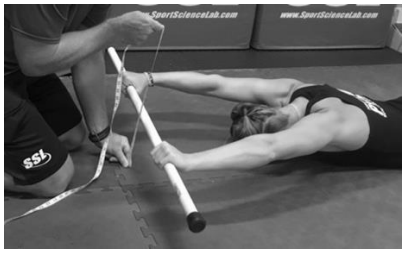
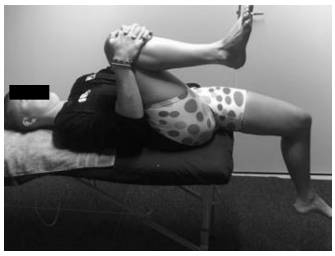
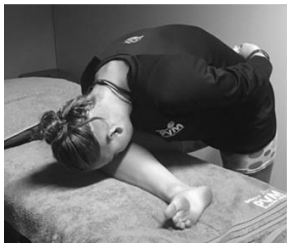
ONLINE APPENDIX 1

TABLE 1-A1: Sport Science Lab ® Screening Test Protocol.

Muscle group tested	Procedure and measurement
Modified V-sit 	**Description and standard instructions:** Participant is seated on the floor, with hands behind the back. Legs are kept straight and abducted at a 90° angle in relation to each other. The participant is then asked to: "lean forward, so that your forehead gets as close to the ground as possible without bending your knees". The vertical distance from mid-forehead is measured perpendicular to ground. **Equipment:** 150 cm tape measure **Proposed minimal standard:** ≤ 21cm
Toe-touch test 	**Description:** Participant stands on a 35cm box, with feet together and knees fully extended. Participant is asked to: "reach down with fingertips as far as possible without bending the knees". If a participant is able to touch his toes with the tip of the third finger, a measurement of 0 cm is recorded. If not, the vertical distance from the tip of the third finger to top of the box is measured.[1] If a participant is able to reach past the level of the surface of the box, the distance from third fingertip to box surface is measured and recorded as a negative (-) measurement. **Equipment:** 150 cm tape measure and 35 cm box **Proposed minimal standard:** 0 cm to -8 cm
Ankle dorsiflexion wall test 	**Description:** Tape measure is placed on the floor perpendicular to a vertical line drawn on the wall. The participant is asked to: "keep the heel of the test leg flat on the ground while lunging forward so that his knee touches the vertical line on the wall". The opposite leg can rest on the floor and participant can hold onto the wall for support. Maximum distance from wall to big toe is measured to the closest cm.[2] (Dennis et al, 2008) **Equipment:** 150 cm tape measure **Proposed minimal standard:** ≤ 12cm

Ankle plantar flexion test 	**Description:** The participant is asked to: "sit with your bottom touching your heels while keeping both heels together and the dorsal (top) aspect of the feet and shin on the ground". If the participant is able to keep the dorsal aspect of the feet and ankle flat against the ground, the examiner marks "yes" on the score sheet. If not, the examiner marks "no". **Equipment:** 150 cm tape measure **Proposed minimal standard:** "yes" rating i.e. both ankles should be fully plantar flexed and dorsal aspect of the feet and ankles flat against the ground.
Combined prone shoulder elevation 	**Description:** Participant lies in prone of floor with arms outstretched in front of him and forehead against the floor. Dowel is held in both hands. While wrists remain in neutral and forehead and chest remain flat on the ground, the participant is asked to: "raise the dowel as high as possible off the ground". Vertical distance (perpendicular to the ground) is measured from ground to the bottom of the dowel is measured to the nearest cm.[3] (Allen et al, 2017). **Equipment:** 150 cm tape measure, dowel. **Proposed minimal standard:** ≥ 45cm
Combined prone shoulder extension 	**Description:** Participant lies in prone on the floor with arms next to the sides and forehead against the floor. Dowel is held in both hands behind the back. Participant is asked to: "raise the dowel as high as possible off your low back while wrists remain in neutral and elbows fully extended". Distance from midway between anterior superior iliac spine to the bottom of the dowel is measured to the nearest cm. **Equipment:** 150 cm tape measure, dowel. **Suggested minimal standard:** ≥ 45cm
Combined shoulder mobility 	**Description:** Standing upright, the participant is asked to attempt to bring the third fingers of each hand together behind his back by reaching over head with one arm and underneath with the other. If the participant is able to do so, the examiner marks "yes" on the scoresheet. If not, the examiner marks "no" and the distance between the two third fingers is measured (to the nearest cm) and recorded. **Equipment:** 150 cm tape measure **Proposed minimal standard:** "Yes" rating i.e. third finger of each hand reach each other.
Combined shoulder rotation test	**Description:** The participant lies in a supine position on the plinth with the test arm abducted to 90° and the elbow flexed at a 90° angle. Standing on the test side of the plinth, the examiner depresses the AC joint to prevent protraction of the scapula while moving the arm into maximum external rotation (ER). Thereafter, following the same procedure the examiner moves the arm into internal shoulder rotation (IR). If the forearm is parallel to the longitudinal side of

