Flexibility and Muscle Balance Assessment

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Introduction to Flexibility and Muscle Balance Assessment

Flexibility is an integral component of an athlete’s physical conditioning. An athlete’s flexibility is influenced by the demands placed on the musculoskeletal system as a result of sport participation and is related to the level and length of involvement. Flexibility is of interest to coaches, health professionals and sport scientists due to the role of flexibility in sports performance, influence on posture and muscle balance, injury prevention and rehabilitation.

Assessment of flexibility is an important component of an athlete’s fitness profile as it helps to provide the following:

- Ensure an athlete can successfully complete the full range of motion (ROM) required in performing skills and techniques of a particular sport.
- Detect any restricted ROM that may adversely affect an athlete’s performance, predispose an athlete to injury and/or occur after injury.
- Identify and monitor any changes in flexibility as a result of training and performance. Regular testing provides an opportunity to assess the appropriateness of a training or rehabilitation programme on an athlete’s flexibility.
- Examine and predict the performance potential of an individual wishing to compete in a sport that requires extreme flexibility.
- Determine the return to sport status of an athlete following injury.

Flexibility should not be thought of as an overall body component but rather as being joint specific. An athlete has many joints and some have more movement than others.

Static flexibility may be defined as the ROM that is available at a joint, where ROM is the total amount of movement (degrees) through which an articulation’s segments may pass (Kreighbaum and Barthels, 1996). The ROM may be attained actively, where the athlete moves the body part, or passively, where the body part is moved for them. Attempts have also been made to define dynamic flexibility in terms of resistance to the movement of a joint (MacDougall et al., 1991). It has been argued that assessment of dynamic flexibility would be a more valid measurement of an athlete’s flexibility (MacDougall et al., 1991; Wilson, 1997) as it would reproduce the patterns of movement of a sport. Another perceived advantage would be the ability to analyse the range and ease of movement whilst reproducing the type of muscle contraction in the required range for that sport. However, an accepted definition, and valid and reliable tests to measure dynamic flexibility, is yet to be widely endorsed in the literature. For this reason further discussion will be limited to static flexibility testing.

The specific demands of a sport should be assessed and applied as the basis for selecting appropriate joints and movements for flexibility testing. Restricted flexibility will reduce the ROM available (Wilson et al., 1992). Subsequently, this may have an adverse affect on speed and endurance as at any given resistance muscles will have a greater workload (Nicholas, 1997). Specific flexibility training has been shown to increase joint ROM (Girouard, 1995). Excessive flexibility, in the absence of adequate muscle control, may also be detrimental to an athlete’s performance and/or predispose to injury. Favourable body mechanics for skill performance will be accomplished by attainment of sport specific flexibility requirements, as opposed to the ‘more is better’ principle. Emphasis should be placed on the achievement and maintenance of sport specific requirements rather than obtaining maximal flexibility in related joints and muscles. For those sports that do not require excessive flexibility, attainment beyond the necessary level may not enhance sport performance.
Flexibility results have been described in the literature in terms of hypo-(low), normal or hyper-(high) mobility. The use of this terminology may encourage the belief in athletes that attainment of hypermobility is desirable for enhancing sport performance. For this reason, terminology such as limited, acceptable or excessive may be more appropriate.

ROM is a commonly used, noninvasive measure of static flexibility, and is specific to a particular joint. Active and passive ROM testing are frequently used as an assessment of an athletes flexibility (Kendall et al., 1993; MacDougall et al., 1991). Passive ROM testing will allow measurement of the available ROM as limited by passive constraints e.g. joint capsule and connective tissue, but does not assess a muscle/muscle group’s ability to move that body segment. Conversely, active testing indicates a muscle/muscle group’s ability to move the body segment(s) throughout the available ROM but does not differentiate between active or passive restraints. Active testing is a more appropriate form of flexibility testing for the majority of sports as it requires muscle strength and, in addition, the tester is able to observe the quality of movement throughout the ROM available.

Joint ROM testing has been widely endorsed in the scientific community as a simple measurement of static flexibility (Bunnermanet et al., 1996; Tyler et al., 1996). A number of measurement techniques have been developed and attempts to validate protocols and relate testing to sport performance have been made (Ekstrand and Gillquist, 1982; Ekstrand et al., 1982). Despite a prevalence of articles there is little information available with which to ascertain the required angular displacement of joints during sport specific skills and establish testing protocols that are accepted amongst all interest groups. Therefore, comparison of flexibility testing results with established norms is difficult due to the paucity of information available on sport specific flexibility data for athletes.

Throughout the literature little consideration has been paid to the complexity of variables that influence flexibility and, in turn, testing and results. The shape of its articular surfaces and soft tissue structures determines the ROM of a joint. These include the joint capsule, skin, and connective and muscle tissue and in turn may be influenced by age, gender, temperature, current/past type and level of activity, and current or pre-existing musculoskeletal injuries.

