CHAPTER 3: ISOKINETIC TESTING

3.1 INTRODUCTION

Since the advent of isokinetics, it has become the most **popular** method for evaluating muscle strength, mostly because of its validity, objectivity, and repeatability (Baltzopoulos & Brodie, 1989; Anderson *et al.*, 2000). However, not since the X-ray machine has one single testing apparatus been as **abused** as the isokinetic dynamometer (Brown, 2000). Isokinetic testing also brings a new **terminology** that is unique to this mode of testing and training.

3.2 ISOKINETIC TERMINOLOGY AND INTERPRETATION

Muscle performance may be classified as normal or abnormal (Davies *et al.*, 2000), or as normal, but not sufficient for a specific task, that is, a rugby player's knee extension torque may be normal when compared to the general population, but not large enough for the high demands of competition.

When interpreting isokinetic exercise, the biokineticist needs to be able to analyse a lot of information to make the correct clinical decision or interpretation. For this reason, the biokineticist should have a firm grasp of the terminology associated with isokinetics.

It is important to consider all aspects of the isokinetic test results. To consider peak torque (Nm) in isolation, may lead to the biokineticist missing vital information regarding a client's status.

3.2.1 Peak torque

Torque is a force that produces or aims to produce a rotation about a point or axis, and it is equal to the product of perpendicular force applied and the length of the lever arm. In isokinetics, torque is measured in **Newton-metres (Nm)** or foot-pound (ft-lb). One Nm equals 0.74 ft-lb and one ft-lb equals 1.36 Nm. Some isokinetic dynamometers like the Cybex range of machines measure torque directly at the axis of rotation, while other makes, like the KinCom, measurements force distally and then calculates the torque by multiplying the force with the lever arm.

Peak torque is the most commonly reported parameter and it represents the single highest point on the torque curve. Sapega (1990) constructed the following guidelines for classifying **"abnormality"** between two bilateral muscle groups (for example, left and right quadriceps muscle groups) in "normal" subjects:

"normal":	deficits up to 10%;
"possibly abnormal":	deficits between 10 and 20%, and
"probably abnormal":	deficits greater than 20%.

In subjects where one extremity is **expected** to be weaker due to a previous injury or disuse, the following criteria are used:

- "normal": deficits up to 10%;
- "probably abnormal": deficits between 10 and 20%, and
- "almost certainly abnormal": deficits greater than 20% (Sapega, 1990).

These criteria are partly supported by Malone *et al.* (1980) who stated that bilateral differences larger than 10% to 15% are to be considered for asymmetry. In support of this, Knapik *et al.* (1991) reported that female collegiate athletes, who had bilateral knee flexor strength differences of 15% or more, were at increased risk for lower extremity injury.

3.2.2 Average torque

Average torque represents the average of the sum of each repetition's peak torque. However, this data is not always available from all makes of isokinetic devices.

Wessel *et al.* (1992) suggested that when testing limbs with a relatively large mass (for example the hip and trunk musculature), it might be more accurate to consider the average torque instead of the peak torque. However, the author is of the opinion that comparing the "work" (J) done by each limb, instead of peak torque (Nm) would solve this problem. Furthermore, when compared, peak torque and average torque displayed a strong correlation in both concentric and eccentric contractions (Dvir *et al.*, 1989).

3.2.3 Peak torque relative to body mass (% BM)

In order to compare two individuals' peak torque values with one another, it is useful to express the respective torque values as a percentage of body mass (Nm/kg), so that possible differences in body mass do not lead to inaccurate findings (Davies, 1992). It is also advisable to consider this value (% BM), when comparing an individual's values with that of a normative database.

Other isokinetic values, like work and power, are also expressed as a percentage of body mass, for example: *"Power (BMR) % BM"*.

3.2.4 Angle-specific torque

Angle-specific torque is measured in degrees. The angle of peak torque is the specific angle in the ROM that corresponds to the peak torque value. Angle of peak torque in concentric knee extension, is normally given as approximately 60° of knee flexion at a velocity of 60°/s. However, this angle may vary as a function of the isokinetic velocity (Rothstein *et al.*, 1987), because of different athletic training programmes, or due to an injury. An increase in the isokinetic velocity normally results in a delay in reaching the peak torque (Dvir, 1995). Ivey *et al.* (1985) demonstrated that angle of peak torque may vary greatly between subjects when evaluating the shoulder joint.

It is sometimes helpful to consider the torque at a specific joint angle, as well as to establish the angle of peak torque production (for example, in patella femoral syndrome cases). A lot of research still needs to be done in this regard, especially in pathological conditions such as hamstrings strains. The angle in the ROM where peak torque occurred may also be of clinical value. A client that is recovering from a ligament repair procedure may exhibit different angles of peak torque for the affected limb compared to that of the unaffected limb, due to the muscle's inability to rapidly produce force or because of joint pathologies.

3.2.5 Work

Work is the product of torque and distance moved and is measured in joules (J). Thus work values may change if either one or both of the following two parameters change: torque and/or ROM (Davies *et al.*, 2000). Graphically, work is the area beneath the torque-position curve, or alternatively the average torque ($T_{average}$) times the angular displacement (A): **Work = $T_{average}$ x A** (Dvir, 1995).

The total work (J) may be useful in a variety of cases. For instance, two limbs may have identical torque values, but vary greatly when considering the amount of work (J) done. A bilateral variation in work done may indicate a limitation in ROM or some joint pathology like patella femoral syndrome (PFS) for example, where a certain ROM may be painful.

3.2.6 Power

Power is work done per unit of time and measured in watts (W), or joules per second (J/s). In isokinetics, peak power is the product of peak torque and average velocity. If a subject moves with the dynamometer through the maximum ROM, the only way of increasing power is to produce a higher torque value (Davies *et al.*, 2000), or to have a shorter acceleration and/or deceleration time.

If: **Power (P) = Work done (W) / Time taken (T)**

Then: $P = T_{average} \times A / T$

Thus: $P = T_{average} \times V$

Where **V** is the angular velocity and **A** is the angular displacement (Dvir, 1995).

By plotting **peak and average power** at different velocities, it may be possible to determine the optimal velocities where a subject can produce his or her maximum force (Davies, 1992). Training programmes may then be tailored around these findings (that is, whether to perform slow or fast contractions during resistance exercises).

Average power is the total work performed, divided by the time it took in seconds (Davies, 1992), or the product of average torque and angular velocity.

3.2.7 Contractional impulse (CI)

Contractional impulse is the product of the average torque multiplied by the time in which it acts: **CI = $T_{average}$ x T.** CI is measured in Nm.s (Dvir, 1995).

Studies by Sale (1991) and Dvir *et al.* (1991) have shown the significance and possible clinical application of CI in both patients and athletes, but this variable is not widely used by clinicians.

3.2.8 Torque acceleration energy (TAE)

Torque acceleration energy is a measure of the **"explosiveness"** of a muscle contraction and is defined as the total amount of work performed in the first 1/8th of a second of the contraction (Davies *et al.*, 2000).

TAE may be one of the most important parameters when evaluating isokinetic data (Davies *et al.*, 2000), since several studies have demonstrated that TAE deficits may correlate with joint pathologies like knee sprain, ACL-deficient knees (Kannus & Jarvinen, 1989; Kannus & Latvala, 1989; Wojtys & Huston, 1994; Huston & Wojtys, 1996;), and muscular dystrophy.

Manske & Davies (in review) have reported that TAE can be improved to within 10% of the uninvolved side through training.

In contrast to the above, Rothstein *et al.* (1987) stated that the validity of TAE measurements should be questioned, since it is not based on *"Newtonian mechanics"*. Clinicians should thus not make use of TAE in their clinical evaluation, but if they did decide to use TAE to measure the muscle's explosiveness, they should only use slow velocity testing. This is probably due to the longer acceleration time observed during faster (larger than°/s) isokinetic testing.

3.2.9 Force decay rate

Force decay rate is a measurement of the downward slope of the torque curve. It reflects the subject's ability to exert maximum force through the entire range of motion (Davies *et al.*, 2000). Currently, there is no widely accepted method to calculate this parameter (Davies *et al.*, 2000). However, Ellenbecker (1998) states that the downward slope of a torque curve should follow a convex or flat line. If the curve's downward slope displays a concave shape, the force decay rate is probably too large and could signal possible muscle weakness. If a subject is weak towards the end of the ROM, or if the subject does not give a maximum effort through the entire ROM, the torque curve may exhibit a rapid **force decay rate**. This is characterized by a torque curve that slopes down rapidly following the achievement of the peak torque.

3.2.10 Fatigue index

The fatigue index is the percentage difference between the maximal and minimum amount of work performed in a set, or the work performed at the start of a set compared to the work performed at the end. By comparing the work performed at the start of a set of repetitions to the work done at the end of the set, one can calculate a subject's **fatigue index** or **endurance ratio**. A common protocol for determining a subject's endurance ratio, involves terminating the test when the torque drops below 50% of the peak torque measured at that specific velocity. Another protocol involves the use of a predetermined number of repetitions (for example, 30 repetitions) or time (Davies *et al.*, 2000). The endurance ratio as well as the total amount of work performed, is then used for bilateral comparisons, sport-specific normative comparisons (Burdett & VanSwearingen, 1987; DeNuccio *et al.*, 1991), baseline data at pre-season, and for diagnostic purposes in patients. Although there is no rule governing the number of contractions to use for endurance testing, the repetitions have varied between 10 (Barnes, 1981) and 150 (Elert & Gerdle, 1989; Gerdle *et al.*, 1989). Twenty to thirty repetitions are commonly used to determine endurance ratio.