 	the plinth or pass the level of the plinth, the examiner knows ER/IR of ≥90° was obtained (combined shoulder rotation is therefore ≥180°) and marks “yes” on the scoresheet. If rotation in either direction is <90° or > 90°, the vertical distance from neutral mid-wrist to the level of the plinth is measured. If the distance “gained” is equal the distance” lost in the opposite direction the examiner knows that combined rotation is 180°. If not, the examiner marks “no” and records the difference between the two measurements. **Equipment:** Plinth and 150 cm tape measure. **Proposed minimal standard:** Combined rotation of ≥ 180°
Modified Thomas test  	**Description:** Participant sits on the edge of the end of the plinth and is then asked to: “roll back on the plinth and pull both knees up to your chest. While one leg is held in flexion against the chest, the test leg is lowered towards the floor and allowed to hang freely.”[2] *Iliopsoas:* If the back of the thigh of the test leg is level to the surface of the plinth or lower the, the rater marks “yes” if not the rater marks “no”. *Rectus femoris*: If the knee of the test leg is flexed to 90° while in the test position the rater marks “yes”, if not the rater marks “no”. *ITB/Hip abductors:* If the knee of the test leg remains in a straight line in relation to the test hip, the rater marks “yes”, if not the rater marks “no” **Equipment:** Plinth **Proposed minimal standard**: “yes” rating for assessment of iliopsoas, rectus femoris and ITB/Hip abductors.

Hip internal rotation 	**Description:** Participant lies in prone on plinth or floor with knees together and flexed to 90°. The examiner moves the participant's ankles away from each other, while knees remain together as far as possible. If ankles/heels move past half the distance from initial position to surface, the examiner knows that internal hip rotation is > 45° and marks "yes". If not, a "no" is marked. **Equipment:** Plinth **Proposed minimal standard**: "yes" rating i.e. hip internal rotation >45degrees.
Hip external rotation  	**Description:** Participant places lateral side test leg (thigh) on top of the plinth and bends the knee to 90°. The knee is then moved inward so that the knee is in a straight line in relation to the hip that is flexed at 90°. If the participant is tall, the opposite leg can be bent to achieve 90° hip flexion of the test leg. If the participant is short, he can stand on a step to obtain 90° hip flexion. With both hands behind the back, the participant is asked to lean forward so that his forehead touches the plinth without compromising the knee or hip angles. If the participant is able to touch the bed with his forehead the examiner marks "yes" if not the examiner marks "no". **Equipment:** Plinth **Proposed minimal standard**: "yes" rating i.e. forehead can touch the plinth with test leg hip flexed at 90° and internally rotated at 90°.

STRENGTH TESTS

NOTE: For all strength tests, **except** the Double leg lower (Abdominal) and Oblique Twist tests, listed below, the following SSL manual strength rating scale applies

5 = Examiner is unable to break participant's initial isometric hold.

4 = Examiner is able to break participants' initial isometric hold, but participant is able to stop downward limb movement by maximum eccentric resistance after initial break

3 = Examiner is able to break initial isometric hold and move participant through range but against moderate eccentric resistance from participant.

2 = Examiner is able to break initial isometric hold and move participant easily through range with minimal eccentric resistance from participant.

1 = Examiner is able to break initial isometric hold with minimal effort and no resistance offered by participant through the rest of the range.

0 = Pain during performance of the test.