Muscle length is an important determining factor of an athlete’s flexibility. Joint ROM testing per se fails to identify the influence of muscle length, or change in muscle length, on flexibility. One-joint muscles should be able to lengthen sufficiently to allow full ROM of the joint they cross. Two-joint and multi-joint muscles allow full ROM of one of the joints they cross if they are not lengthened over the other joint(s). However, these muscles generally do not permit simultaneous full ROM of all joints they cross due to lack of extensibility e.g. hamstring muscle length does not permit simultaneous attainment of full hip flexion and knee extension. Following joint ROM measurement it may be desirable to assess the length of muscles that cross and move the joint(s)\(^1\).

Handedness influences our movement patterns and musculoskeletal development in sport participation and in activities of daily living. Therefore, left and right side comparison will provide a useful tool in determining the influence of training effects, injury or disuse on an athlete, and in predicting their return to sport ability.

The remainder of this chapter will address flexibility profiling of the athlete. Specific tests and their recommended procedures will be outlined and discussed.

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\(^1\) Due to the nature of the test procedures it is recommended that, where possible, a suitably qualified physiotherapist perform relevant muscle length tests. Sports physiotherapists are listed on the Sports Science New Zealand web page http://www.sportscience.org.nz/
Methodologies of flexibility and muscle balance assessment

The flexibility requirements for sports are dependent on the actual requirements of a specific sport, and an individual’s ability to develop the required ROM for that sport in different areas of the body. It has been suggested that one single test may suffice to measure an individual’s overall flexibility (Hoshizachi and Bell, 1984). However, after reviewing a number of studies concerning individual versus several flexibility tests, Soper and Hume (1998) concluded that it is more suitable to use a battery of tests. Therefore, given that flexibility demands differ between sports and that currently used in the literature a battery of tests are described to measure the flexibility of different body parts.

In order to achieve a test result that can be applied to the athlete’s training programme and reassessed as appropriate, a number of factors need to be considered such as the reliability and validity of the test, the equipment used, and subject preparation procedures.

Reliability of the test

The test is able to be repeated a number of times on different occasions, where, with the same test conditions, the results are reproducible. The ability to test an individual on two different occasions and attain results that can be substantiated and compared refers to test–retest reliability. Intra-tester reliability refers to an individual’s ability to perform a test reliably on a number of occasions and therefore produce accurate results. “It is necessary that reliability is high so the difference between two tests is solely due to a change in the athletes’ ability rather than a change in the test itself. Measures of reliability are most often numerically reported in the form of a correlation coefficient (r) between 0.0 and 1.0. The larger the numeric value the more reliable the test” (Soper and Hume, 1998, p 4).

Validity of the test

The validity of a test refers to the ability of the test to truly test what it states it tests e.g. measurement of shoulder flexion ROM which allows for concurrent extension of the thoracic spine would not be a valid test of shoulder flexion. The thoracic spine would need to be stabilised in a set position for this to be a valid test of shoulder flexion.

Subject preparation

The following should be considered when preparing the subject for flexibility testing:

- Standardisation of the warm-up, instructions to the athlete and performance of the test will assist in improving accuracy of the result. One tester should administer all ROM tests.
- The athlete should be screened for the presence of any existing injuries/condition(s) that may be exacerbated by, and/or influence testing.
- To ensure test repeatability twenty-four hour pre-test level of activity should be standardised for each athlete.
- Prior to testing of the athlete a clear explanation of the purpose, handling and procedures should be given.
- The athlete should be comfortable during each test and uninvolved body segments stabilised to avoid unnecessary strain.
- Minimal clothing should be worn.
- Performance of a warm up is optional but should be standardised to enable between test comparison where appropriate. It is recommend that when administering flexibility tests a standardised warm-up is used with the best of three ROM trials being recorded.
**Equipment, environment and protocol considerations**

It is advisable that the following general guidelines are followed for flexibility assessment:

- The flexibility tests selected and ROM required are relevant to the particular sport.
- Testing is repeated at appropriate times eg. change in training or competition programme, seasonal variation.
- Where possible, testing should be unilateral/one-sided, to avoid non-detection of right and left side difference.
- Every attempt should be made to ensure identical test procedures to eliminate confounding variables, improve reliability and enable valid comparison of successive results. Set-up, protocols, equipment and instructions should be standardised. If the same tester is not available eg. athlete is overseas, reproduction of identical test protocols will also minimise potential inter-tester variation.
- Results should be compared to normative data with respect to a particular sports requirements and possible measurement error.
- Equipment should be examined prior to testing to ensure calibration.

Several pieces of equipment are available to measure flexibility eg. motion analysis systems, photographic imaging and radiology. Discussion will be limited to equipment which is easily available, has minimal cost and which is in common use.

Direct measurement of angular displacement of adjacent segments about the joint angle (relative angle) or an external object (absolute angle) is measured in degrees (˚) with a goniometer. The advantage of direct measurement is that it enables within and between subject comparison as segment proportions do not influence the results. The disadvantage of direct measurement is that precise location of anatomical segments and the centre of joint rotation may vary between testers.