3.2.11 Coefficient of variance (COV)

The coefficient of variance represents the standard deviation (STD) as a percentage of the average/mean torque measured. The COV for a single set of data is a statistical measure of how closely the data points are grouped. In this way, a set of repetitions may be quantifiably evaluated for reproducibility and accuracy of data collection (User's Guide: Norm testing and rehabilitation system, 1996). When several isokinetic repetitions are performed, there should be a COV of less than 15% for clinical use and less than 10% for research purposes (Brown *et al.*, 1993; Brown & Whitehurst, 2000; Davies *et al.*, 2000).

When performing an isokinetic evaluation, the biokineticist should encourage a maximal and consistent response. The difference between the lowest value and the highest value should be less than 10% (Davies *et al.*, 2000). If there is an average points variance or COV larger than 10% to 15%, the biokineticist may conclude that the subject did not give a consistent effort, or that the subject experienced some pain or discomfort while performing the test, or that the subject was not well familiarized with the testing procedure or process. The COV value should be viewed with caution when performing endurance testing (that is, more than 10 to 15 repetitions), because the COV will be inflated as a function of the increasing repetitions. Furthermore, testing at high speeds or using unwindowed data, may also increase the COV (Brown & Whitehurst, 2000).

3.2.12 Average standard deviation (ASD)

The average standard deviation is the square root of the average statistical variance. It is a measurement for analysing the consistency of a subject's effort during each contraction. For every angle in the ROM, there is a level of variance. By dividing the sum of the variance of every angle throughout the ROM by the total ROM, the average standard deviation (ASD) is obtained. Large ASD's may indicate inconsistent efforts or malingering by the subject.

3.2.13 Speed-specific data

Each subject may have different force-producing capabilities at different movement velocities. As velocity increases with concentric isokinetics, the torque or force normally decreases (according to the "force-velocity curve"), however with eccentric isokinetics the opposite might be true. Eccentric torque may actually increase with increased velocity according to Davies *et al.* (2000) and then plateaus or decreases as the velocity rises even further. However, other researchers differ on this phenomenon and they have reported no increases in eccentric peak torque over a spectrum of velocities in male subjects, while the opposite was true for their female subjects (Colliander & Tesch, 1989).

Whether peak torque rises or remains stable across increasing speeds appears to be dependent on subject gender, training condition, muscle group, and joint position (Westing *et al.*, 1988; Colliander & Tesch, 1989). The fact remains however, that subjects should be tested at a variety of isokinetic velocities, called **"velocity-spectrum" testing**. The reason for velocity-spectrum testing is to determine whether the subject is ready to perform a variety of functional tasks required during normal **activities of daily living (ADL)** and/or to return to his/her particular sport.

3.2.14 Acceleration time or time rate of torque development

Acceleration time is the time taken to achieve a predetermined variable, like peak torque or a specific joint angle in the ROM (Davies *et al.*, 2000). Acceleration time or time rate of torque development may be especially useful in the testing of athletic populations, since a rapid rate of force development is crucial in various sports events (javelin throwing, tennis, sprinting, rugby, and wrestling, for example). Acceleration time may also be used in evaluating neurological function in orthopaedic patients who have undergone surgery or sustained an injury. This is done to determine the function of the subject's neuromuscular integrity. Acceleration time may also be an indicator of explosive strength or power.

3.2.15 Agonist/antagonist ratios

This ratio is obtained by dividing the subject's antagonistic peak torque value or work, by the agonistic value. The "hamstrings/quadriceps ratio" is probably the best-known agonist/antagonist ratio. Knapik *et al.* (1991) reported an increased risk for lower extremity injury in collegiate female athletes who demonstrated a knee flexor/extensor ratio of 75% or less at a concentric angular velocity of 180°/s.

By considering the **antagonist/agonist ratio**, the biokineticist aims to address the important aspect of muscle balance or imbalance. This ratio may identify weaknesses in certain muscle groups, exposing the subject to the risk of injury (Burdett & VanSwearingen, 1987; Scoville *et al.*, 1997; Aagaard *et al.*, 1998). The **eccentric antagonistic/concentric agonistic ratio** is currently very popular, but the concentric antagonistic/concentric agonistic ratio is currently not regarded as sport-specific (Scoville *et al.*, 1997; Aagaard *et al.*, 1998).

Another question raised about antagonist/agonist ratios, refers to the concept of **"interval-scaled data":** the zero level on the torque curve does not represent a true absence of muscularly generated torque. Thus the actual torque curve represents the resistive torque generated by the dynamometer to keep a limb segment from accelerating (Rothstein *et al.*, 1987). However, this viewpoint is not shared by Dvir (1995), who stated that the zero level moments are never considered, since they represent equivalent forces to that of grade III, in manual muscle testing. The author tends to agree more with Rothstein *et al.* (1987), especially at high angular velocities (larger than 180°/s), where the gravitational forces become larger relative to the torques generated. Thus to minimize the above-mentioned phenomenon, the author suggests testing at slower speeds, in non-gravitational positions (horizontal), and without performing gravitational correction.

3.2.16 Isomap procedure

The **"isokinetic moment angular position" or "Isomap"** is a graphical representation of the torque at each angle in the ROM. The Isomap procedure was developed by Biodex for computerized data analysis through a multi-dimensional approach (Davies *et al.*, 2000). Although not widely used, this new procedure may expand our knowledge regarding isokinetic behaviour of muscles in future.

3.2.17 Eccentric/concentric ratio

To obtain this value, a subject's eccentric knee extension torque for example, is divided by the concentric knee extension torque value. This ratio then reflects the muscle's ability to function under both eccentric and concentric conditions.

Many functional activities make use of an **eccentric/concentric** activation pattern. For example, in throwing there is firstly an eccentric contraction in the internal shoulder rotators during the cocking phase, followed immediately by a concentric contraction during the acceleration phase (Scoville *et al.*, 1997). At slow isokinetic speeds, the eccentric torque is usually 30% larger than the concentric torque (Wilmore & Costill, 1999).

The **eccentric hamstrings/concentric quadriceps** ratio, developed by Aagaard *et al.* (1998), has become popular amongst biokineticists when screening for possible muscle imbalances in elite athletes during the pre-season evaluation. However, the correlation between injury occurrence and this ratio has not yet been proven.

3.2.18 Total leg strength (TLS)

To calculate TLS, several isolated OKC tests of the lower extremity are performed and the data is then summated to develop a composite score of the whole kinetic chain (that is ankle, knee, and hip joints). The same may be done for the upper extremity, namely: total arm strength (TAS) (Davies *et al.*, 2000). Previous research results indicate very low correlations (0.15-0.44) between knee extension torque (OKC) and leg press strength (CKC) (Dvir, 1995). The author reported correlations of 0.34 and 0.28 between leg press and knee extension and leg press and knee flexion, respectively.

Several researchers have published information on the concept of **TLS** (Nicholas *et al.*, 1976; Gleim *et al.*, 1978; Boltz & Davies, 1984). The validity of calculating TLS or TAS and comparing it to CKC exercises like leg press and bench press, is still under review and should not be used blindly.

3.2.19 Average and maximum range of motion

A subject's maximum ROM is normally determined before conducting the test. During the evaluation, the dynamometer calculates the average ROM by dividing the total number of degrees moved by the number of repetitions performed. If the maximum possible ROM for knee flexion/extension is not achieved consistently during the test, parameters like work, power and fatigue index may not be accurately used for bilateral comparisons. Work and power measurements are dependent on the ROM (W = T x D; P = W/T) (Brown & Whitehurst, 2000).

3.2.20 Windowing of data

This involves cutting out those portions of a test where free limb acceleration or deceleration occurs (Brown, 2000; Davies *et al.*, 2000). The portion of the torque curve that is left is then referred to as the **"load range"** or **"true" isokinetic movement**. Some of the latest dynamometers may actually perform this function through its software (for example, the Cybex Norm).

During an isokinetic contraction, there are parts of the ROM where the limb does not move at the predetermined isokinetic velocity. This normally occurs during the acceleration phase at the start of the movement and during the deceleration phase, normally near the end of the movement. It is referred to as "free limb acceleration or deceleration". Acceleration is not a fixed velocity and therefore it cannot represent isokinetic movement. Consequently, some researchers recommend **"windowing"** the data, to select only the "pure" isokinetic portion of the ROM, called the **"load range"**, for analysis (Davies *et al.*, 2000).

3.2.21 Damp setting and velocity overshoot

The damp setting is an indication of the amount of filtering that takes place during an isokinetic contraction. It is very similar to the filters that are employed when conducting an ECG recording. Dampening of the isokinetic data is used to eliminate **"overshoot";** the conspicuous spike that may occur at the beginning or end of a contraction (Dvir, 1995). This spike has been referred to as the **"impact artefact"** (Winter *et al.*, 1981), the "torque overshoot" (Sapega *et al.*, 1982), the "impact torque" (Sale *et al.*, 1987), or the "moment overshoot" (Dvir, 1995).

Some modern dynamometers overcome the overshoot phenomenon by employing **"ramping"** and/or **"windowing of data"** (Farrel & Richards, 1986; Brown, 2000). Ramping is a computer-generated acceleration of the lever arm that allows smooth acceleration to the preset angular velocity (Farrel & Richards, 1986). In most Cybex dynamometers the problem of overshoot artefacts are overcome by not calculating the peak torque within the first 1/8 second (windowing the data) and by employing ramping (User's Guide: Norm testing and rehabilitation system, 1996). During the "windowing of data", the acceleration and deceleration phases of the repetition is eliminated and only the load range data is preserved. This technique has been shown to increase the reliability of testing substantially (Brown, 2000).