Test	Procedure and measurement
Glut/Ham test 	**Description**: Participant lies on floor in prone position with hands next to his chest as if getting ready to do a “push-up”. Chest remains flat on the floor at all times. Participant asked to: “bend knee of test leg to 90°, lift thigh and hip off the ground and resist examiners external force with maximum effort”. In a half kneeling position, the examiner with hand placed on the mid-posterior thigh of participant, tries to break participant’s hold by pushing the thigh down towards the ground. **Proposed minimum standard**: 4-5/5
Hip external rotator test 	**Description**: Participant lies on floor in prone position with hands next to his chest as if getting ready to do a “push-up”. Chest and pelvis remain flat on the floor and knees together at all times. Knee of the test leg is bent to 90° and participant asked to” “resist examiners external force with maximum effort”. In a half kneeling position and holding onto the medial aspect of the of the participant’s ankle, the examiner tries to break participant’s hold by moving the ankle outward towards the ground. **Proposed minimum standard**: 4-5/5
Hip internal rotators test 	**Description**: Participant lies on floor in prone position with hands next to his chest as if getting ready to do a “push-up”. Chest and pelvis remain flat on the floor and knees together at all times. Knee of test leg is bent to 90° and participant asked to resist examiners internal force with maximum effort. In a half kneeling position and holding onto the lateral aspect of the of the participant’s ankle, the examiner tries to break participant’s hold by moving the ankle inward towards the ground. **Proposed minimum standard**: 4-5/5
Bilateral hip abductor test 	**Description**: Participant is seated on the plinth with legs stretched out in front of him and heels on the corners of the plinth. The participant is allowed to hold onto the sides of the plinth to stabilise himself. The examiner stands at the foot of the plinth and places his/her hands on the lateral aspect of the participant’s ankles. Participant is asked to: “maximally resist inward force applied by the examiner while keeping buttocks flat on bed and knees straight.” **Proposed minimum standard**: 4-5/5
Bilateral hip adductor test 	**Description**: Participant is seated on the plinth with ankles together and legs stretched out in front of him. The participant is allowed to hold onto the sides of the plinth to stabilise himself. The examiner stands at the foot of the plinth and places his/her hands on the medial aspect of the participant’s ankles. Participant is asked to: “maximally resist outward force applied by the examiner while keeping the buttocks flat on bed and knees straight”. **Proposed minimum standard**: 4-5/5

Shoulder external rotation strength test 	The participant lies in a supine position on the plinth with the test arm abducted to 90° and the elbow flexed at a 90° angle. Standing on the test side of the plinth, the examiner depresses the AC joint to prevent protraction of the scapula while moving the arm into maximum IR. Participant is asked to maximally resist downward force applied by the examiner. **Proposed minimum standard**: 4-5/5
Shoulder internal rotation strength test 	**Description:** The participant lies in a supine position on the plinth with the test arm abducted to 90° and the elbow flexed at a 90° angle. Standing on the test side of the plinth, the examiner depresses the AC joint and prevents protraction of the scapula while moving the arm into maximum ER. Participant is asked to maximally resist downward force applied by the examiner. **Proposed minimum standard**: 4-5/5
Double leg lower test  	**Description**: Participant lies in supine with both legs straight and in a vertical position (hips flexed to 90°). The examiner places a flat hand between the participants lumbar spine and the floor. The participant is then asked to: ”lower the both legs simultaneously to the floor as many consecutive times as possible, while keeping the knees straight and contracting the deep abdominal muscles to hold the low back flat against the examiners hand” (to prevent anterior tilting of the pelvis.[4] If the participant in unable to hold his low back against the examiners hand while performing the leg lowers the test is terminated and the number of repetitions recorded. If the participant is able to perform 23 repetitions the test is also terminated. **Proposed minimal standard:** 23 repetitions
Oblique twist test   	**Description**: Participant lies in supine with both knees straight (or slightly bent) and in a vertical position (hips flexed to 90°). Arms are spread out at 90° abduction and kept flat on the ground at all times. Maintaining this position, the participant in asked to: “moved legs simultaneously, in one motion from side-to-side, lightly touching the ground on each side.” Each ground touch is counted as a repetition. **Proposed minimal standard:** 20 repetitions

TABLE 2-A1: Purpose and Rationale for inclusion, modification and minimal standards for flexibility and strength tests included in the SSL® Screening protocol.