Indirect measurement is the recording of the linear distance between anatomical segments or between these and an object eg. sit and reach test (Wells and Dillon, 1952). The advantage of indirect measurement is that it provides an overall approximation of an athlete’s general flexibility. The disadvantage of indirect measurement is that specific limitations may be difficult to detect. This is because indirect tests tend to involve more than one articulation. Between-subject comparison is neither appropriate nor valid as anatomical proportions influence test results.

For a variety of tests a firm, stable plinth should be used. If available, an up/down plinth is recommended to aid examiner posture.

**Standardised laboratory conditions apply; temperature 18-23˚C.**

**Flexometer**

A flexometer consists of a gravity needle and an attached strap used to secure it to the body segment being measured, and may be used as a direct measure of joint ROM. Location of the axis of rotation is not necessary, however correct location of anatomical landmarks will reduce inter-tester and between-test error.

“As described by Leighton (1955) a flexometer consists of a weighted 360˚ dial and a weighted pointer mounted in a case. The dial and pointer operate independently, with each being controlled by gravity. Harris (1969) reported intra-tester reliability to range from 0.83 to 0.98 for thirteen composite flexibility measures. These values support those reported by Leighton in 1955 which showed intra-tester reliability to be high ($r = 0.91 – 0.996$).
Advantages:

- The flexometer is relatively easy to use after sufficient instruction and practice.
- The flexometer is easily calibrated against known angles.
- The flexometer is small in size, approximately 15cm’s round.
- Sound levels of reliability have been reported.

Limitations:

- Correct placement of the flexometer on the subject is required.

A flexometer is available from Spokane, Washington USA at an approximate cost of $200 each (Soper and Hume, 1998, p 5).

**Goniometer**

A goniometer consists of a protractor with a moveable and a fixed arm and may be used as a direct measure of joint ROM. The fulcrum of the goniometer is aligned with the axis of rotation of the joint to be measured and the arms placed parallel to the long axis of adjacent segments/external reference point. Electronic, metal and plastic goniometers are available which measure to 1 degree on the protractor. Measurement precision relies on correct location of anatomical landmarks and starting position. Intra- and inter-tester reliability may be increased by ensuring surface anatomy is accurate. Precise location of the centre of rotation may be difficult in complex articulations.

For the purpose of flexibility testing in athletes the goniometric measurements following are described as active ROM procedures. This enables the testor to observe the quality of movement throughout the range and assess the muscle/muscle groups ability to hold the end point whilst the measurement is made.

The majority of normative values in the literature are presented as a single figure, and are referenced to Kendall et al. (1993). Tables of acceptable norms have not been presented as the actual value required for each joint movement is sport specific (See ROM norms in each sport specific chapter). The desired measurement for one sport may be deemed too small or too great for another sport, leading to misinterpretation of results.

Results may be obtained from a single, or the best of three measurements. The protocol selected should be recorded and followed for repeat testing.

Some movements have been eliminated from the test procedures below. Adduction has not been included as a specific test as it requires motion into shoulder or hip flexion/extension and is accompanied by varying degrees of rotation. This, along with anthropometric influence eg. approximation of the limb with the chest, makes measurement of angular displacement due to adduction questionable.

Spinal ROM is a result of accumulated movement at a series of joints and consequently, is difficult to assess using measurement of angular displacement. In addition, hip and lumbar motion are often coupled, further confounding the results. Due to these factors spinal ROM will not be specifically described as a goniometric measurement.

“Differences in results gained from goniometer testing may be due to: (1) inconsistent placement of the goniometer; (2) unfamiliarity of goniometer use; and (3) low intertester reliability.

Advantages:

- The goniometer is relatively easy to use after sufficient instruction and practice.
- The goniometer is easily calibrated against known angles.
- The goniometer is small in size, approximately 31 x 13 cm.
Limitations:

- Measures flexibility in 2D whereas true range of motion is occurring in 3D about a joint.
- Correct placement of the goniometer on the subject is required.

Recommendations for goniometer use (Borms and Van Roy, 1996):

- The arms of the goniometer should be long, e.g. greater than 30cm.
- The protractor component should have precision of one degree.
- All measurements should be taken prior to removing the goniometer from the segments.
- All measurements should be made at eye level.

A goniometer is available from FITNESS WORKS (35 Dornwell Rd Three Kings) at a cost of $74 + GST each.” (Soper and Hume, 1998, p 5)

**Sit and reach box**

The sit and reach box is a 30cm x 30cm x 30cm box or bench with a 50cm ruler placed on the superior (top) surface. The ruler is marked at 1cm intervals and is placed on the box such that 20cm is projecting over the front. A horizontal bar, centred across the ruler, may be added for the athlete to push on.

**Test procedures**

**Apley scratch test**

The Apley scratch test provides an indirect test of shoulder flexibility in a combined movement pattern. Comparison is made between external rotation, flexion and abduction in one test, and internal rotation, extension and adduction in the other test.