The velocity overshoot increases with increasing contraction velocity. At slow speeds such as 60°/s, the overshoot is mild, compared to faster speeds (larger than 180°/s) (Brown, 2000).

3.3 PRINCIPLES OF ISOKINETIC TESTING

When performing isokinetic testing, it is of great importance to control for certain variables. Failure to control/standardize these variables, may affect the reliability of isokinetic testing. Therefore, certain strict principles should be adhered to during isokinetic testing.

3.3.1 Pre-testing procedures

Certain procedures should always precede an isokinetic test in order to optimise the testing process and data collected. **Indications and contra-indications** for participation in isokinetic exercise testing should be adhered to at all times (Kleiner, 1990; ACSM, 1991; Davies, 1992; Richter, 1992; Timm, 1992; Dvir, 1995; Kleiner *et al*., 1999).

After establishing the **purpose** of testing, the appropriate protocol is selected. Subjects have to be educated regarding the test to improve compliance. It is also important for the subjects to understand the purpose of the testing and how it would benefit them personally (Davies *et al.*, 2000).

The isokinetic equipment should be properly maintained and the dynamometer **calibrated** on a regular basis, in accordance to the manufacturer's guidelines, and all personnel involved should be **qualified** and trained in the use of isokinetics (Davies *et al.*, 2000).

3.3.2 Safety procedures

The biokineticist is responsible for the well-being of each subject. It is therefore imperative to conduct a thorough **medical history** of each person, before any testing takes place (this is done to identify relative or absolute contra-indications for isokinetic testing). All subjects must also complete a written **informed consent**, after having received a thorough explanation of the testing procedure (Davies *et al.*, 2000).

Clinicians should consider the **cardiovascular health/readiness** of their subject, before conducting an isokinetic test. Douris (1991) studied the cardiovascular responses to isokinetic exercise in 10 experienced weight trainers. He reported significant increases in heart rate (HR), systolic and diastolic blood pressure (BP), and rate pressure product (RPP = SBP x HR/100), following one minute of knee flexion/extension isokinetic exercise at maximal effort. This was true for 30°/s, 120°/s, and 300°/s. Generally, the cardiovascular system was increasingly affected with increased training velocities. However, even at 30°/s the SBP rose from 133 mmHg to 188 mmHg; the DBP rose from 79 mmHg to 98 mmHg; the HR rose from 79 bpm to 137 bpm, and the RPP rose from 106 to 260. Negus *et al.* (1987) compared the cardiovascular responses between maximum cycle ergometry and a velocity spectrum isokinetic protocol. They concluded that systolic BP rose more during the isokinetic protocol than during cycle ergometry. These studies serve to caution all biokineticists when utilizing isokinetics in elderly individuals and clients with compromised cardiovascular systems.

The biokineticist should always ensure that the subject performs an applicable **warm-up** routine before testing; this should include an aerobic warm-up and light stretching (Davies *et al.*, 2000). The subject should then be stabilized on the apparatus, while paying careful attention to the **correct alignment** of the joint's **axis of rotation** to that of the dynamometer (Perrin, 1993).

The biokineticist must carefully **document all aspects** (for example, lever arm length and gravitational correction) of the test for legal reasons and to ensure accurate repeat testing (Wilk & Andrews, 1993).

3.3.3 Test speed selection

It is generally recommended that subjects be tested across a **spectrum of isokinetic velocities**. The subsequent results could then be used to design a more scientific training programme compared to having the data of only one test velocity available. Testing across a velocity spectrum may also indicate specific pathologies in the injured individual (Davies, 1992).

One big misconception regarding the assessment of peak torque is that slow isokinetic test velocities reflect strength and that faster test velocities represent power and endurance. Perrin (1993) stated that: ***"Determination of torque, work, and power is independent of test velocity."*** However, it is by changing effort and number of repetitions that the different muscle fibres are preferentially recruited during isokinetic testing and training (Perrin, 1993).

3.3.4 Test repetitions

When evaluating a subject's ability to produce peak torque, it is advisable to use approximately five repetitions. When evaluating muscular power, less than 10 repetitions are normally required, and when testing muscular endurance, more than 20 repetitions are commonly used (Burdett & VanSwearingen, 1987; DeNuccio *et al.*, 1991; Davies, 1992). The important factor to bear in mind is which type of muscle fibre is predominantly recruited by the test and which energy pathway is called upon for the specific test protocol.

3.3.5 Rest intervals during testing

Although Davies *et al.* (2000) proposed a rest interval of 90 seconds between each set of repetitions, and three minutes between sets when power-profile testing is performed, other researchers have employed different rest intervals (Sherman *et al.*, 1982; Ariki & Davies, 1985; Pincivero *et al.*, 1997b). Longer rest periods (> 60 seconds) are used for optimal strength and power development. Shorter rest periods (< 60 seconds) are utilized for improving muscular endurance and hypertrophy (Pincivero *et al.*, 1997b). Rest intervals should be tailored according to:

- the type of contraction (concentric or eccentric);
- the number of repetitions (for example, different rest times for bouts of five versus 30 repetitions);
- the isokinetic velocity (slow-velocity testing/exercise require longer rest periods compared to the same number of repetitions at a faster isokinetic velocity);
- the intensity of effort and
- the overall volume and intensity of the test or exercise session.

3.3.6 Range of motion (ROM)

Most tests should be performed through the full possible ROM, however, there may be instances where it is important to limit the ROM (Davies *et al.*, 2000). For example, when testing a patient with anterior cruciate ligament (ACL) pathology early on during the rehabilitation period (Botha, 1997), it may be safer to limit the ROM. Another reason for limiting the ROM for testing, may be to mimic movement pattern of a specific sport (Davies *et al.*, 2000).

The size of the ROM may have a significant effect on the isokinetic performance. Narici *et al.* (1991) demonstrated that a larger ROM resulted in approximately 9% higher torque values when evaluating concentric knee extension torque. They attributed this to the longer time available for tension development and a greater level of neural activation (possibly due to a larger pre-activation stretch).

3.3.7 Feedback

Several studies have indicated that providing some form of feedback (visual or verbal) may enhance isokinetic torque production and test performance (Figoni, & Morris, 1984; Baltzopoulus *et al.*, 1991). The biokineticist should thus be consistent in giving or withholding feedback, especially in the view of obtaining reliable values when retesting a subject (Davies *et al.*, 2000). The effects of feedback becomes more pronounced when the isokinetic test velocity decreases (Figoni & Morris, 1984; Dvir, 1995) and during eccentric isokinetic muscle testing.

3.3.8 Subject positioning

Ideally a subject should be positioned as closely as possible to his/her sporting position when performing isokinetic tests. By changing a subject's position, it may alter factors like muscle length-tension relationship and the kinaesthetic input into the joint (Davies *et al.*, 2000). While it is obvious that a longer lever arm length would give the subject a greater advantage, this advantage is discounted because the subject's limb also acts as a lever arm (e.g. consider the insertion of the patella tendon onto the tibial tubercle). As the input arm is lengthened, the point at which resistance is applied to the subject's limb is placed farther from the axis of rotation of the joint. This puts the subject's joint at a greater lever disadvantage. Thus any advantage on the dynamometer is negated by an exactly equal disadvantage of the subject's joint complex (User's Guide: Norm testing and rehabilitation system, 1996).

3.3.9 Order of testing

Although researchers (Kovaleski *et al.*, 1992; Kovaleski & Heitman, 1993a) do not agree regarding the velocity order when performing isokinetic testing, it would seem that velocity progression order may affect test results, especially when subjects are not well-familiarized with isokinetics and when performing tests at low and high speeds (Brown & Whitehurst, 2000).

When evaluating a subject at more than one isokinetic velocity, it is usually advisable to start with the slowest velocity and to progressively move to the faster velocities. According to Griffen (1987), this progression will facilitate motor learning and increase the reliability of measurement, especially in subjects with limited experience in isokinetic testing (Wilhite, *et al.*, 1992). Certain joint pathologies may require a different approach: subjects suffering from patello-femoral syndrome (PFS), may find progression from a faster to a slower velocity more comfortable, due to the decreased compression forces experienced at higher isokinetic velocities.

There should also be consistency on whether to test the uninvolved- or involved limb first (Davies *et al.*, 2000). Testing the uninvolved limb first, allows the subject to familiarize him-/herself with the equipment and movement required. This decreases apprehension and increases the reliability of the test (Davies *et al.*, 2000). Once a policy has been established, it should be followed consistently. Eccentric testing should always be conducted last to prevent the effects of fatigue on the concentric evaluation. There should also be an adequate rest period between the initial concentric evaluation and the subsequent eccentric evaluation, to allow the muscles to replenish their energy stores before the next bout of testing.

3.3.10 Skill and training of the tester

The biokineticist or sport scientist conducting the test should have adequate training and experience in isokinetic testing and exercise, as well as a sound knowledge of exercise physiology and exercise science. In South Africa, the biokineticist qualifies as an independent practitioner after **four years of academic training and a one-year practical internship** period. It is advisable that other practitioners who wish to become involved in isokinetic testing and training, should undergo thorough theoretical and practical training.

For purposes of consistency, the same person should perform the retesting of a subject (Davies *et al.*, 2000).

3.3.11 Reciprocal testing

Reciprocal testing implies that both the agonist and the antagonist are being tested simultaneously. For example, knee extension and flexion are evaluated simultaneously, as opposed to testing only knee extension with a passive return to the starting position (Brown, 2000). Physiological factors playing a role here include: length-tension relationships, neural activation, functionality, and muscle memory aspects (Figoni, & Morris, 1984; Grabiner, 1994). Reciprocal testing is thought to enhance force generation by activation of the antagonist's motor units (Grabiner, 1994; Brown, 2000).