TEST	Purpose and Rationale for inclusion/ modification of the test and minimal standards
Rationale for inclusion of tests based on body region	*Upper limbs* The shoulder comprises of 20% of all rugby injuries and which is the second most common injury sustained.[1] De Beer et al.[6] highlights that certain injury patterns are specific to the game of rugby. The position and way screening tests aimed at identifying injury risk factors are done should exploit these patterns. Crichton et al.[7] summarises three mechanisms of traumatic shoulder injury among elite rugby players. The "try-scorer" is characterised by hyperflexion of the outstretched arm with or without direct inferior forces. "The tackler" describes how the shoulder is forced into extension, abduction and external rotation during the execution of a tackle on a ball carrier at high speeds. "Direct impact" is a result form a direct blow to a shoulder held in a neutral position or in slight adduction. The ranges and movements described above were considered when selecting the upper limb strength and flexibility tests included in this protocol. *Spine and trunk* Lumbar disc and nerve root are amongst the injuries causing greatest absence from training amongst forwards.[8] The spine functions as part of a complex neuromusculoskeletal system and is an essential part of rugby players' functional kinetic chains.[9] Moreover, the spinal column, together with the rib cage and pelvis forms part of the central component of the skeleton which together with the surrounding soft tissue function to absorb and dissipate forces which act upon the body.[10] Hopkins et al.[10] conclude that amongst other interventions, improved muscular strength around the spine and eliminating impairments in spinal flexibility not only benefit players' on-field performance but also prevent injury during strength conditioning. Considering the above, the authors included tests challenging trunk and low back mobility and strength. *Lower body* Kaux et al.[11] found that lower limb injuries occurred more often than injuries to other body areas. Hamstring and adductor injuries are common among professional English forwards and backs, while ACL injuries cause the longest absence from training among backs.[8] Among elite Australian rugby union players thigh, knee and ankle injuries were the most prevalent lower limb injuries. Considering the sites of the reported injury incidences above and the role of the respective lower limb joints and surrounding soft tissue during multidirectional propulsion, the developers included various lower limb strength and flexibility screening tests.

Flexibility	
	Rationale for modification of flexibility testing: While the reliability of some of the flexibility tests included (i.e. dorsiflexion lunge test) have been investigated among, for example, cricketers[2], limited published studies include elite rugby players. The measurement of other existing flexibility tests have been modified to ease the practicality thereof. These tests and others included in, for example, the current SARU screening protocol, requires the angular measurement of joint ROM and related muscle length. Angular measurements are time consuming and require sophisticated equipment (goniometers or inclinometers) and skill compared to lineal tests that only require distance or length measurement with a standard tape measure.[12] The flexibility or joint ROM tests included in the SSL® screening protocol, are therefore measured using a tape measure or considered relative to stationary objects with either 0° horizontal or vertical planes such as a plinth.
Modified V-sit reach test **(MVSR)**	**Purpose:** To assess mobility of the spine (especially lumbar spine) and hamstrings.[13] **Rationale for inclusion and modification of test**: Odds ratio's for back pain have been found to be significantly higher in elite athletes who participate in amongst others rugby.[14] Devlen et al.[15] have found posterior thigh on of the most common injuries in rugby and acknowledges its multifactorial aetiology which includes lumbar spine dysfunction. Poor performance of the sit-and-reach and modified sit-and reach have been associated with increased risk of hamstring injuries.[15,16] The traditional sit-and-reach and V-sit-and-reach tests requires participants to perform trunk flexion while the arms are outstretched. This position elongates the Latissimus dorsi muscle and the associated thoraco-lumbar fascia (TLF). A participant's lack of flexibility of the upper limbs (through flexion) via the thoracolumbar fascia might therefore limit his reaching ability in this position. To eliminate limitations posed by lack of upper limb flexibility, the developers of the SSL screening protocol propose a modified version of the V-sit test, where the athlete places the hands behind the back. The vertical distance from the mid-forehead perpendicular to the ground is measured, instead of reach distance. **Rationale for minimal standard:** As this is a modified version of and existing tests there are no documented norms, therefore minimal standards are based on clinical experience.
Toe-touch-test	**Purpose:** To assess global trunk movement (total thoraco-lumbar pelvic) mobility when bending forward in standing position.[17]