- The athlete sits with buttocks fully supported and feet flat on the floor.
- The athlete is asked to place one arm behind their head, the elbow is flexed fully, and they reach as far down their back as possible.
- A measurement is made between the spinous process of C7 and the tip of the index finger and is recorded in cm (See Figure 1).
- Repeat for the contralateral lower limb.
- The athlete is then asked to place one arm behind their back with the elbow fully flexed, and reaches as far as is possible up their back toward their head.
- A measurement is made between the spinous process of C7 and the tip of the index finger and recorded in cm (See Figure 2). Repeat for the contralateral lower limb.

**Figure 1:** Apley scratch test reaching down the back.

**Figure 2:** Apley scratch test reaching up the back.
As presented above, the Apley scratch test differs from that formerly described in the literature. Previously, contralateral upper limbs are simultaneously tested in opposite movement patterns and the distance between opposing index fingers recorded as the result (cm). However, this does not allow the tester to differentiate on which side movement is restricted or excessive. By utilising a fixed reference point (C7) and measuring each movement pattern independently, an accurate assessment of left and right shoulder flexibility can be made.

A perceived advantage of this test is that shoulder flexibility is measured in movement patterns that more closely resemble actual sport requirements eg. commencement of swimming stroke. This test provides a useful tool to compare left and right side differences but does not differentiate between specific movement(s) or tissues that may limit results. Anthropometrics may influence test scores, therefore intra-subject comparison is more appropriate than inter-subject comparison.

*The sit and reach test*

The sit and reach test (Wells and Dixon, 1952) is widely used as an indirect measure of flexibility. The athlete sits on the floor with their lower limbs extended and pushes on the box’s horizontal bar with their arms extended as far as they can reach. This involves movement toward, or over, the athlete’s feet as far as they can possibly reach. The results are recorded as a numerical score to the nearest cm, where a positive measurement is attained by the athlete’s hands reaching beyond their feet and a negative score when their hands do not reach their feet. This test indicates changes in an athlete’s bilateral hamstring length, pelvis movement and back flexibility when forward bending.

Whilst performing the test the pelvis will tilt towards the thigh causing the hip joint to flex to a limit determined by hamstring muscle length. During normal flexion of the back the lumbar spine will flatten, the pelvis will move, and the thoracic spine flex. The sit and reach test cannot establish where limited or excessive motion has occurred, as it is bilateral and unable to differentiate between back and hamstrings muscle length.

Variation in results will occur between age groups and body type. During early adolescence results may appear limited due to comparative changes in length of the trunk and lower limbs. In adults whose lower limbs are proportionately longer than their trunk results will appear limited even if their hamstring and back muscle length are within normal limits (Kendall et al., 1993).

Several studies have shown the influence of anthropometrics on test scores (Jackson and Langford, 1989; Shepherd et al., 1990). Therefore intra-subject comparison is more appropriate than inter-subject comparison. The sit and reach test does not provide valid measures of baseline data or changes in flexibility and the application of results to sport performance is questionable.

The procedures for the sit and reach test are:

- The sit and reach box should be placed on even ground with the posterior surface against a stable object eg. wall.
- The athlete is in long sitting, knees fully extended with his/her bare feet resting in full contact on the front vertical surface of the box approximately 10cm apart.
- One hand is placed over the other with the elbows in extension, palms facing inferiorly and fingers fully extended.
- The athlete leans forward pushing the horizontal bar as far as possible along the scale, the movement should be controlled and no bouncing permitted.
- The end position should be held for at least two seconds and the tester measures this to the nearest centimetre (See Figure 3).
- The best of three repetitions is recorded as the score.
- Standardisation of a warm up is recommended.
Table 1 shows normal values for the sit and reach test as described in the “Test Methods Manual” by the Australian Sports Commission (Draper, Minimkin and Telford, date unknown), however, it is not known whether their values are for males or females, or what age the athletes are.

### Table 1: Normal values for the sit and reach test.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Score (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&gt; 15</td>
</tr>
<tr>
<td>Good</td>
<td>5 to 14</td>
</tr>
<tr>
<td>Average</td>
<td>-5 to 4</td>
</tr>
<tr>
<td>Fair</td>
<td>-15 to -6</td>
</tr>
<tr>
<td>Poor</td>
<td>&lt; -16</td>
</tr>
</tbody>
</table>

**Straight leg raise test**

The straight leg raise test was developed to measure hamstring flexibility and is widely used in the clinical setting. However, different authors have recommended the non-tested leg to be extended on the plinth in a hip neutral position, or in hip flexion, as a means of controlling the potential influence of pelvic movement (Gajdosik, 1991; Kendall et al., 1993). Consideration must be given to the variable amount of pelvic movement that may occur during the test. It is essential that the test position, whether with the non-tested leg in hip neutral or flexion, be recorded to enable direct and accurate comparison of results on different occasions.

The procedures for the straight leg raise test are:

- The athlete lies on his/her back and lifts one leg as far as possible straight upwards towards their head.
- The knee remains extended and the toes pointed/plantar flexed throughout the movement.
- A measurement is made at the hip joint to determine the angle of hip flexion (See Figure 4).

