Doherty C, Bleakley C, Hertel J, *et al*. Recovery from a first-time lateral ankle sprain and the predictors of chronic ankle instability: a prospective cohort analysis. *Am J Sports Med* 2016;44:995–1003.
20 Thompson C, Schabrun S, Romero R, *et al*. Factors contributing to chronic ankle instability: a systematic review and meta-analysis of systematic reviews. *Sports Med* 2018;48:189–205.
21 Delahunt E, Bleakley CM, Bossard DS, *et al*. Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International ankle Consortium. *Br J Sports Med* 2018;52:1304–10.
22 Smith MD, Vicenzino B, Bahr R, *et al*. Return to sport decisions after an acute lateral ankle sprain injury: introducing the PAASS framework-an international multidisciplinary consensus. *Br J Sports Med* 2021;55:1270–6.
23 Tassignon B, Verschueren J, Delahunt E, *et al*. Criteria-based return to sport decision-making following lateral ankle sprain injury: a systematic review and narrative synthesis. *Sports Med* 2019;49:601–19.
24 De Boer AS, Schepers T, Panneman MJM, *et al*. Health care consumption and costs due to foot and ankle injuries in the Netherlands, 1986-2010. *BMC Musculoskelet Disord* 2014;15:128.
25 Donovan L, Hetzel S, Laufenberg CR, *et al*. Prevalence and impact of chronic ankle instability in adolescent athletes. *Orthop J Sports Med* 2020;8:2325967119900962.
26 Cooke M, Marsh J, Clark M, *et al*. Treatment of severe ankle sprain: a pragmatic randomised controlled trial comparing the clinical effectiveness and cost-effectiveness of three types of mechanical ankle support with tubular bandage. The cast trial. *Health Technol Assess* 2009;13:ix–x,
27 Shah S, Thomas AC, Noone JM, *et al*. Incidence and cost of ankle sprains in United States emergency departments. *Sports Health* 2016;8:547–52.
28 Valderrabano V, Horisberger M, Russell I, *et al*. Etiology of ankle osteoarthritis. *Clin Orthop Relat Res* 2009;467:1800–6.
29 Knowles SB, Marshall SW, Miller T, *et al*. Cost of injuries from a prospective cohort study of North Carolina high school athletes. *Inj Prev* 2007;13:416–21.

30 Bielska IA, Wang X, Lee R, *et al*. The health economics of ankle and foot sprains and fractures: a systematic review of english-language published papers. Part 2: the direct and indirect costs of injury. *Foot (Edinb)* 2019;39:115–21.
31 Bielska IA, Wang X, Lee R, *et al*. The health economics of ankle and foot sprains and fractures: a systematic review of English-language published papers. Part 1: overview and critical appraisal. *Foot (Edinb)* 2019;39:106–14.
32 Gribble PA, Bleakley CM, Caulfield BM, *et al*. Evidence review for the 2016 International Ankle Consortium consensus statement on the prevalence, impact and long-term consequences of lateral ankle sprains. *Br J Sports Med* 2016;50:1496–505.
33 Vargas C, Bilbeny N, Balmaceda C, *et al*. Costs and consequences of chronic pain due to musculoskeletal disorders from a health system perspective in Chile. *Pain Rep* 2018;3:e656.
34 von Elm E, Altman DG, Egger M, *et al*. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61:344–9.
35 Gribble PA, Delahunt E, Bleakley CM, *et al*. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. *J Athl Train* 2014;49:121–7.
36 Gribble PA, Delahunt E, Bleakley C, *et al*. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. *J Orthop Sports Phys Ther* 2013;43:585–91.
37 Peduzzi P, Concato J, Kemper E, *et al*. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol* 1996;49:1373–9.
38 Sharma S, Mudgal S, Thakur K, *et al*. How to calculate sample size for observational and experimental nursing research studies. *Natl J Physiol Pharm Pharmacol* 2019;10:1–8.
39 Hultman K, Fältström A, Öberg U. The effect of early physiotherapy after an acute ankle sprain. *Advances in Physiotherapy* 2010;12:65–73.
40 Kachanathu S, Hafez A, Alenazi A, *et al*. Efficacy of closed and open kinematic chain exercises on ankle sprain rehabilitation. *Phys Med Rehab Kuror* 2016;26:28–31. 10.1055/s-0035-1565047 Available: http://www.thieme-connect.de/products/ejournals/issue/10.1055/s-006-31049
41 Lazarou L, Kofotolis N, Malliou P, *et al*. Effects of two proprioceptive training programs on joint position sense, strength, activation and recurrent injuries after ankle sprains. *IES* 2017;25:289–300.