	Rationale for inclusion of test: Takaki et al.[18] found that elite university level players with low back pain (LBP), has significantly greater finger-to-toe distances compared to those without LBP. Poor correlations between isolated low back flexion and low back disability have been documented, therefore global trunk flexion during testing was therefore deemed more accurate.[19] **Minimal standard:** Magnusson et al.[1] suggested a normative value of 8cm for endurance athletes while, Carregaro et al.[20] suggested 10 cm for healthy males (average age 35). Based on clinical experience, the authors of the SSL screening protocol have found lower risk of injury among various elite level athletes, reaching within a range of 0 and -8cm.
Ankle dorsiflexion	**Purpose:** To assess the dorsiflexion ROM of the ankle joint in a weight bearing position. **Rationale for inclusion/modification of the test:** Compared to other tests including muscle plantar- and dorsiflexion strength and ankle joint laxity, Okgaki et al.[1,2] identified lack of ankle dorsiflexion range as an important risk factor for ankle sprains among collegiate rugby players. Weight bearing ankle dorsiflexion range more accurately reflect ROM during functional activities running or scrummaging compared to open chain ROM.[21] **Rationale for minimal standard:** Yeomans et al.[22] reported that an ADFW norm of 9.90-10.90 cm among amateur rugby union players did not have an association with injury. However, risk of injury using a measure of less than 10 cm increased Australian football players' risk of sustaining a hamstring injury.[23] Cricket bowlers with a range of less than 14 cm have also been found to be more injury prone. [2] The minimum standard was therefore set at a figure between the above standards at 12 cm.
Ankle plantar flexion	**Purpose:** To assess passive plantar flexion ROM of the ankle joint. **Rationale for inclusion/modification of the test:** Full range plantar flexion allow players to execute powerful take-off during sprinting and jumping**.** During the push off-phase in running, maximal force is generated during concurrent triple extension of the ankle, knee and hip.[24] Limitations in PF ROM restrict the lever (i.e. the foot) to accelerate to optimal velocity achieved at the end range of motion and therefore might inhibit optimal transfer of forces. As a result, compensations may appear further up along the kinetic chain i.e. greater demand for force production on muscles of the posterior chain, resulting in injury. Open-chain plantar flexion ROM measurement is angular in nature and the authors therefore preferred to include a non-angular, clinically friendly test (also used as a modification strategy for limited plantar flexion range) that requires maximal plantar flexion.

	Rationale for minimal standard: The test has not previously been used as a screening test and the minimal standard is therefore based on clinical experience.
Modified Thomas test (MTT)	**Purpose:** To assess the flexibility of the hip flexors, (Iliopsoas and rectus femoris), knee extensors (quadriceps) and tensor facia lata/ITB.[2] **Rationale for inclusion:** Among various team sport athletes including rugby players, tightness of the hip flexors (as tested by the MTT) has been associated with low back pain[18], hamstring injuries[16] and patellar tendinitis[25]. Also, during the terminal moment of the push-off phase of sprinting, the hip and knee have to extend maximally to allow the stretch-reflex to recoil the hip through flexion during the swing phase. The authors hypothesise that if full hip extension can't be achieved due to a lack of flexibility, the stretch-reflex can't be utilised optimally and causing the athlete to actively force knee drive resulting in acute or overuse type injuries.
Hip internal rotation **Hip external rotation**	**Purpose:** To assess internal- (IR) and external rotation (ER) of the hips. **Rationale for inclusion/modification of the test**: Rugby is multi-directional in nature and require rapid change of direction (COD). During training and play, players will repeatedly move the hips internally across the opposite leg either in kicking or side stepping or externally as in drop kicking or turning. Correct COD technique requires athletes to turn the foot by internally or externally rotating the hip in the intended new direction.[26] Lack of full range internal and external hip rotation are associated with injury mechanisms involving torsion (e.g. ACL, meniscus and groin tears).[27] Reduced total hip rotation has been associated with injury (e.g. chronic groin[28] and low back[29] in several sporting populations.[28,29] The general method for assessing hip rotation is an angular measurement using a goniometer.[23] The SSL protocol developers prefer tests which are more clinically friendly and side-to-side comparisons obvious and simple. **Rationale for minimum standard and position of testing Hip IR:** Normative values for internal hip rotation among rugby players are yet to be investigated. The minimum standard was therefore based on results published by Han et al.[19] who reported IR in prone as (44.2±10.1). The 45° is easier to judge by eye (mid-way between starting position and surface on which participant is positioned) the authors set 45° as minimal standard. **Rationale for minimum standard and position of testing ER:** As this test has only been used as therapeutic modality where reduced hip ER has been identified, no minimal standards have been documented and are therefore based on clinical experience.