3.3.12 Force or torque limits

Some dynamometers make extensive use of minimum and maximum force limits (for example, the KinCom), while others (for example, the Cybex range) rarely require it. Optimally selected torque limits may enhance reproducibility of tests, but poorly selected levels may compromise accurate results. Force limits may also interfere with high-speed concentric and eccentric isokinetics and even make it dangerous. Once the force limit is exceeded, the dynamometer starts to move at the predetermined speed and it takes a period for the dynamometer to decelerate when no more force is being elicited. This could force a patient into a painful ROM; this is especially true of the KinCom dynamometer at speeds exceeding 180°/s (Brown, 2000).

3.3.13 Load range

Isokinetic exercise involves three main phases of movement: an acceleration phase to reach the pre-selected velocity, the true isokinetic phase or load range, and the deceleration phase. The higher the selected isokinetic velocity, the smaller the load range or true isokinetic phase. Thus there is an inverse relationship between load range and isokinetic velocity (Brown *et al.*, 1995; Brown & Whitehurst, 2000). Osternig (1975) was the first to point out this inverse relationship. He demonstrated that load range decreased from 92% to 16% between isokinetic speeds of 50°/s and 400°/s. This implies that high-speed isokinetics may have such a small load range that it may become ineffective as far as an "isokinetic" training goes, especially in small joints like the wrist, ankle, and elbow (Taylor *et al.,* 1991; Brown & Whitehurst, 2000).

3.4 FACTORS THAT MAY INFLUENCE ISOKINETIC RESULTS

Many factors may influence the results of an isokinetic test/measurement. For example, age, gender, weight, height, and athletic background may have a pronounced effect on the results of the isokinetic test (Keating & Matyas, 1996).

3.4.1 Gender

Even when male and female subjects are matched for age and activity levels, males generally exceed the forces/torques generated by females.

Thomas (1984) evaluated 97 "healthy" women with an average age of 35 years. An isokinetic speed of 60°/s was used to measure knee flexion and extension torques on a Cybex II dynamometer (values were not corrected for gravity). The author reported concentric values of 89 Nm (151 %BM) and 52 Nm (88 %BM) for knee extension and flexion respectively, and a flexion/extension ratio of 60%. Wyatt & Edwards (1981) in turn investigated 50 "healthy" men with an average age of 40 years. They also utilized a Cybex II dynamometer and conducted their concentric tests at 60°/s without any gravity correction. Their results were as follows: knee extension torque was 183 Nm (236 %BM) and 130 Nm (168 %BM) for knee flexion. The reported flexion/extension ratio was 72 %. Comparing the two sets of data, differences between the knee flexion and extension torques of men and women were between 60% and 51%. Analysis of work done by other researchers (Gross *et al.*, 1989; Krüger *et al.*, 1992), who considered gravity corrections, yielded smaller differences in peak torque values, when comparing women to men (between 27% and 39% difference).

Previous researchers indicate that men are able to generate higher torque levels than women (Thomas, 1984; Gross *et al.*, 1989; Krüger *et al.*, 1992). The proposed explanation is that men have a larger percentage of fat-free mass than women do. The role of testosterone and other hormones may also explain some of the observed effects. Therefore, separate norms should be developed for each gender (Davies *et al.*, 2000).

3.4.2 Age

Isokinetic dynamometers have not been designed for very young **children**. In some cases, the proportions of the dynamometer may even prohibit the biokineticist from proceeding with a certain test. Ideally, isokinetic tests should be performed on older children (> 12 years), whose body dimensions are more suited to that of the isokinetic apparatus in use. Sometimes it is possible to make modifications to the dynamometer's set-up in order to accommodate smaller children (for example, using the upper extremity input arm for knee extension and flexion testing) (Henderson *et al.*, 1993).

Although previous test reliability studies reported high reliability (Molnar *et al.*, 1979; Burnett *et al.*, 1990; Merlini *et al.*, 1995; Van den Berg-Emons *et al.*, 1996) for isokinetic testing in children, a lot of research still needs to be done in this regard. Intra-class correlations and the associated standard errors of measurement need to be incorporated in future studies, and reliability studies for eccentric isokinetic testing needs to be undertaken (Weir, 2000).

When evaluating isokinetic strength in children, it is important to account for differences in body size and gender when interpreting the results. The most popular method is to divide the torque value by the subject's body mass (BM), although other methods have also been used (Weir, 2000). Some authors have used height or muscle cross-sectional area instead of BM (Gilliam *et al.*, 1979; Kanehisa *et al.*, 1995), or fat free BM (Docherty & Gaul, 1991). Apart from the practice to divide the torque value by body mass, allometric scaling has shown some promise in correcting for differences in torque between subjects that differ in size (Weir *et al.*, 1990; Kanehisa *et al.*, 1995).

Many studies have shown that older children are stronger than younger ones, even after adjusting for differences in body size (Housh *et al.*, 1989; Balague *et al.*, 1993; Roemmich & Sinning, 1997).

The **ageing** individual's isokinetic testing or training should warrant special attention, due to the physiological effects of ageing. Ageing affects all organ systems of the human body, and the muscular system is no exception (Israel, 1992). Atrophy and absolute loss of type II (fast twitch) fibres have been observed with the ageing process (Larsson, 1983; Hopp, 1993). Lexell *et al.* (1988) and Rogers & Evans (1993) reported that age-related muscle atrophy begins as early as 25 years of age and that at the age of 50, approximately 10% to 25% of the muscle cross-sectional area is lost. Thereafter, the atrophy rate increases until almost 50% of the muscle cross-sectional area is lost by the age of 80. Rogers & Evans (1993) reported that this translated to a loss of strength of about 15% by the age of 60 to 70 years, after which the loss in strength was approximately 30% per decade. These findings were also supported by other researchers (Larsson & Karlsson, 1978; Grimby *et al.*, 1980; Larsson, 1983; Lexell *et al.*, 1986).

The following functional changes associated with the ageing process were observed in skeletal muscles. A decrease of 10% per year after the age of 60 was observed in muscle endurance, maximal voluntary contraction, and velocity of contraction of the quadriceps muscle group (Pendergast *et al.*, 1993). Graves *et al.* (1994) and Birren *et al.* (1979) demonstrated that motor performance also decreased in conjunction with losses in muscle strength due to ageing. Ageing muscles also displayed significantly slower reaction times and prolonged speed of contraction during testing (Birren *et al.*, 1979; Graves *et al.*, 1994).

Several research studies have reported significant **isokinetic strength losses** associated with the ageing process. Concentric isokinetic strength losses of between 35% and 47% have been reported between male and female subjects in their second decade compared to subjects in their seventh to eighth decade (Murray *et al.*, 1980, Clarkson *et al.*, 1981; Johnson, 1982; Murray *et al.*, 1985; Harries & Bassey, 1990; Stanley & Taylor, 1993).

Gross *et al.* (1989) reported on isokinetic concentric strength differences between women aged 30 and 69 years, respectively. They reported a 37% and 22% difference in knee extension and flexion torque at 60°/s, between the two groups.

Freedson *et al.* (1993) reported differences of 25% and 27% for concentric knee extension and flexion, respectively at 30°/s, when comparing women aged 30 years of age to women aged 55 years. Weldon *et al.* (1988) studied 1282 female subjects between the ages of 9 & 73 years. They tested concentric isokinetic values in the knee, shoulder, elbow, and ankle and reported that isokinetic torque increased from the age of 9 years to the age of 30 years, but then decreased incrementally with increasing age after 30.

Thus it appears from the above studies that isokinetic strength showed similar declines with ageing, compared to that reported for isometric and isotonic strength.

3.4.3 Body mass (BM)

By dividing a person's isokinetic torque values by body mass (BM), one normalizes the test results to his or her size in order to interpret the values more accurately (Davies, 1992). As mentioned previously in section 3.4.1, some authors have used height or muscle cross-sectional area instead of BM (Gilliam *et al.*, 1979; Kanehisa *et al.*, 1995), or fat free BM (Docherty & Gaul, 1991) to normalize isokinetic torque for body size, while allometric scaling has shown some promise (Weir *et al.*, 1990; Kanehisa *et al.*, 1995).

3.4.4 Stature/height

Although several researchers have investigated the effect of height/stature on isokinetic strength (Alexander & Molnar, 1973; Asmussen, 1973; Kanehisa *et al.*, 1995), the relationship between a subject's height and isokinetic performance however, is still inconclusive (Davies *et al.*, 2000).

3.4.5 Activity level and athletic background

Subjects that reported participation in athletics and other strenuous sports, were generally stronger, more powerful, and had better endurance than their sedentary counterparts. A 31% difference in concentric peak torque (at 30°/s) of the ankle plantar flexors was reported between competitive athletes and inactive subjects of similar age (Fugl-Meyer, 1981). Even when BM was accounted for, there was still a difference of 27% between the two groups. When comparing the concentric torque values reported for collegiate athletes by Nunn & Mayhew (1988), and for students (Lucca & Kline, 1989), their results showed a difference of 30% for knee extension, and 17% for knee flexion peak torque values at 60°/s between the two groups, with the collegiate athletes showing consistently higher peak torques. The collegiate athletes reported a mean hamstrings to quadriceps ratio of 68%, compared to 65.5% for the student population of Lucca & Kline (1989). In both cases, no correction was made for the effects of gravity.

Thus norms developed for athletic populations should not be applied to sedentary populations (Davies *et al.*, 2000).