42 Lazarou L, Kofotolis N, Pafis G, *et al*. Effects of two proprioceptive training programs on ankle range of motion, pain, functional and balance performance in individuals with ankle sprain. *J Back Musculoskelet Rehabil* 2018;31:437–46.
43 Punt IM, Ziltener J-L, Monnin D, *et al*. Exercise therapy for the rehabilitation of ankle sprains: its effect compared with physical therapy or no functional exercises at all. *Scand J Med Sci Sports* 2016;26:816–23.
44 van Rijn RM, van Os AG, Kleinrensink G-J, *et al*. Supervised exercises for adults with acute lateral ankle sprain: a randomised controlled trial. *Br J Gen Pract* 2007;57:793–800.
45 D'Hooghe P, Cruz F, Alkhelaifi K. Return to play after a lateral ligament ankle sprain. *Curr Rev Musculoskelet Med* 2020;13:281–8.
46 Verhagen E, van der Beek A, Twisk J, *et al*. The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. *Am J Sports Med* 2004;32:1385–93.
47 Wikstrom EA, Tillman MD, Chmielewski TL, *et al*. Discriminating between copers and people with chronic ankle instability. *J Athl Train* 2012;47:136–42.
48 Henderson REA, Walker BF, Young KJ. The accuracy of diagnostic ultrasound imaging for musculoskeletal soft tissue pathology of the extremities: a comprehensive review of the literature. *Chiropr Man Therap* 2015;23:31.
49 van Dijk CN, Lim LS, Bossuyt PM, *et al*. Physical examination is sufficient for the diagnosis of Sprained Ankles. *J Bone Joint Surg Br* 1996;78:958–62.
50 George J, Jaafar Z, Hairi IR, *et al*. The correlation between clinical and ultrasound evaluation of anterior talofibular ligament and calcaneofibular ligament tears in athletes. *J Sports Med Phys Fitness* 2020;60:749–57.
51 Schneiders A, Karas S. The accuracy of clinical tests in diagnosing ankle ligament injury. *European Journal of Physiotherapy* 2016;18:245–53.
52 Hawker GA, Mian S, Kendzerska T, *et al*. Measures of adult pain: visual analog scale for pain (VAS pain), numeric rating scale for pain (NRS pain), McGill pain questionnaire (MPQ), short-form McGill pain questionnaire (SF-MPQ), chronic pain grade scale (CPGS), short form-36 bodily pain scale (SF-36 BPs), and measure of intermittent and constant osteoarthritis pain (ICOAP). *Arthritis Care Res (Hoboken)* 2011;63 Suppl 11:S240–52.
53 Katz J, Melzack R. Measurement of pain. *Surg Clin North Am* 1999;79:231–52.
54 Matthews M, Rathleff MS, Vicenzino B, *et al*. Capturing patient-reported area of knee pain: a concurrent validity study using digital technology in patients with patellofemoral pain. *PeerJ* 2018;6:e4406.
55 Vuurberg G, Kluit L, van Dijk CN. The cumberland ankle instability tool (CAIT) in the Dutch population with and without complaints of ankle instability. *Knee Surg Sports Traumatol Arthrosc* 2018;26:882–91.
56 Hoch JM, Legner JL, Lorete C, *et al*. The validity of the quick-faam in patients seeking treatment for an acute or subacute foot or ankle health condition. *J Sport Rehabil* 2017;26:jsr.2016-0089.
57 Hoch JM, Hartzell J, Kosik KB, *et al*. Continued validation and known groups validity of the quick-faam: inclusion of participants with chronic ankle instability and ankle sprain copers. *Phys Ther Sport* 2020;43:84–8.
58 Hoch JM, Powden CJ, Hoch MC. Reliability, minimal detectable change, and responsiveness of the quick-faam. *Phys Ther Sport* 2018;32:269–72.
59 Moss-Morris R, Weinman J, Petrie K, *et al*. The revised illness perception questionnaire (IPQ-R). *Psychology & Health* 2002;17:1–16.
60 Leysen M, Nijs J, Meeus M, *et al*. Clinimetric properties of illness perception questionnaire revised (IPQ-R) and brief illness perception questionnaire (brief IPQ) in patients with musculoskeletal disorders: a systematic review. *Man Ther* 2015;20:10–7.