**Adductor/Groin length test**

This test has been developed to provide assessment of an athlete’s adductor muscle length. When selecting this test consideration must be given to the fact that the hip is in 90º flexion. Therefore, this test is more appropriate for those sports that require the athlete to assimilate this position eg. hockey, as opposed to those sports which require the athlete to be more upright.
The procedures for the adductor/groin length test are:

- The athlete sits with his/her legs positioned as wide apart as possible whilst maintaining their knees fully extended and toes pointing towards the ceiling. The athlete’s back must remain upright as supported by a table or the testor’s leg (that used must be recorded for reference for future testing) and their head in mid-position looking forwards, not up, down or sideways.
- The tester stands above and behind the player and looks down on him/her. The axis of rotation of the goniometer is placed above the middle of the player’s head and the arms positioned in line with the athlete’s legs. The angle of the goniometer is recorded and reflects the angle between the legs (See Figure 5).

**Figure 4:** The straight leg raise test.  
**Figure 5:** The adductor/groin length test.

Note: in the same position a measurement may be made by using a ruler to measure the distance between the athlete’s heels.

**Tensor fascia latae and iliotibial band**

The following test was described by Kendall (1993) to assess the length of an individual’s tensor fascia latae muscle and their iliotibial band (TFL/ITB length).

- The subject is in side lying at the edge of the plinth with their pelvis stabilised by a belt or the testor.
- The upper leg is hung off the side of the bed.
- If the leg drops at least 10° below horizontal the TFL/ITB length is said to be normal (See Figure 6).

**Thomas test – iliopsoas and rectus femorus**

The Thomas test was described as a measurement of iliopsoas muscle length by Kendall et al (1993) and may also be used to measure rectus femorus length. This test is used widely in the clinical setting. To ensure test-retest reliability is improved the lumbar spine/pelvis should be in a neutral position and the starting position noted to prevent the athlete being too far up the plinth or in a pelvic tilt on separate testing occasions.

The procedures for the Thomas test are:

- The athlete sits on the edge of the plinth and simultaneously pulls one knee up towards their chest in the sagittal plane whilst leaning back into a supine lying position with the leg to be tested hanging relaxed off the edge of the plinth.
- The angle of the femur/thigh in relation to the floor of the hanging leg is measured using a goniometer. Alternatively, the distance from the floor to the patellar/knee-cap is measured.
• Rectus femoris may be measured by the angle of the femur in relation to the fibula (See Figure 7).

**Figure 6:** The tensor fascia latae and iliotibial band test.

**Figure 7:** The Thomas test.

*Gastrocnemius/soleus*

Adequate length of the gastrocnemius and soleus muscles is necessary in order for an athlete to achieve their full dorsiflexion ROM. A weight-bearing test for length of these muscles will enable rapid assessment of their length.

The testing procedures for the gastrocnemius are:

• The athlete stands an arms length away from the wall, the knee is extended, foot straight and heel on the ground.
• The non-tested leg is flexed at the knee with the foot flat on the floor. The athlete leans forward until their end point is reached.
• A measurement is made using a goniometer aligned along the lateral border of the foot and the fibula, with the axis of rotation about the lateral malleolus (See Figure 8).

The testing procedures for the soleus are:

• The athlete stands with the great toe of the leg to be tested 4cm from the wall and the foot straight.
• The athlete is then asked to bend their knee. Full ROM is achieved when the athlete is able to touch their knee to the wall (See Figure 9).
• If this is not possible measurement is made using a goniometer aligned along the lateral border of the foot and the fibula, with the axis of rotation about the lateral malleolus.

**Figure 8:** The gastrocnemius test.  
**Figure 9:** The soleus test.
Shoulder extension

Several tests have been described in the literature to examine extension range of the shoulder joint. Given the large variance in shoulder ROM requirements throughout several sports, and the potential to compensate with changes in body position whilst testing e.g. thoracic extension +/- trunk side flexion, the following test has been recommended. This test ensures minimal opportunity for compensation away from the test position thereby enabling a more accurate result.

The testing procedures for shoulder extension are:

- Starting position described by Popov (Australian Institute of Sport). Prone lying with arms extended above their head, elbows straight and thumbs touching together in the midline. Chin remains in contact with the plinth.
- Measurement using electronic goniometer from humerus. Alternatively, measurement may be made using a plastic goniometer using 0° from an angle of 180° of shoulder flexion to end range of the movement (See Figure 10).
- Ranges 5 -25° less likely to have shoulder injuries, ranges <5° or >25° more predisposed to shoulder injuries.