Combined shoulder elevation test	**Purpose:** To assess shoulder girdle mobility (shoulder elevation through flexion and scapular retraction) and thoracic spine extension.[3] This test also assesses the strength of the peri-scapular and posterior glenohumeral musculature. **Rationale for inclusion of the test**: Less frequent but not uncommon shoulder injuries associated with inferior displacement of the GHJ, such as humeral avulsion of the glenohumeral ligaments, occur with the arm in forward elevation with an inferiorly directed force.[6,7] **Rationale for minimal standards:** No minimal standards have been reported for rugby players or other contact sport athletes the minimal standard is therefore based on clinical experience.
Combined shoulder extension test	**Purpose:** To assess upper limb mobility (shoulder extension, scapula retraction) and thoracic spine extension. **Rationale for inclusion of the test**: As shoulder extension is a component of global glenohumeral joint motion during running as well as required for the absorption of direct impact to the shoulder girdle during a tackle, a test assessing shoulder extension mobility should be included in an official screening protocol. **Rationale for inclusion of the test**: As this is a newly designed test, no minimal standard has been reported for rugby players or other contact sport athletes the minimal standard is therefore based on clinical experience.
Combined shoulder rotation test	**Purpose:** Shoulder internal- and external rotation measurements are representative of posterior and anterior capsular tightness respectively. **Rationale for inclusion/modification of the tests:** Rotator cuff and other muscular injuries (e.g. pectoralis major tears) occurs with the shoulder in abduction or extension and forced downward and backward especially during a fall or tackle.[6] Glenohumeral (GHJ) and other common upper limb injuries (e.g. SLAP lesions, bicep tendon tears) related to anterior dislocation is often cause by falling onto a flexed elbow. Assessment of shoulder IR and ER ROM and strength with the shoulder in 90° abduction and elbow flexed at 90° seemed more rugby specific than rotational assessment with the shoulder at 0°. Traditionally, athletes trained for sports which involve overhead activities and movements, present with an adaptive increase in shoulder external range of motion with a concurrent decrease in internal range of motion.[30] Although rugby does not typically involve overhead activities (except for line-out throws and lifts) activities such as overhead power lifting is often included in strength conditioning regimes. Rugby players have also been associated with external rotation range lack.[30] **Rationale for minimum standard:** Normative data for rugby players: Total rotation range (161.7.78±12.99 -167.11±12.12).[30] Considering the reported standard deviations and the fact that 43% of the players included in this study previously sustained shoulder injuries, the normative total

	rotation values for the control groups (180.33-182.53) and the relative ease of judging ("eye-balling") 90° without a goniometer when the participant is lying in supine (forearm directly parallel or flat on plinth surface), the SSL developers set the minimal standard at 180° total rotation range of motion (90° IR and 90° ER).
Shoulder combined mobility test	**Purpose:** To assess concurrent bilateral shoulder ROM. Combined extension, internal rotation and adduction in the bottom shoulder and combined flexion, external rotation and abduction in top shoulder.[31] **Rationale for inclusion/modification of the test:** Forced abduction and external rotation, typically in a tackle situation or landing with the ball with an outstretched arm (flexion), account for 32% of shoulder injuries.[5] Considering the above, the authors include this test in the screening protocol as mobility of the gleno-humeral joint in multiple plane of motions are assessed simultaneously with the stability provided by complementary rhythm of the scapula-thoracic region.[31] To make the test more user friendly, the measurement of the test differs slightly from that initially described by Cook et al.,[31] in that hands are kept open and the distance between the two fingers closed to each other is measured. **Rationale for minimal standard:** Cook et al.[31] rated this test on a score of three to one based on the proximity of the fists to each other in relation to the length of the tip of the third finger to the wrist. As this requires additional measurements and calculations the SSL screening protocol simplifies the rating test on a dichotomous "yes" or "no" scale.

Strength tests

Rationale for modification of manual muscle testing:

Manual muscle testing and strength rating scales have been documented by numerous authors.[32,33] All of these proposed tests and their respective rating scales have the following in common:

a. With the exception of the Grade 5 rating which requires optimal isometric muscle action, only concentric muscle actions are tested and rated.
b. All tests are rated according to the participants ability or inability to move the involved joint against gravity regardless of the functionality of the participants testing position.

Firstly, with regards to the testing of concentric muscle actions: Verkhoshansky[34] reported that forces generated during concentric contractions to be 1.2-1.6 times less than the force produced during an eccentric contraction. Contact sport players are often required to rapidly change direction or counteract external forces generated by opposing players to prevent opposing players from moving forward. Both of these actions require significant eccentric muscle strength. It is therefore not surprising that most musculo-tendinous injuries occur during the eccentric phase of various rugby specific and strength conditioning activities.[35,36] Isometric muscle output (as assessed by among others

HHD) have been found a weak risk factor for injury.[37] To only test the strength associated with concentric or isometric muscle actions is therefore not sufficient for any athlete participating in dynamic contact sports, especially at elite level. The MMT strength rating scales proposed by numerous authors,[38] include gravity eliminated testing positions and related ratings.