3.4.6 Limb dominance

Existing strength differences between limbs may have important implications. When monitoring the progress during **rehabilitation**, the injured limb is often compared to the non-injured side (Henderson *et al.*, 1993; Perrin, 1993). Thus clinicians should be aware of possible differences that existed between limbs before the injury took place. Failure to consider possible **pre-existing bilateral differences**, might lead to erroneous conclusions regarding the progress or success of the rehabilitation programme (Perrin, 1993).

Subjects who participated in **symmetrical lower extremity** activities like cycling and running, do not always show significant differences in isokinetic strength (Perrin, 1993). Although unilateral differences of less than 10% have been reported in lower limb isokinetic strength of soccer players (Agre & Baxter, 1987; Capranica *et al.*, 1992), other researchers have found conflicting results. Chin *et al.* (1994) reported a 36% difference in knee extension torque between the dominant and non-dominant limbs in junior (age = 17.3 years) soccer players at 240°/s. They also reported a moderate difference between the dominant and non-dominant hamstrings, namely 10% at 240°/s. In contrast, Holmes & Alderink (1984) found no significant strength differences between the dominant and the non-dominant limbs for knee extension and flexion torque at 60°/s and 180°/s in high school children. Hageman *et al.* (1988) reported only a 6% difference in peak torque values between the dominant and the non-dominant knee extensors at 30°/s of non-disabled male subjects, while Wyatt & Edwards (1981) found a 4.6% difference in knee extensor torque at 60°/s and a 5.1% difference in knee flexor torque, of non-disabled men.

Athletes competing in **asymmetrical upper extremity** events like javelin throwing, have stronger dominant upper limbs (measured as differences in peak isokinetic torque). The difference may be as much as 15%, at velocities between 60°/s and 180°/s (Perrin *et al.*, 1987). McMaster *et al.* (1991) and McMaster *et al.* (1992), reported differences between 18% and 27% in peak isokinetic torque in the dominant internal shoulder rotation, in national water polo players and competitive swimmers, compared to the non-dominant side, at 180°/s.

Previous research indicated significant differences of up to more than 15% between the dominant and the non-dominant sides when evaluating the **upper extremities** (Perrin *et al.*, 1987; McMaster *et al.*, 1991; McMaster *et al.*, 1992), especially when considering elite athletes who perform unilateral upper limb sports like tennis (Wrigley & Strauss, 1989). The opposite seems to be the case when considering the **lower extremity**; except for athletic populations who partake in asymmetrical lower extremity sports like soccer, most individuals do not show differences larger than 10% between the peak torque of the dominant and the non-dominant lower limbs (Agre & Baxter, 1987; Capranica *et al.*, 1992; Chin *et al.*, 1994).

Thus the effects of dominance on bilateral peak torque should always be considered when screening for muscle imbalances in athletes or when conducting rehabilitation programmes in an orthopaedic setting (Perrin, 1993; Davies *et al.*, 2000).

3.4.7 Subject positioning

Due to length-tension relationships and joint biomechanics, isokinetic torque production will vary if changes occur in the positioning of the subject. For example, when performing knee extension and flexion in the seated position versus the prone position, different results will be obtained (Davies *et al.*, 2000).

Bohannon *et al.* (1986) investigated the effects of two different positions on knee flexion and extension peak torque at 60°/s. The two positions were: (1) upright sitting at about 95° of trunk flexion, and (2) semi reclined at about 30° of trunk flexion. They concluded that knee extension torque did not differ significantly between the two test positions, but that knee flexion torque was significantly greater in the upright position (approximately 8%). These findings were consistent with the research of Felder (1978) and Lunnen *et al.* (1981).

Hageman *et al.* (1989) studied the effects of two different positions (45° gleno-humeral abduction versus 45° gleno-humeral flexion) on shoulder internal and external rotators, at 60°/s and 180°/s. They reported that peak torque values were significantly higher in the abducted position during concentric and eccentric external and internal shoulder rotation.

Previous research thus indicates that the positioning of the subject may have a significant effect on torque production. Subject positioning should thus be standardized and meticulously recorded during isokinetic testing and training.

3.4.8 Contraction mode

Eccentric muscle contractions usually generate larger torque values than concentric contractions. This is attributed to the additional involvement of the non-contractile tissues (elastic components) during eccentric contractions. However, these differences are dependent on the movement velocity (Davies *et al.*, 2000).

3.4.9 Range of motion (ROM)

In order to reach the predetermined angular velocity, the limb has to accelerate from 0°/s, and to reverse the movement at the end of the ROM, the limb has to decelerate back to 0°/s. Thus the true isokinetic ROM or the **load range**, is always smaller than the maximum ROM. There is normally an inverse relationship between angular velocity and the load range: an increased angular velocity implies a smaller load range.

The size or magnitude of the selected ROM may influence the isokinetic test results as mentioned previously (3.3.6). By setting "hard" stops, at each end of the ROM, the biokineticist can ensure that all subjects transverse the same total ROM (Brown & Whitehurst, 2000).

3.4.10 Damp setting

At angular velocities below 90°/s, varying the damp settings (between low, medium or high) does not appear to significantly change the peak or average torque values (Rathfon *et al.*, 1991). However, the extent of the effect of dampening, on higher isokinetic velocities, are not known at present (Dvir, 1995).

3.4.11 Isometric pre-activation (IPA)

Isometric pre-activation (IPA) was introduced in most KinCom machines as a safety measure and to overcome the problem of overshoot. It had a positive effect on average torque, but did not seem to result in higher peak torques (Dvir, 1995). Isometric pre-activation remains controversial and therefore some manufacturers of isokinetic dynamometers have not included this feature in their designs (User's Guide: Norm testing and rehabilitation system, 1996).

3.4.12 Minimum and maximum force

The minimum force or lower isometric bias (LIB) normally serves as a complement to isometric pre-activation in some dynamometers. The LIB is the minimum force that has to be maintained in order for the dynamometer to proceed with the movement at the preset angular velocity (Dvir, 1995). An important factor to take cognizance of is the fact that dynamometers differ in their concentric modes of operation. The lever arm KinCom-type dynamometer moves at the preset velocity once activated, while a dynamometer like the Cybex, allows movement up to a maximum preset velocity. The constant velocity supplied by some dynamometers, is potentially dangerous, especially at high angular velocities and when low LIB values are used (Dvir, 1995). Isokinetic dynamometers are classified according to their velocity control mechanism. For example, some dynamometers use an electronic servomotor, others a hydraulic valve, or a mechanical braking system, while some utilize a magnetic braking system to control its velocity (Perrin, 1993).

The feature that involves limiting the maximum force that a contraction may elicit, is called the upper moment limit (UML). The UML may be activated to ensure the safety of vulnerable structures, like a recently reconstructed ACL. Thus the simultaneous use of LIB and UML, may be beneficial in non-maximal efforts, or for the purpose of fine motor performance analysis or training, and during early phases of the rehabilitation programme (Dvir, 1995).

3.4.13 Feedback

Feedback may be described in terms of form, amount, delay, and content (Peacock *et al.*, 1981; Dvir, 1995).

Peacock *et al.* (1981) demonstrated that isometric peak torque was significantly enhanced by combined visual and auditory feedback. However, this effect was not produced by using either of the methods separately. Figoni & Morris (1984) examined isokinetic performance with and without visual feedback and found a beneficial effect of about 12% at a slow velocity (30°/s), but no benefit at a faster velocity (300°/s). These findings have been confirmed by other researchers

(Baltzopoulos *et al.*, 1991; Hald & Bottjen, 1987). Thus the beneficial effects of visual feedback may be limited to slower isokinetic velocities (Dvir, 1995).

Wilk *et al.* (1991) investigated the effects of verbal feedback and encouragement. They found that aggressive verbal feedback and encouragement resulted in their subjects becoming fatigued earlier. They concluded that verbal feedback should be moderate in intensity and consistent in nature.

Thus any feedback given to a subject should be consistent from one test to the next and from one subject to another (Brown & Whitehurst, 2000).

3.4.14 Stabilization

Subjects should be properly stabilized before conducting an isokinetic evaluation or training session. This will eliminate compensatory movements that may interfere with the intended movement pattern and aid the correct alignment of the joint in question. However, Hanten & Ramberg (1988) reported no significant difference between maximal stabilization procedures and minimal stabilization at a wide range of angular velocities (30°/s to 200°/s) for concentric and eccentric knee extension.

This finding is in contrast with that of Hart *et al.* (1984) who reported significantly greater concentric torque values, regardless of the velocity, when subjects were allowed additional trunk stabilization. Other researchers share their view (Nosse, 1982; Smidt & Rogers, 1982).

3.4.15 Gravity correction (GC)

Failure to report on the gravity correction status of an isokinetic evaluation, will result in erroneous conclusions and interpretation of results (Brown & Whitehurst, 2000). Winter *et al.* (1981) reported mechanical work errors ranging from 26% to over 500% during knee flexion/extension exercise tests at 60°/s and 150°/s.

Researchers are strongly advised to correct for the effects of gravity if high-speed tests are to be conducted. As contraction speed increases, the concentric torque decreases, but gravity stays the same. Thus the relative proportion of the gravitational force increases in relation to the measured force output. This will not only lead to erroneous peak torque values and endurance ratios, but also to incorrect agonist/antagonist ratios (User's Guide: Norm testing and rehabilitation system, 1996).

Fillyaw *et al.* (1986) concluded that failing to correct for gravity effect torque (GET), would significantly decrease knee extension torque values and increase knee flexion torque values. This would lead to erroneous knee flexion/extension ratios. These authors also stressed the importance of correcting for GET in patients with reduced torque output, where the GET is a greater percentage of the measured torque.

