<table>
<thead>
<tr>
<th>Test</th>
<th>Protocol description</th>
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| Tibiofemoral frontal plane alignment | • Palpate & mark tibial tuberosity & midpoint over the talus neck  
• Ask participant to stand on footprint map with foot at 10° external rotation, feet shoulder width, looking forward, 50% weightbearing  
• Place callipers of inclinometer in alignment with the the two landmarks  
• Record varus/valgus direction in degrees |
| Herrington test               | • Participant supine on plinth, knee positioned and supported in 20° of knee flexion (to place the patella within the trochlea groove)  
• With knee in position, place a piece of 1” Leukotape (or similar) across the knee joint, and mark the medial and lateral epicondyles of the femur and mid-point of the patella. Be sure to make note of medial and lateral end of tape  
• Repeat 3 times, attaching tape to this document for measuring later |
| 30 second chair stand test    | • **Shoes on**, middle of chair, feet ~ shoulder width apart and slightly behind knees with feet flat on floor, arms crossed on chest  
• Instructions **“stand up keeping arms across chest, and ensure you stand completely up so hips and knees are fully extended; then sit completely back down, so that the bottom fully touches the seat, as many times as possible in 30 seconds,”**  
• 1-2 practice repetitions for technique  
• One 30-second test trial  
• Record number of correctly performed full stands (if more than ½ of way up at end of the test, counted as a full stand) |
| Repetitive single leg rise test | • **Shoes on**, seated on edge of plinth, foot placed with heel 10 cm forward from a plumb line at edge of plinth, other leg held at side of body, arms across chest.  
• Height of plinth adjusted so knee angle is 90°  
• Instructions: **“keep back of heel on marker, stand as many times as possible on one leg keeping arms across chest, in time with the metronome (45bpm). If you get to 50 we will stop. Control yourself on the descent”**  
• 2-3 practice tests |
| **Timed 12 stair climb** | - If nonweightbearing leg touches ground, do not count that rise; if touches ground 3 times during test, record number of rises to that point only and stop test  
- Participant wears usual footwear  
- Instructions “climb up then down the 2 small flights of stairs as quickly as possible but safely”  
- 1-2 practice trials for technique and to confirm safety  
- Trial: record time to ascend and descend 12 steps - up 2 flights of 6 steps then descend  
- (both feet touch down at bottom of landing to end timer)  
- No use of hand-rails or gait aids  
- Height of step: 18 cm  
- Depth of step: 32 cm |
| **Ankle dorsiflexion range of motion (ROM)** | - Participant stands in front of a wall with horizontal line bisecting calcaneus and second toe  
- Participant instructed to lunge forward to touch knee to wall  
- Move foot back gradually until can just touch wall while maintaining heel on floor  
- Measure distance between tip of great toe and wall  
- Measure shank length from lateral knee joint line to lateral malleolus |
| **Knee hyperextension ROM** | - Participant supine on plinth, towel under Achilles tendon  
- Measure ROM using 12” goniometer – axis over lateral epicondyle of femur; stationary arm towards greater trochanter; movable arm toward lateral malleolus |
| **Knee flexion ROM** | - Participant supine on plinth, slides heel towards buttocks without lifting heel off plinth  
- Measure ROM using 12” goniometer – axis over lateral epicondyle of femur; stationary arm towards greater trochanter; movable arm toward lateral malleolus |
| **Hip extension ROM** | - Participant prone, feet off end of plinth, chin resting on hands  
- Belt across pelvis  
- Measure ROM using 12” goniometer – axis over greater trochanter; stationary arm parallel to mid-axillary line of trunk; movable arm toward lateral epicondyle of femur  
- Knee maintained in extension |
| **Hip flexion ROM** | - Participant supine on plinth, bends knee and draws knee towards chest without using hands  
- Measure ROM using 12” goniometer – axis over greater trochanter; stationary arm parallel to mid-axillary line of trunk; movable arm toward lateral epicondyle of femur |
| **Hip internal rotation ROM** | - Participant prone on plinth, test leg in 90° knee flexion  
- Belt across pelvis |
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<tr>
<th>Test Type</th>
<th>Instructions &amp; Equipment</th>
<th>Notes</th>
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| Hip external rotation ROM         | • Participant prone on plinth, test leg in 90° knee flexion, non-test leg in slight abduction for clearance  
  • Belt across pelvis               | • Inclinometer held to outside of shin 5 cm proximal to lateral malleolus, starting angle is 0°.  
  • Instructions: “let leg drop out to side as far as possible”  
  • Record angle without overpressure |                                                                                           |
| Isokinetic knee extension / flexion strength (Biodex) | • Participant seated in Biodex, back rest at 70-85°  
  • Two speeds: 60° and 180° per second  
  • 1-2 sub-maximal practice trials (~50% effort)  
  • One max test trial at each speed, 5 repetitions  
  • ≥ 30 second rest between each test series  
  • Verbal encouragement “Go! Harder!”  
  • If > 15% coefficient of variance, repeat test |                                                                                           |
| Hip abduction strength            | • Isometric ‘make’ test, 3-5 second hold  
  • Participant supine, belt across contra-lateral thigh  
  • Index leg resting in hip neutral (0°)  
  • Force plate of handheld dynamometer positioned 5 cm above lateral malleolus  
  • Instructions “keep arms folded, heel on the bed and push leg out to side against force plate as hard as possible”  
  • 1-2 sub-maximal practice trials  
  • Verbal encouragement “Go! Go! Go!”  
  • ≥ 5 second rest between each repetition  
  • If > 10% variability, additional trial is performed  
  • Measure lever arm length: greater trochanter to dynamometer marker (5 cm proximal to lateral malleolus) |                                                                                           |
| Hip extension strength            | • Isometric ‘make’ test, 3-5 second hold  
  • Positioned in prone, belt across contra-lateral thigh, chin resting on hands, feet off the end of the bed  
  • Index leg at 90° knee flexion  
  • Force plate over centre of participant’s heel  
  • Instructions “push foot straight up to ceiling” |                                                                                           |
| Therapist matches force once knee leaves surface of plinth. | Hip internal rotation strength |
| 1-2 sub-maximal practice trials | Isometric ‘make’ test, 3-5 second hold |
| Verbal encouragement “Go! Go! Go!” | Positioned in prone, belt across contra-lateral thigh, index leg resting in hip neutral (0°), knee at 90° |
| ≥ 5 second rest between each repetition | Force plate positioned 5 cm above lateral malleolus |
| If > 10% variability, additional trial is performed | Instructions “turn shin outwards as hard as possible, keeping both knees together” |
| Measure lever arm length: inferior greater trochanter to lateral knee joint line | 1-2 sub-maximal practice trials |
| 1-2 sub-maximal practice trials | Verbal encouragement “Go! Go! Go!” |
| ≥ 5 second rest between each repetition | If > 10% variability, additional trial is performed |
| If > 10% variability, additional trial is performed | Measure lever arm length: knee joint line to dynamometer marker (5 cm proximal to lateral malleolus) |
| Measure lever arm length: knee joint line to dynamometer marker (5 cm proximal to lateral malleolus) | Hip external rotation strength |
| 3-5 second hold | Isometric ‘make’ test, 3-5 second hold |
| Positioned in prone, belt across contra-lateral thigh, index leg resting in hip neutral (0°), knee at 90° | Positioned in prone, belt across contra-lateral thigh, index leg resting in hip neutral (0°), knee at 90° |
| Force plate 5 cm proximal to medial malleolus | Force plate 5 cm proximal to medial malleolus |
| Instructions “turn shin inwards towards the centre as hard as possible” | Instructions “turn shin inwards towards the centre as hard as possible” |
| 1-2 sub-maximal practice trials | 1-2 sub-maximal practice trials |
| Verbal encouragement “Go! Go! Go!” | Verbal encouragement “Go! Go! Go!” |
| ≥ 5 second rest between each repetition | ≥ 5 second rest between each repetition |
| If > 10% variability, additional trial is performed | If > 10% variability, additional trial is performed |
| Measure lever arm length: knee joint line to dynamometer marker (5 cm proximal to medial malleolus) | Measure lever arm length: knee joint line to dynamometer marker (5 cm proximal to medial malleolus) |