**Figure 10:** The shoulder extension test.

Shoulder flexion/extension

- Athlete is supine with the side to be tested at the edge of the plinth. The upper limbs are placed by the side with the elbows in extension and palm of the side to be tested facing medially.
- The centre of the goniometer is placed laterally on the humerus over in line with the greater tuberosity, and the fixed arm aligned with the upper limb using the lateral epicondyle of the humerus as the reference point.
- The athlete then flexes their upper limb whilst maintaining elbow extension. Movement continues until maximal ROM is achieved, the free arm of the goniometer is aligned as above and the flexion angle is recorded.
- The subject returns their upper limb to the starting position and goniometer placement checked with reference to the aforementioned alignment.
- The subject then lowers their upper limb as far as possible below the plinth whilst maintaining elbow extension. Movement continues until maximal ROM is achieved, the free arm of the goniometer is aligned with the reference point as above and the angle of extension recorded (See Figure 11).
- Repeat for the contralateral upper limb.
- A normal value for shoulder flexion is 180°, and for shoulder extension is 45°.
Figure 11: Shoulder flexion/extension test.

If the greater tuberosity is unable to be located the tip of the acromian process may be used to centre the goniometer for testing. This should be recorded for successive tests. The upper limb must remain in the sagittal plane throughout testing to eliminate the influence of abduction, adduction or rotational variation on test results.

Stabilisation of the pelvis so that the lumbar spine is flat on the plinth should be achieved at the commencement of, and during, the test procedure. If this is not possible the athlete’s knees should be flexed prior to testing with their feet flat on the plinth. Potential confounding variables are pelvic tilt, lower thoracic or lumbar extension, elbow or knee flexion as outer range is approached. The point of detection of any or all of these during testing will indicate cessation of the test. Measurement should occur immediately prior to this whilst the subject is able to maintain correct test position.

Shoulder abduction

• Athlete is supine with the side to be tested at the edge of the plinth. The upper limbs are in the anatomical position.
• The centre of the goniometer is placed over the greater tuberosity of the humerus and the fixed arm aligned with the upper limb using the lateral epicondyle of the humerus as the reference point.
• The athlete abducts their upper limb whilst maintaining elbow extension. Movement continues until maximal ROM is achieved, the free arm of the goniometer is aligned as above and the angle is recorded (See Figure 12).
• Repeat for the contralateral upper limb.
• A normal value for shoulder abduction is 180˚, and for shoulder adduction is 0˚

Figure 12: Shoulder abduction test.
If the greater tuberosity is unable to be located the tip of the acromian process may be used to centre the goniometer for initial and successive testing. The upper limb must remain in the frontal/coronal plane throughout testing. This will eliminate flexion, extension or rotation as confounding variables.

The pelvis must be stabilised so the lumbar spine is flat on the plinth at commencement of, and during, the test procedure. If this is not achievable the athlete’s knees should be flexed prior to testing with their feet flat on the plinth. Point of detection of pelvic tilt, lower thoracic or lumbar extension, elbow or knee flexion will indicate cessation of the test. Measurement should occur immediately prior to this whilst the subject is able to maintain correct test position.

**Shoulder internal/external rotation**

- Athlete is supine with the side to be tested at the edge of the plinth. The upper limb to be tested is at 90° shoulder abduction with the elbow in 90° flexion and forearm supinated.
- The centre of the goniometer is placed over the olecranon process and the fixed arm aligned with the midline of the forearm.
- The athlete then externally rotates their arm whilst maintaining 90° shoulder abduction. Movement continues until maximal ROM is achieved, the free arm of the goniometer is aligned as above and the angle is recorded (See Figure 13).
- The subject returns their upper limb to the starting position and goniometer placement checked with reference to the aforementioned alignment.
- The subject then internally rotates their upper limb as far as possible until maximal ROM is achieved. The free arm of the goniometer is aligned as outlined above and the angle recorded (See Figure 14).
- Repeat for the contralateral upper limb.
- A normal value for shoulder internal rotation is 90°, and shoulder external rotation is 70°

*Figure 13: Shoulder external rotation test. Figure 14: Shoulder internal rotation test.*

The upper limb must remain in 90° abduction and neutral flexion/extension throughout the test. The pelvis must be stabilised so the lumbar spine is flat on the plinth at commencement of, and during, the test procedure. If this is not achievable the athlete’s knees should be flexed prior to testing with their feet flat on the plinth. Point of detection of pelvic tilt, lower thoracic or lumbar extension, elbow or knee flexion will indicate cessation of the test. Measurement should occur immediately prior to this whilst the subject is able to maintain correct test position.

**Elbow flexion**

- Athlete is supine with the upper limb to be tested near the side of the plinth and the forearm supinated.
- The fulcrum of the goniometer is placed over the lateral epicondyle of the humerus and the fixed arm aligned parallel with the forearm using the styloid process of the radius as a reference
point. This may be used as a measurement of extension in athletes whose elbows do not hyperextend.

- The subject then flexes their elbow until maximal ROM is achieved.
- At completion of the movement the moveable arm of the goniometer is linearly aligned as above and the angle recorded (See Figure 15).
- Repeat for the contralateral lower limb.
- A normal value for elbow flexion is 145°

The forearm must remain in supination throughout the entire movement. The ROM achieved will be limited by approximation of soft tissue structures. Due to the influence of anthropometrics on results inter-subject comparison is invalid, however between test comparison of the athlete’s results is appropriate.