One problem with correcting for the effects of gravity however, is the fact that it is a complex procedure, which requires the subject to relax completely. Some subjects are unable to relax one or both of their limbs. This leads to an inaccurate determination of bilateral torque values.

3.4.16 Effects of eccentric exercise

Maximal eccentric contractions may lead to a subsequent decrease in muscle tension development and strength. Research indicates that this muscle weakness is noted immediately after the eccentric exercise bout and it may last up to one week. This aspect should be considered when conducting research or isokinetic testing that involves eccentric protocols, and when designing rehabilitation programmes (User's Guide: Norm testing and rehabilitation system, 1996).

3.5 SOURCES OF ERROR IN ISOKINETIC DYNAMOMETRY

Numerous authors have commented on the reliability, validity, and efficacy of using isokinetics as part of testing and training. Today, isokinetic testing is regarded as a very accurate method for evaluating muscle performance (Farrel & Richards, 1986; Burdett & VanSwearingen, 1987; Wilhite, *et al.*, 1992; Brown *et al.*, 1993; Davies, 1995; Davies *et al.*, 1997; Davies & Zillmer, 1999).

However, the following **sources of error** have been highlighted in the use of isokinetics:

- acceleration and deceleration phases (Sapega *et al.*, 1982);
- the effects of gravity (Winter *et al.*, 1981);
- alignment of the dynamometer's axis to that of the joint (Herzog, 1988); and
- failure to calibrate the dynamometer on a regular basis (at least once a week).

Modern dynamometers make it possible to eliminate the first two sources of error largely, but the third source of error is probably the most problematic, unless one is dealing with the knee joint. The shoulder joint is particularly problematic and poor reproducibility for test-retest has been reported (Magnusson *et al.*, 1990).

If the object is evaluation of the maximal force of the contractile elements of a muscle, then only concentric contractions should be evaluated. During an eccentric contraction, the tension being generated is actually the combination of the contractile and the non-contractile elements within the muscle that are being pulled apart. Thus eccentric contractions at slow to moderate speeds are nearly always larger (approximately 30%), than the corresponding concentric contractions (User's Guide: Norm testing and rehabilitation system, 1996; Wilmore & Costill, 1999).

The largest source of error in the use of isokinetics however, is incorrect application and interpretation by the clinician (**human error**). This may be prevented by more comprehensive training of clinicians and by regular workshops conducted by "isokinetic experts".

3.6 NORMATIVE VALUES FOR INTERPRETING AN ISOKINETIC TEST

"Norm" is the abbreviated form of the word ***"normal"***. In the context of measurement and evaluation of physical properties like muscle strength, it denotes the *average* or *mean* performance of a group of individuals under similar circumstances. The plural form ***norms,*** refers to the availability of the mean, standard deviation, and percentile ranks for various performances of a comparative group, or reference group (Kirkendall *et al.*, 1979).

The use of normative data is **controversial**; however if it is utilized in an appropriate manner, it can be used as a valuable guideline for testing and for developing strength, for conditioning, and for rehabilitation programmes (Goslin & Charteris; 1979; Thompson *et al.*, 1985; Davies *et al.*, 2000).

The idea of setting or prescribing a norm or standard for any one individual or groups of individuals, will usually **evoke criticism** or emotional responses. The preoccupation with norms by some uninformed individuals must be condemned and discouraged. Norms and standards for isokinetic values could be **useful tools** when used by informed professionals, who are able to intelligently discriminate between the performances of different individuals, in different population sub-groups. The utilization of norms may be extremely useful if they are **viewed in context**, client individuality is recognized, and realistic goals are set for each individual (Krüger et al, 1995).

When constructing an isokinetic test protocol, an important decision to make is whether to use a norm-referenced or criteria-referenced test. The type of standard selected would probably depend on the nature of the decisions the biokineticist needs to make after completion of a specific test. When evaluating sporting performance, a norm-referenced score may not apply to the elite athlete. Similarly, criteria-referenced scores developed for athletes may not be realistic for the average individual recovering from an injury sustained in a motor vehicle accident.

In each individual case the following question should be asked: "What is the ***critical score*** that should be achieved in order to fulfil the specific individual's requirement?" For the average person, a percentile score of 50 might be required, whereas the elite athlete might only be satisfied with a score above the 95th percentile (Kirkendall *et al.*, 1981).

Norms can be prepared as percentile ranks, standard scores, T scales, or 6-σ scales. The most common method for reporting on isokinetic norms is to express the norm in terms of torque relative to body mass (% BM) (Kirkendall *et al.*, 1981).

3.6.1 Guidelines for constructing and utilizing norms

Dvir (1995) states that if norms are used, they should be related to **gender, age, and activity level**. To ensure that norms are based on a representative population, they have to be based on a **large number** of scores. It is desirable to have **more than 200** cases when developing norms, although some researchers require a sample equal to 10% of the specific population. In a very large population group (for example, 40 million people), this would not seem practical. However, large number of scores will enhance the reliability of rank ordering.

Although some studies have utilized very **small sample groups**, they may indicate **valuable trends** and actually serve as pilot studies for subsequent future research.

The most appropriate norms for comparing performances must be **local** and as specific as possible to the parameter tested. It is also important to supply all relevant information regarding the test **protocol** for which the norms were developed so that subsequent clinicians may follow **identical procedures** in their evaluations. The criteria used in developing the test must be addressed in detail and validation procedures must be described. The methods of establishing content validity and actual reports of validity and reliability studies should be included, as well as the age, sex, race, and cultural background of the population (Kirkendall *et al.*, 1981).

It is important to take **body mass** and **gender** into account when establishing normative data, since positive correlations exist between body mass, gender, and peak torque (Falkel, 1978, Gilliam et al, 1979). To eliminate the effect of body mass on peak torque, Thorstensson *et al.*(1977) suggested expressing peak torque in Nm/kg body mass (relative torque value), instead of Nm (absolute torque value). By using this method, individuals of different sizes may be compared.

Different researchers have embarked on the mission to establish normative data for different muscle groups. However, biokineticists should exercise caution when attempting to extrapolate test data from one isokinetic dynamometer to another or from one population group to another. Thompson *et al.* (1989) demonstrated significant differences between values obtained from two **different isokinetic dynamometers** (for example, the *Biodex Model b-2000* and the *Cybex II Plus*).

When reviewing the literature on isokinetic norms, how should one approach it? The author made use of certain selection criteria during the literature research. For data to be considered as normative, the following criteria had to be met:

- sample group preferably larger than 50 to 100;
- similar isokinetic dynamometers;
- same gender;
- similar age and activity level;
- body mass corrected torque values;
- peer-reviewed published research articles or publications;
- velocity-specific norms;
- similar set-up, for example, body position: prone or supine; and
- similarity regarding gravity correction.

The following sections (3.6.2 to 3.6.6) are the result of the literature research and may provide some useful normative data for male subjects. No attempt has been made to arrive at one absolute or ideal norm, since such a practice would have been stripped of any scientific basis.

3.6.2 Normative isokinetic values for shoulder flexion and extension

At **60°**/s, concentric shoulder flexion and torques varied from 62 Nm to 65 Nm, and shoulder extension values varied from 80 Nm to 122 Nm. Torque relative to bodyweight (% BM) varied between 80% and 76% for shoulder flexion, and between 97% and 150% for shoulder extension (Ivey *et al.*, 1985; Cahalan *et al.*, 1991). These two authors reported flexion/extension ratios of between 53% (Cahalan *et al.*, 1991) and 77% (Ivey *et al.*, 1985). Both these researchers used a **Cybex II** dynamometer, **did not correct for gravity**, used **healthy males** between the ages of 21 and 50 years, and their sample consisted of 36 (Ivey *et al.*, 1985) and 26 (Cahalan *et al.*, 1991) subjects. When the author pooled (n=62) the data, the following values were obtained: shoulder flexion 64 Nm (78% BM), shoulder extension 101 Nm (123% BM), and a flexion/extension ratio of 65%.

The abovementioned authors also conducted some research at **180°**/s on the same subjects, utilizing the same protocol. The pooled data resulted in the following values: shoulder flexion 47 Nm (57% BM), shoulder extension 70 Nm (86% BM), and a flexion/extension ratio of 68%.

Cahalan *et al.* (1991) also included **300°**/s in their research with the following resulting values: concentric shoulder flexion was 36 Nm (44% BM), shoulder extension was 64 Nm (79% BM), and the flexion/extension ratio was 56%.

3.6.3 Normative isokinetic values for shoulder horizontal abduction and adduction

Weir *et al.* (1990) conducted research on **104 male high school wrestlers** between the ages of 16 and 18. They used a **Cybex II** dynamometer and the dominant side was evaluated. The damp setting was two (2) and **no gravity correction was made**. Test speeds of **30°/s, 180°/s, and 300°**/s were used. The resultant values were as follows. Concentric shoulder horizontal abduction was 68 Nm, 51 Nm and 35 Nm at 30°/s, 180°/s, and 300°/s, respectively. Horizontal adduction measured 74 Nm, 53 Nm, and 35 Nm. Torque relative to BM yielded the following: shoulder horizontal abduction was 100% BM, 73% BM, and 52% BM at 30°/s, 180°/s, and 300°/s, respectively; horizontal shoulder adduction was 106% BM, 76% BM, and 51% BM. The shoulder horizontal abduction/adduction ratios varied from 93% at 30°/s, to 96% at 180°/s, and to 103% at 300°/s.