Secondly, the developers of the SSL Screening protocol argue that is reasonable to assume that seemingly injury free elite level athletes, participating in sports which requires them to tolerate self-generated and external forces in mostly upright positions, are able to move joints against gravity. Testing and ratings which include anti-gravity positions are therefore largely irrelevant to elite level rugby players. All strength tests included in this protocol therefore not only challenge athletes to overcome gravity but also an external force.

The "break" and "make" tests have respectively been described as manual muscle tests where the examiner applies maximal resistance at end of range under static conditions (i.e. testing isometric muscle action).[39,40] Hand-and-held dynamometers (HHD) have been used to gain more objective measures for the forces generated during these tests. However, one of the main limitations of MMT, tester strength, is not overcome by the use of HHD and only forces related to isometric muscle actions can be tested. The developers of the SSL strength rating scale therefore reasons that well designed MMT procedures (in terms of tester and player position, point of force application etc.) where athletes have to resist the testers' external force eccentrically, are more appropriate for rugby players. A score of 5/5 is however indicative of a players' ability to resist the testers external force, such that the tester can't move the joint in question. It is therefore a quasi-isometric test.

Glut/ham test	**Purpose of the test:** To assess the isometric/eccentric muscle strength of the hip extensor muscle group. **Rationale for inclusion of test:** Several studies have confirmed the incidence and severity of hamstring injuries among rugby players.[41–43] Weakness of the hamstrings eccentric ability has not only been associated with hamstring muscle injuries,[42,43] but also other injuries such as low back[18] and ACL injuries.[26] From a performance perspective sprinting is an integral part of sports performed at high speeds. Athletes who produce the greatest amount of horizontal force during sprinting have been found to have superior ability to highly activate their gluteal and hamstring muscles just before ground contact and present high eccentric hamstring peak torque capability. Producing horizontal force is also required when opposing another player or in set situations such as scrummaging.
Hip adduction **Hip abduction**	**Purpose of the tests:** To assess the isometric/eccentric muscle strength of the hip abductors and adductors respectively. **Rationale for inclusion of tests:** Musculo-tendinous injuries of the groin have been reported as one of the most prevalent injuries among rugby players.[43] Hip abduction- and adduction-with-external rotation peak torque have been associated with groin[36] and knee injuries.[26] Hip adduction and abduction strength further plays an important role in the prevention lower limb injuries by stabilising the pelvis in the frontal plane during

	single leg activities.[1] From a performance aspect team sports that are multi-directional in nature, require rapid lateral movement. Lateral movement requires abduction and/or adduction of the hips and force production by these muscle groups are therefore essential. **Rationale for modification of testing position:** Several studies have investigated the difference in adductor activity at different hip and knee angles and found maximal activity at 0°[44] and 45°[45] hip and knee flexion angles respective. The weakest adductor activity was therefore measured at hip flexion angle of at 90°. The developers of the SSL protocol reasoned that the test has to expose players weakest position during strength testing. The upright seated position was therefore the chosen method of screening in this protocol, as the hip is placed at approximately 90° of flexion and, more similar to upright activities, the upper body remains fairly unsupported by external devices such as a plinth. Simultaneous testing of both the abductors and adductors of both limbs simultaneously is more time efficient and makes side-to-side comparisons simple.
Hip internal rotation **Hip external rotation**	**Purpose of the tests:** To assess the isometric/eccentric muscle strength of the internal and external rotators of the hips. **Rationale for inclusion of tests:** As mentioned above hip abduction- and adduction-with-external rotation peak torque have been associated with groin[36] and knee injuries.[26] Team sports that are multi-directional in nature require rapid COD. Correct COD technique requires athletes to turn the foot by internally or externally rotating the hip in the intended new direction.[26] **Rationale for test position:** Johnson & Hoffman[21] found no difference in hip external rotation torque at different hip flexion angles. Internal rotation torque production was significantly greater at 90° hip flexion compared to 10° of flexion. The authors of the SSL screening tool therefore hypothesised that internal rotation has to be tested at hip flexion angle where least torque is produced (during IR) as this might be the athlete's weaker point. Also, in an upright or slighted flexed forward trunk position as is mostly the case during rapid change of direction, the hip angle is closer to 10° than 90°.
Shoulder internal rotation	**Purpose of the tests:** To assess isometric/eccentric muscle strength of the internal rotators of the shoulder **Rationale for inclusion and position of the test:** "The Tackler", characterised by an anterior force inflicted on the shoulder while in abduction and external rotation, has been described as one of the most frequent mechanisms of shoulder injuries (MOI) sustained by rugby players.[23,24] Impact usually occurs on the arm or forearm and transferred to the glenohumeral joint, causing excessive anterior translation within the joint. The ability of the shoulder internal rotators to counteract these forces on impact, might be associated with decreased risk of shoulder injuries associated with this MOI (e.g. pectorial tendon tears, Bankart lesions etc.) where the anterior stability of the shoulder is compromised.