**Single leg squats**
- Video camera 3 metres from participant, at height of lowest tripod setting (~65 cm)
- Adjust height of plinth behind participant to provide squat depth target to 45° knee flexion, using 12” goniometer
- Place reflective markers: midpoint of femoral condyles, bilateral ASIS, proximal thigh along line from ASIS to knee marker, midpoint of ankle malleoli, manubrium
- Participant stands, **shoes off**, on foot map with arms across chest
- free leg held in front of squat leg
<table>
<thead>
<tr>
<th><strong>Metronome and Exercise Details</strong></th>
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<tbody>
<tr>
<td>metronome 60 bpm, 2 ‘ticks’ each direction</td>
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<tr>
<td>single leg squat to 45° knee flexion (plinth behind participant – buttock touch plinth as target to reproduce angle)</td>
</tr>
<tr>
<td>2-3 practice trials</td>
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<tr>
<td>Repeat 5 times</td>
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<td>On test completion, participants were asked “How easy was it to perform the task?”. Response options were on a 5-point Likert scale ranging from ‘markedly easy’ to ‘markedly hard’</td>
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Supplementary Figure 1: Participants were positioned in supine for 2D (left) and upright for 3D (right) alignment measures. Note image on right shows standing two-legged, but in the present study participants stood on one leg only. Right-hand image from Journal of Magnetic Resonance Imaging, Macri EM et al., “Patellofemoral and tibiofemoral alignment in a fully weight-bearing upright MR: Implementation and repeatability” Published Online First: Doi:10.1002/jmri.25823, 2017, with permission from John Wiley and Sons.
A. Bisect offset (2D)  
Lateral translation (3D)

B. Patellar tilt angle (2D)  
Mediolateral tilt (3D)

C. Insall-Salvati ratio (2D)  
Proximal translation (3D)

Supplementary Figure 2: Description of alignment measures

A. 2D bisect offset is the percentage (%) of the widest line across the patella that lies lateral to a line bisecting the deepest part of the trochlea (arrow indicates direction of 3D lateral translation of patella relative to femur, in mm).  
B. 2D patellar tilt angle: Angle (θ) between posterior condylar line and line across widest part of patella (arrow indicates direction of 3D lateral tilt of patella relative to femur, in degrees).  
C. 2D Insall-Salvati Ratio is the ratio of patella tendon length to the patellar height (arrow indicates direction of 3D proximal translation of patella relative to femur, in mm)