3.6.4 Normative isokinetic values for shoulder internal and external rotation

Ivey *et al.* (1985); Connelly Maddux *et al.* (1989), and Cahalan *et al.* (1991) conducted research at **60°/s and 180°**/s using the **Cybex II** dynamometer. They **did not correct for the effects of gravity** and their subjects were **63 males** between the ages of 21 and 50 years. Subjects were positioned with their shoulders in **90° of abduction**. They reported the following values: concentric shoulder internal rotation torque varied between 49 Nm and 42 Nm, at 60°/s and 180°/s, respectively. External shoulder rotation torque varied between 30 Nm and 24 Nm. Torque relative to BM for internal shoulder rotation was 60% BM and 51% BM, and between 36% BM and 29% BM for external shoulder rotation. The external/internal shoulder rotation ratio measured 61% and 58%, at 60°/s and 180°/s, respectively.

Wang *et al.* (2000) studied **10 elite male volleyball players**, with an average age of 20 years, using a **KinCom** dynamometer. Both shoulders were included in the evaluation. The following results were reported: the external/internal shoulder rotation ratios at **60°**/s **and 120°**/s varied between 67% and 69% for the dominant limb, and between 98% and 97% for the non-dominant limb. The **eccentric** shoulder external/internal rotation ratio varied between 74% and 84% for the dominant limb and between 93% and 84% for the non-dominant side at 60°/s and 120°/s, respectively.

Cahalan *et al.* (1991) reported the following values for the dominant shoulder of 26 male subjects at **300°**/s. They used a **Cybex II** dynamometer and did not correct for gravity. Concentric shoulder internal rotation was 34 Nm (42% BM), external shoulder rotation was 14 Nm (17% BM), and the shoulder external/internal rotation ratio was 41%.

3.6.5 Normative isokinetic values for shoulder abduction and adduction

Smith *et al.* (1981) and Weir *et al.* (1992) conducted research on **wrestlers** and **elite ice hockey players**, respectively. They both used a **Cybex II** dynamometer and did not correct for gravitational effects. The pooled sample consisted of 68 male subjects with an average weight of 76 kg and an average age of 21 years. They reported the following values at **60°/s and 180°/s.** Shoulder abduction torque was 73 Nm (97% BM) at 60°/s and 56 Nm (72% BM).at 180°/s. Shoulder adduction torque was 92 Nm (119% BM) and 68 Nm (88% BM) at 60°/s and 180°/s, respectively. The shoulder abduction/adduction ratios measured 82% at 60°/s and 84% at 180°/s.

The following data was presented by Ivey *et al.* (1985) and Cahalan *et al.* (1991) using a **Cybex II** dynamometer for **44 male** subjects between the ages of 21 and 50 years. Concentric shoulder abduction values were between 48 Nm (57% BM) at **60°**/s, and 38 Nm (45% BM) at **180°**/s, while the shoulder adduction values were 85 Nm (103% BM) at 60°/s, and 74 Nm (91% BM) at 180°/s. They also reported the following shoulder abduction/adduction ratios: 56% at 60°/s and 51% at 180°/s. These authors **did not correct for the effects of gravity**.

Wilk *et al.* (1992) studied the shoulders of **50 professional male baseball pitchers** using a **Biodex** dynamometer. The average age was 25 years, the average BM 91 kg, and the average height 188 cm. No visual feedback was given and **no correction was made for gravity**. They compared the values of the dominant side to that of the non-dominant side. The angular velocities used were 180°/s and 300°/s. At **180°/s** the following values were reported: shoulder abduction torque was 75 Nm (83% BM) and 80 Nm (87% BM) for the dominant and non-dominant side, respectively. Shoulder adduction was 94 Nm (103% BM) and 86 Nm (94% BM) at 180°/s, and the shoulder abduction/adduction ratio was 80% for the dominant side and 93% for the non-dominant side.

At **300°/s** they reported a concentric shoulder abduction torque of 59 Nm (64% BM) and 53 Nm (58% BM) for the dominant and non-dominant sides, respectively. Shoulder adduction torque at 300°/s was 76 Nm (83% BM) and 74 Nm (81% BM), and the shoulder abduction/adduction ratio was 78% for the dominant side and 72% for the non-dominant side.

3.6.6 Normative isokinetic values for knee flexion and extension

Krüger *et al.* (1992) investigated dominant knee flexion and extension at **60°**/s, in **536 inactive Caucasian males**, using a Cybex II dynamometer. The average height, body mass (BM), and age of the subjects were 177 cm, 79 kg, and 25 years, respectively. Their isokinetic values **were all corrected for the effects of gravity**. Average concentric knee flexion was 127 Nm (183% BM), and knee extension was 238 Nm (338% BM). These authors reported a knee flexion/extension ratio of 54%.

Gross *et al.* (1989) also investigated dominant knee flexion and extension at **60°/s** in **49 males**, between the ages of 15 and 50 years (the average age was 31 years). Their subjects had an average height of 174 cm and an average weight of 73 kg. The authors used a **Cybex II** dynamometer and **corrected for the effects of gravity**. They reported values of 134 Nm (184% BM) for knee flexion, 198 Nm (272% BM) for knee extension, and the knee flexion/extension ratio was 68%. However, when only the values of the 30-year old group were considered, a knee extension value of 240 Nm (307% BM) was reported, knee flexion was 153 Nm (196% BM), and the knee flexion/extension ratio was 64%. The values reported for the 15-year old group yielded a knee extension value of 152 Nm (264% BM), a knee flexion value of 108 Nm (189% BM), and a ratio of 72% between flexion and extension. The different torque values from this study between different age groups serve as a caution to compare non-population specific torque values.

Ghena *et al.* (1991) used a **Biodex B-2000** to investigate concentric and eccentric knee flexion and extension at **60°/s** in **male, university athletes**. The dominant side was selected and values were **corrected for gravity**. The average age, height and weight were 20 years, 182 cm, and 76 kg, respectively. Their values were as follows: **concentric** knee flexion (142 Nm and 186% BM), knee extension

(260 Nm and 340% BM), and knee flexion/extension ratio (55%). They also reported on **eccentric** values. Eccentric knee flexion was 166 Nm (218% BM), eccentric knee extension 257 Nm (337% BM), and the eccentric knee flexion/extension ratio was 65%. The eccentric knee flexion/concentric knee extension ratio was 64%.

Schlinkman (1984) reported very similar values at **60°/s** compared to that of Krüger *et al.* (1992) and Ghena *et al.* (1991). Their values were 127 Nm and 179% BM for knee flexion, 235 Nm and 338% BM for knee extension, and a flexion/extension ratio of 54%. They used a **Cybex II** dynamometer and **corrected for the effects of gravity**. Their subjects consisted of male, **high school football players** (n=342) with an average age of 16 years. Thus it may seem that the subjects from the study of Krüger *et al.* (1992), although reported to be inactive, might have been quite active during their high school years.

Highgenboten *et al.* (1988) also investigated **eccentric** knee flexion and extension at **60°/s**, but they used a **KinCom** dynamometer. They tested both the left and the right side and the data that will be presented is the average of the two sides. It is **unclear** from their publication **whether they corrected for the effects of gravity**. Their sample group consisted of 54 **males** with an average age of 25 years and an average weight of 75 kg. Their values were slightly lower than that of Ghena *et al.* (1991), probably because the age of their sample group was higher and did not exclusively consist of athletes. Eccentric knee flexion was 106 Nm (141% BM), eccentric knee extension 216 Nm (288% BM), and the eccentric knee flexion/extension ratio was 52%.

Wyatt & Edwards (1981) were the only researchers that the author came across who **did not correct for the effects of gravity**, and who fitted the criteria for a **normative** database. However, it must be stated that several other researchers (Lucca & Kline, 1989; Nunn & Mayhew, 1988; Holmes & Alderink, 1984) conducted non-gravity corrected studies on groups smaller than 50 subjects, but they were not considered for this text.

Wyatt & Edwards (1981) conducted their research on **"healthy" male subjects** with an average age, height, and weight of 29 years, 179 cm, and 78 kg. These authors used a **Cybex II** dynamometer for their study. They reported the following values: concentric knee flexion (130 Nm & 168% BM), knee extension (183 Nm & 236% BM), and a ratio of 72% for knee flexion/extension.

It is clear that the ratio of 72%, reported by Wyatt & Edwards (1981) is much higher than that of the abovementioned researchers, who took the effects of gravity into consideration (Krüger *et al.*, 1992; Schlinkman, 1984). It was only the knee flexion/extension value reported by Gross *et al.* (1989) of 68%, that did not agree with these low ratios (54%). When comparing the data of Krüger *et al.* (1992) and that of Gross *et al.* (1989), a possible explanation lies in the fact that the subjects of Krüger *et al.* (1992) displayed much higher knee extension torques compared to Gross *et al.* (1989) (238 Nm vs. 198 Nm). Even when the torque values are expressed relative to body mass, the trend still holds (338% BM vs. 272% BM). Seen together with the fact that the knee flexion values were fairly similar (127 Nm vs. Nm, and 183% BM vs. 184% BM), one might conclude that the subjects of Krüger *et al.* (1992) were more athletically inclined.

When one compares the findings of the author at **60°/s** (**non-gravity corrected torques**), the following was found: concentric knee flexion (159 Nm & 222% BM), knee extension (236 Nm & 331% BM), and a flexion/extension ratio of 68%. Apart from the flexion/extension ratios of the author (68%) and the 72% reported by Wyatt & Edwards (1981) that seem quite similar, the knee flexion and extension values are quite different (flexion: 222% BM vs. 168% BM and extension: 331% BM vs. 236% BM). This comparison should caution all biokineticists and clinicians involved in orthopaedic rehabilitation to use population-specific normative databases.