**Elbow extension/hyperextension**

- Athlete is supine with the elbow of the upper limb to be tested on the side of the plinth and the forearm supinated.
- The fulcrum of the goniometer is placed over the lateral epicondyle of the humerus and the fixed arm aligned parallel with the forearm using the styloid process of the radius as a reference point. This may be used as a measurement of extension in athletes whose elbows do not hyperextend.
- The subject then allows their forearm to extend over the side of the plinth until maximal ROM is achieved. At completion of the movement the moveable arm of the goniometer is linearly aligned as above and the angle recorded (See Figure 16).
- Repeat for the contralateral lower limb.
- A normal value for elbow extension is 0° -10°

![Figure 15: Elbow flexion test.](image)

![Figure 16: Elbow extension/hyperextension test.](image)

Hyperextension of the elbow and an increase in carrying angle is more common in females than males.

**Hip flexion**

- Athlete is supine with upper limbs placed by their side. The unassessed lower limb is in knee flexion with the foot flat on the plinth.
- The fulcrum of the goniometer is placed over the greater trochanter of the femur and the fixed arm aligned parallel to the thigh using the lateral epicondyle of the femur as an external reference.
- The subject then raises their lower limb whilst maintaining knee extension and the foot in plantigrade. Movement continues until maximal ROM is achieved.
• At completion of the movement the moveable arm of the goniometer is linearly aligned with the lateral epicondyle of the femur and the angle recorded (See Figure 17).
• Repeat for the contralateral lower limb.
• A normal value for hip flexion is 125˚

The pelvis must be stabilised so the lumbar spine is flat on the plinth at commencement and during testing. Potential confounding variables are pelvic tilt, lower thoracic or lumbar extension and/or knee flexion. The point of detection of any or all of these during testing will indicate cessation of the test. Measurement should occur immediately prior to this whilst the subject is able to maintain correct test position.

This is not a test for hamstrings muscle length as the start position and test procedure for this are different (refer above). However, shortened hamstring muscles may limit the ROM obtained.

**Hip extension**

• Athlete is prone with the knee in extension, hip in neutral rotation and upper limbs placed by their side. If knee extension is unable to be obtained in this position eg. athlete’s knees hyperextend, the feet should be permitted to rest off the end of the plinth and this start position recorded for further tests.
• The fulcrum of the goniometer is placed over the greater trochanter of the femur and the fixed arm aligned parallel with the thigh using the lateral epicondyle of the femur as a reference point.
• The subject then raises their lower limb whilst maintaining knee extension. Movement continues until maximal ROM is achieved.
• At completion of the movement the moveable arm of the goniometer is linearly aligned with the lateral epicondyle of the femur and the angle recorded (See Figure 18).
• Repeat for the contralateral lower limb.
• A normal value for extension is 10˚

**Figure 17: Hip flexion test.**  
**Figure 18: Hip extension test.**

The lower limb must remain in neutral position in the sagittal plane, the knee in extension and the pelvis stabilised so the lumbar spine is flat on the plinth throughout the entire movement. The athlete may attempt to compensate by shifting their body weight to the contralateral side, this is detected by the pelvis lifting off the plinth on the side being tested.

Hip extension may also be tested with the knee in 90˚ flexion. The procedure is the same as that outlined above and will eliminate the influence of two-joint muscles.
**Hip abduction**

- Athlete is supine with the side to be tested at the edge of the plinth. The lower limbs are in neutral rotation and upper limbs are placed by their side.
- The centre of the goniometer is placed over the greater trochanter of the femur and the fixed arm linearly aligned with the lateral epicondyle.
- The athlete abducts their lower limb whilst maintaining knee extension and neutral hip rotation. Movement continues until maximal ROM is achieved, the free arm of the goniometer is aligned along the midline of the thigh and the angle recorded (See Figure 19).
- Repeat for the contralateral lower limb.
- A normal value for hip abduction is 45°

The lower limb must remain in neutral position in the frontal / coronal plane throughout the entire movement and the pelvis stabilised so the lumbar spine is flat on the plinth at commencement of, and during, the test procedure. If this is not possible the knee of the contralateral lower limb should be flexed and the foot resting flat on the plinth prior to testing.

Potential confounding variables are pelvic tilt, lower thoracic or lumbar side flexion, hip rotation or knee flexion as outer range is approached. The point of detection of any or all of these during testing will indicate cessation of the test. Measurement should occur immediately prior to this whilst the subject is able to maintain correct test position.