Shoulder external rotation	**Purpose of the tests:** To assess isometric/eccentric muscle strength of the external rotators of the shoulder **Rationale for inclusion of the test:** The "Direct impact"[7] MOI results in direct forces to the anterior superior surface of the glenohumeral joint during an offensive or defensive tackle. In turn this results in a posteriorly directed force with the joint, especially when the arm is in a horizontally abducted position. Like Haines et al.[46] the researchers hypothesise that eccentric strength of the rotator cuff and peri-scapular musculature (more specifically the external rotators of the GHJ), has a protective role in injury risk during these large deceleration forces related to the direct impact tackle.
Double leg lower (Abdominals)	**Purpose:** To assess the ability of the lower abdominal wall to stabilize the lumbo-pelvic-hip complex.[4] Hoskins et al. [47] reported that athletes participating in football codes, including rugby, have significantly more severe and frequent low back pain (LBP) than non-athletic groups which escalates with level of competition. Stabilisation of the lumbo-pelvic-hip complex have been identified as an integral factor for the biomechanical efficiency during maximal force production[48] as well as absorption and dissipation of forces that act upon the body.[49] This role is mainly fulfilled by the spine and surrounding musculature. Dysfunction of the spine's protective and load distributing capacity therefore increase the risk of back injuries among athletes involved in high impact sports such as rugby.[10] The double leg lower test as described by Krause et al.[50] and Zanotti et al.[4], is performed at a slow pace (10 seconds for lowering the legs from a 90° vertical hip flexion to 0° hip flexion) and only test muscle strength up to the angle at which the participant fails to maintain abdominal wall contraction. According to the principle of dynamic correspondence,[34] inferences regarding muscles' strength capabilities cannot be made if not performed under the same circumstances (angles, velocity, etc.) that the sporting activity requires. A multi-faceted, fast pace contact sport, such as rugby, rarely require muscle strength only at certain angles and at slow velocities. The SSL screening protocol developers therefore modified the test, to lower the legs through full range (from 90° flexion to 0°) at a self-selected quick pace (1-3 seconds) while maintaining abdominal wall contraction, as many times as possible. **Rationale for inclusion/modification minimal standard:** As the test have been modified there are no normative values and the minimum standard is therefore based on clinical experience.
Oblique twist	**Purpose of the test:** To assess the strength and mobility of the anterior oblique myofascial sling and the athlete's shoulder-pelvic-girdle decoupling ability.

	Rationale for inclusion of the test: As mentioned above, elite level rugby players suffer more frequent and severe LBP compared to the non-athletic and lower level player population.[10] Additionally, posterior muscle chain (especially hamstring) strains are one of the most prevalent injuries among forward and back line players.[41] The combined, simultaneous lumbar spine and hip joint rotary movements that occur in the frontal plane during running, plays integral role in the decoupling of the pelvic and from the shoulder girdle motions.[30,31] Decoupling not only allows for lateral balance to be maintained,[24] but also contributes to the generation of torque within the trunk by rotation (and slight ipsilateral flexion) of the lumbar spine. Gracovetsky[48] has described decoupling as the pivotal point of the lower extremity system during running. Optimal torque generation within the spine allows for transfer of these forces to the lower limbs, thereby relieving the strain of maximal force production by the lower limbs only.[48] In turn, the risk of prevalent acute and overuse injuries of not only the low back but also posterior chain muscles of the lower limb might be limited. **Rationale for inclusion/modification minimal standard:** There are currently published no normative values and the minimum standard is therefore based on clinical experience.

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