Numerous studies have been conducted on the knee flexion and extension torque of males at **other angular velocities** (see Table 3.1).

Table 3.1: A summary of previous studies on the knee flexion and extension torque of males at angular velocities other than 60°/s.

Authors	Ext. % BM	Flex. % BM	Ratio	GC	Dynamo-meter	Subjects	Age	BM kg	n
12°/s	CON								
Borges, 1989	348%	198%	57%	Yes	Cybex II	Mixed	30	76	76
30°/s	CON								
Knapik & Ramos, 1980	200 Nm	115 Nm	58%	No	Cybex II	Infantry soldiers	24	74	352
Freedson *et al.*, 1993	238%	153%	66%	No	Cybex II	Medium-heavy work	35	82	3345
90°/s	CON								
Borges, 1989	280%	152%	54%	Yes	Cybex II	Mixed	30	76	76
Borges, 1989	246%	132%	54%	Yes	Cybex II	Mixed	45	78	139
Knapik & Ramos, 1980	138 Nm	90 Nm	65%	No	Cybex II	Infantry soldiers	24	74	352
120°/s	CON								
Ghena *et al.*, 1991	287%	165%	58%	Yes	Biodex B-2000	University athletes	20	76	100
Ghena *et al.*, 1991	341%	220%	65%	Yes	Biodex B-2000	University athletes	20	76	100

Authors	Ext. % BM	Flex. % BM	Ratio	GC	Dynamo-meter	Subjects	Age	BM kg	n
180°/s	CON								
Gross *et al.*, 1989	184%	158%	87%	Yes	Cybex II		31	73	49
Knapik & Ramos, 1980	88 Nm	60 Nm	68%	No	Cybex II	Infantry soldiers	24	74	352
Freedson *et al.*, 1993	131%	104%	81%	No	Cybex II & Cybex II+	Medium-heavy work	35	82	3345
Wyatt & Edwards, 1981	170%	131%	78%	No	Cybex II	"Healthy"	29	78	50
Smith *et al.*, 1981	175%	141%	81%	No	Cybex II	Ice hockey players	24	83	43
240°/s	CON								
Schlinkman, 1984	191%	126%	66%	Yes	Cybex II	High school male football	16		342
300°/s	CON								
Ghena *et al.*, 1991	191%	116%	61%	Yes	Biodex B-2000	University athletes	20	76	100
Freedson *et al.*, 1993	89%	82%	96%	No	Cybex II & II+	Medium-heavy work	35	82	3345

Authors	Ext. % BM	Flex. % BM	Ratio	GC	Dynamo-meter	Subjects	Age	BM kg	n
Wyatt & Edwards, 1981	115%	94%	83%	No	Cybex II	"Healthy"	29	78	50
Schlinkman, 1984	161%	108%	67%	Yes	Cybex II	High school football players	16		342
450°/s	CON								
Ghena *et al.*, 1991	148%	120%	80%	Yes	Biodex B-2000	University athletes	20	76	100

For the purpose of this text, only knee flexion and extension torques at 60°/s were considered, but the present author is well aware of the trend that Biokineticists and other clinicians include higher angular velocities into their test protocols. It is therefore hoped that the above table will be of practical use.

3.6.7 Normative isokinetic values for ankle plantar and dorsiflexion

Before the study by Krüger *et al.* (1995), very little normative data existed regarding the ankle musculature. Krüger *et al.* (1995) stated that previous researchers negated testing the ankle's plantar and dorsi flexor strength as well as the strength of the ankle invertors and evertors, possibly due to methodological problems such as the isolation of the invertors and evertors in order to reproduce accurate measurements (Gleim *et al.*, 1978).

Isokinetic testing of the ankle joint's plantar and dorsiflexion may be conducted with the knee straight or bent at 90°. In the 90° knee flexion position, the gastrocnemius muscle is thought to be at a disadvantage and cannot contribute hugely to ankle plantar flexion torque production (Kendall *et al.*, 1993).

No research study fitting the **author's criteria** for a **normative database** was found in the literature for ankle plantar and dorsiflexion at 30°/s with the knee straight **(0° knee flexion)** however, Fugl-Meyer (1981) conducted some research on inactive subjects (n=15) and competitive athletes (n=15). He reported the following values **(not corrected for gravity)** for inactive subjects and athletes, respectively: ankle dorsiflexion (33 Nm & 47% BM vs. 35 Nm & 47%), plantar flexion (126 Nm & 180% BM vs. 184 Nm & 245% BM), and dorsi/plantar flexion ratio (26% vs. 19%). The author's results compare well with that of the inactive population of Fugl-Meyer (1981): dorsiflexion (36 Nm & 52% BM), plantar flexion (131 Nm & 186% BM), and a dorsi/plantar flexion ratio of 29%.

Fugl-Meyer *et al.* (1980) also conducted some research on ankle plantar flexion in **"healthy" Swedish men**, using the **straight knee position** at angular velocities of **90°/s** and **180°/s**. Their sample consisted of 30 subjects, with an average height and BM of 179 cm and 72 kg, respectively. The subjects were between the ages of 20 years and 39 years, and both the left and right ankles were tested. The authors used a **Cybex II** dynamometer and **no correction** was made **for the effects of gravity**. They reported the following results: average concentric plantar flexion at 90°/s was 76 Nm (106% BM), and at 180°/s it was 40 Nm (56% BM).

Krüger *et al.* (1995) evaluated dominant ankle plantar and dorsiflexion at **30°/s** with the **knee flexed to 90°**. They used a **Cybex II** dynamometer and their subjects totalled 306 inactive Caucasian males. The average age, height, and weight of the subjects were 26 years, 176 cm and 78 kg, respectively. **No correction** was made **for the effects of gravity**. The average for concentric dorsiflexion was 30 Nm (34% BM), and 70 Nm (102% BM) for plantar flexion.

3.6.8 Normative isokinetic values for ankle inversion and eversion

Wong *et al.* (1984) conducted research on concentric ankle inversion and eversion at three angular velocities (**30°/s, 60°**/s **& 120°**/s), using a **Cybex II** dynamometer. Although they only utilized 21 subjects (which disqualifies their data for inclusion into a normative database), their results are included in the text, due to the scarcity of data in this mode of testing. Their subjects consisted of **"healthy" males** with an average age, height, and body mass of 29 years, 178 cm and 76 kg, respectively. Their results were as follows: concentric ankle eversion torque at 30°/s, 60°/s, and 120°/s (28 Nm, 24 Nm, & 19 Nm), inversion torque (32 Nm, 26 Nm, & 22 Nm), and eversion/inversion ratios of 87%, 90%, and 86%, respectively. When expressing their torque values relative to body mass, they reported values 37% BM, 32% BM and 26% BM for ankle eversion, and 43% BM, 35% BM and 30% BM for ankle inversion.

Gross & Brugnolotti (1992) conducted similar research on **"healthy" males** at velocities of **60°**/s and **120°**/s. Forty-three subjects were used (age = 40 years, height = 177 cm, body mass = 78 kg), **no correction** was made **for gravity**, and a **Biodex** dynamometer was used. They reported the following concentric values: ankle eversion at 60°/s and 120°/s (26 Nm & 33% BM (60°/s), and 20 Nm & 25% BM (120°/s)), ankle inversion (31 Nm & 40% BM (60°/s), and 26 Nm & 34% BM (120°/s)), and an eversion/inversion ratio of 82% and 76%, respectively.

The abovementioned authors' results (Gross & Brugnolotti, 1992; Wong *et al.*, 1984) are very similar and could possibly be adopted as **"normative"**, in the absence of other available data.

3.6.9 Normative isokinetic values for elbow flexion and extension

When evaluating the elbow's flexors and extensors, there are two main set-up procedures. The first involves an anatomical zero (AZ) position grip (that is, forearm in full supination). The second method has the forearm pronated 90° from full supination or AZ (90°-pronated). No normative data was found for the second positional set-up (90°-pronated) however, Knapik & Ramos (1980) used the first set-up method (AZ) and conducted research on 352 **infantry soldiers** at **0°/s, 30°/s, 90°/s, and 180°/s**. They used a Cybex II dynamometer and **did not correct for the effects of gravity**. Their subjects (age=24 years, height=176 cm, body mass=74 kg) were all **males**. They reported the following values. At **30°/s** elbow flexion was 50 Nm (67% BM), extension was 44 (59% BM), and the flexion/extension ratio was 114%. At **90°/s and 180°/s** elbow flexion values were 36 Nm (48% BM) and 29 Nm (39% BM), extension values were 33 Nm (44 % BM) and 27 Nm (36% BM), and the elbow flexion/extension ratios were 109% and 107%, respectively.

3.6.10 Normative isokinetic values for forearm pronation and supination

Very few researchers have studied isokinetics of the forearm movements, and no normative database could be found (Perrin, 1993).

3.6.11 Summary

In order to conduct and interpret an isokinetic test, a sound knowledge of isokinetic terminology is crucial. Testers should also be aware of any factors that may influence the outcome of isokinetic testing. When interpreting the results from an isokinetic test, it is sometimes helpful to refer to normative values for a specific joint. However, norms should preferably be specific for each population tested. Additionally, sport-specific norms should not be used when evaluating sedentary individuals. Thus the absence of non-gravity corrected normative values for young South African men is seen as problematic when trying to interpret isokinetic test results in this population. This is especially true for patients that suffered bilateral joint injuries or in cases where there was a certain amount of muscle atrophy in the non-involved extremity.