![Hip flexion test](image.png)

**Figure 19: Hip flexion test.**

**Hip internal/external rotation**

- Athlete is supine with upper limbs resting by their sides. The hip joint is in 90° flexion and foot in plantargrade.
- The fulcrum of the goniometer is placed over the mid-point of the knee joint and the fixed arm aligned with the midline of the leg using the mid-point of the medial and lateral malleoli as a reference point.
- The athlete then externally rotates their hip (foot moves medially) whilst their knee remains in 90° flexion. Movement continues until maximal ROM is achieved, the free arm of the goniometer is aligned as above and the angle is recorded (See Figure 20).
- The subject returns their lower limb to the starting position and goniometer placement checked with reference to the aforementioned alignment.
- The subject then internally rotates their hip (foot moves laterally) as far as possible until maximal ROM is achieved. The free arm of the goniometer is aligned as outlined above and the angle recorded (See Figure 21).
• Repeat for the contralateral upper limb.
• A normal value for hip internal rotation is 45°, and hip external rotation is 45°

**Figure 20:** Hip external rotation test.  
**Figure 21:** Hip internal rotation test.

The hip must remain in 90° flexion and neutral abduction/adduction throughout the test. Due to the position of the test the pelvis and lumbar spine should remain stabilised throughout the procedure, however no trunk side flexion is permitted.

*Knee flexion*

• Athlete is prone with the hip in neutral rotation and foot projecting off the end of the plinth. Upper limbs are placed by their side.
• The fulcrum of the goniometer is placed over the lateral epicondyle of the femur and the fixed arm aligned parallel with the leg using the tip of the lateral malleolus as a reference point. This may be used as a measurement of extension in athletes whose knees do not hyperextend.
• The subject then flexes their knee until maximal ROM is achieved.
• At completion of the movement the moveable arm of the goniometer is linearly aligned as above and the angle recorded.
• Repeat for the contralateral lower limb.
• A normal value for knee flexion is 140°

The ROM achieved will be limited by approximation of soft tissue structures. Due to the influence of anthropometrics on results inter-subject comparison is invalid, however between test comparison of the athlete’s results is appropriate.

*Knee extension/hyperextension*

• Athlete is supine with upper limbs positioned by their side and foot in plantar grade.
• The fulcrum of the goniometer is placed over the lateral epicondyle of the femur and the fixed arm aligned parallel with the leg using the tip of the lateral malleolus as a reference point. This may be used as a measurement of knee extension in athletes whose knees do not hyperextend.
• The subject is then asked to squeeze their quadriceps and push their knee down. The foot will then lift off the plinth, the moveable arm of the goniometer is aligned as above and the angle recorded (See Figure 22).
• Repeat for the contralateral lower limb.
• A normal value for knee extension is 0°-10°
Knee extension/hyperextension test.

If the quadricep muscles are weakened in inner range a false reading will result. The test may be modified to passive ROM by the examiner lifting the leg into extension and measuring the angle obtained.

Ankle dorsiflexion/plantarflexion

- Athlete is supine with upper limbs placed by their side. The unassessed lower limb is in knee flexion with the foot flat on the plinth. The foot to be tested is off the end of the plinth and in plantargrade position.
- The fulcrum of the goniometer is placed over the tip of the lateral malleolus of the fibula and the fixed arm aligned parallel with the leg. The free arm of the goniometer is aligned parallel to the foot, the fifth metatarsophalangeal used as a reference point.
- The subject then dorsiflexes their foot whilst maintaining their knee in extension. Movement continues until maximal ROM is achieved, the free arm aligned as above and the dorsiflexion angle recorded (See Figure 23).
- The subject then returns their foot to the starting position and goniometer placement checked with reference to the aforementioned alignment.
- The subject then maximally plantarflexes their foot whilst maintaining their knee in extension. Movement continues until maximal ROM is achieved, the free arm aligned as above and the plantarflexion angle recorded (See Figure 24).
- Repeat for the contralateral lower limb.
- A normal value for ankle plantarflexion 45˚, and for ankle dorsiflexion is 20˚

Gastrocnemius tightness will cause the knee to flex prior to attainment of full dorsiflexion. This will produce a falsely limited result. The foot should remain in the sagittal plane and neutral position with respect to inversion and eversion.
Evaluation

• Where possible the following information should be included:
• Results should be interpreted and explained to the athlete and coach with regard to the test used and the athlete’s experience in the sport, injury history, previous testing results, age and gender.
• Areas of limited, normal and/or excessive flexibility identified.
• Advice on addressing the above with regard to enhancing sport performance and injury prevention eg. specific stretching and strengthening techniques.

Summary

This chapter has discussed the application of flexibility testing on athletic performance. Various testing procedures, their advantages and disadvantages were discussed. Recommended flexibility testing and goniometric protocols were presented and the significance of the correct starting position and accurate location of the axis of rotation of the goniometer emphasised.

Ultimate optimal utilisation of the results is difficult due to a paucity of literature on the ROM required for specific sports and normal values for athletes participating in those sports. Development of a normative data base, and tests to assess dynamic flexibility and differentiate variables that affect flexibility would greatly benefit the application of flexibility testing to enhance athletic performance, and potentially prevent injury. Result interpretation and application relies on an understanding of the demands of a specific sport on joint structure and biomechanics, and the influence of muscle length on function.
References


Guidelines for Athlete Assessment in New Zealand Sport
Flexibility and Muscle Balance Assessment