61 Williamson E. Fear avoidance beliefs questionnaire (FABQ). *Aust J Physiother* 2006;52:149.
62 Woby SR, Roach NK, Urmston M, *et al*. Psychometric properties of the TSK-11: a shortened version of the Tampa scale for kinesiophobia. *Pain* 2005;117:137–44.
63 Thompson AJ, Turner AJ. A comparison of the EQ-5D-3L and EQ-5D-5L. *Pharmacoeconomics* 2020;38:575–91.
64 Edwards JE, Babington P, Ozmun JC, *et al*. Validity and reliability of an activity monitor with the capability of providing geographic location using GPs. *Medicine & Science in Sports & Exercise* 2002;34:S41.
65 Konor MM, Morton S, Eckerson JM, *et al*. Reliability of three measures of ankle dorsiflexion range of motion. *Int J Sports Phys Ther* 2012;7:279–87.
66 O'Shea S, Grafton K. The intra and inter-rater reliability of a modified weight-bearing lunge measure of ankle dorsiflexion. *Man Ther* 2013;18:264–8.
67 Fraser JJ, Koldenhoven RM, Saliba SA, *et al*. Reliability of ankle-foot morphology, mobility, strength, and motor performance measures. *Int J Sports Phys Ther* 2017;12:1134–49.
68 Powden CJ, Hoch JM, Hoch MC. Reliability and minimal detectable change of the weight-bearing lunge test: a systematic review. *Man Ther* 2015;20:524–32.
69 Spink MJ, Fotoohabadi MR, Menz HB. Foot and ankle strength assessment using hand-held dynamometry: reliability and age-related differences. *Gerontology* 2010;56:525–32.
70 Thorborg K, Bandholm T, Hölmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surg Sports Traumatol Arthrosc* 2013;21:550–5.
71 Mentiplay BF, Perraton LG, Bower KJ, *et al*. Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: a reliability and validity study. *PLoS One* 2015;10:e0140822.
72 Baert IAC, Lluch E, Struyf T, *et al*. Inter- and intrarater reliability of two proprioception tests using clinical applicable measurement tools in subjects with and without knee osteoarthritis. *Musculoskelet Sci Pract* 2018;35:105–9.
73 Robbins S, Waked E, Rappel R. Ankle taping improves proprioception before and after exercise in young men. *Br J Sports Med* 1995;29:242–7.
74 Kynsburg A, Halasi T, Tállay A, *et al*. Changes in joint position sense after conservatively treated chronic lateral ankle instability. *Knee Surg Sports Traumatol Arthrosc* 2006;14:1299–306.
75 Halasi T, Kynsburg A, Tállay A, *et al*. Changes in joint position sense after surgically treated chronic lateral ankle instability. *Br J Sports Med* 2005;39:818–24.
76 Docherty CL, Arnold BL, Gansneder BM, *et al*. Functional-performance deficits in volunteers with functional ankle instability. *J Athl Train* 2005;40:30–4.

77 Linens SW, Ross SE, Arnold BL, *et al*. Postural-stability tests that identify individuals with chronic ankle instability. *J Athl Train* 2014;49:15–23.
78 Shaffer SW, Teyhen DS, Lorenson CL, *et al*. Y-balance test: a reliability study involving multiple raters. *Mil Med* 2013;178:1264–70.
79 Liebermann DG, Katz L. On the assessment of lower-limb muscular power capability. *IES* 2003;11:87–94.
80 Haynes T, Bishop C, Antrobus M, *et al*. The validity and reliability of the my jump 2 APP for measuring the reactive strength index and drop jump performance. *J Sports Med Phys Fitness* 2019;59:253–8.
81 Markovic G, Dizdar D, Jukic I, *et al*. Reliability and factorial validity of squat and countermovement jump tests. *J Strength Cond Res* 2004;18:551–5.
82 Raya MA, Gailey RS, Gaunaurd IA, *et al*. Comparison of three agility tests with male servicemembers: edgren side step test, t-test, and Illinois agility test. *J Rehabil Res Dev* 2013;50:951–60.
83 Robinson LS, Sarkies M, Brown T, *et al*. Direct, indirect and intangible costs of acute hand and wrist injuries: a systematic review. *Injury* 2016;47:2614–26.
84 Jo C. Cost-Of-Illness studies: concepts, scopes, and methods. *Clin Mol Hepatol* 2014;20:327–37.