

NATIONAL PROTOCOLS FOR THE ASSESSMENT OF STRENGTH AND POWER

DEVELOPED BY:

**NATIONAL & STATE INSTITUTE/ACADEMY OF SPORT
STRENGTH AND CONDITIONING
COACHES / SCIENTISTS**

SUPPORTED BY:

NATIONAL SPORT SCIENCE QUALITY ASSURANCE PROGRAM



Australian Government
Australian Sports Commission



**AUSTRALIAN
INSTITUTE OF SPORT**
**NATIONAL SPORT SCIENCE
QUALITY ASSURANCE PROGRAM**

Version 1.6
Effective May 2006

Contents

1. INTRODUCTION:.....	3
1.1 Objectives of Testing:.....	3
1.2 Applied Definitions for Strength and Power Assessment Tests:.....	4
2. ATHLETE PREPARATION:	5
2.1 Training:.....	5
2.2 Diet and Supplements:.....	5
2.3 Frequency and Scheduling of Testing:.....	7
2.4 Time of Testing:.....	7
2.5 Test Order:	7
3. PRE-TEST PREPARATION:.....	9
3.1 Suggested Warm Up Protocol:.....	9
4. STRENGTH/POWER TESTS:	11
4.1 Bench Press:	11
4.2 Bench Pull:	12
4.3 Chin Ups:.....	13
4.4 Incline Leg Press:.....	13
4.5 Single Leg Press:	14
4.6 Squats:	15
4.7 Power Cleans:	16
4.8 Power Snatch:	17
4.9 Deadlift:	18
5. STRENGTH ENDURANCE TESTS:	19
Absolute Strength Endurance:	19
Relative Strength Endurance:	19
Testing Strength Endurance:.....	19
6. OTHER STRENGTH & POWER TESTS:.....	20
6.1 Reactive Power Tests:	21
6.2 Vertical Jump:.....	25
6.3 Multi-Stage Abdominal Strength Test:	26
6.4 Core Stability Test:.....	27
7. References:.....	30

1. INTRODUCTION:

Elite sport in Australia, leading up to and particularly following the Sydney Olympics has evolved into a national approach through effective communication and cooperation between the national and state institute/academies of sport. A system that is the envy of the rest of the world that will hopefully help to maintain Australia's leading performance on the international stage.

This national approach to sport science servicing and research of the high performance athlete has seen the standardisation of testing protocols across institutes/academies so that comparable data can be obtained in different parts of the country. Often this data is used as part of the selection criteria into national teams, to investigate the effectiveness of training programs and to answer the many research questions that arise in attempts to optimise sports performance. As such, there needs to be a high standard of quality control to be exhibited during testing situations.

The assessment of strength and power is not as well developed as the other components of fitness with little consistency between institutes/academies in terms of the rationale for and execution of testing protocols. The following document therefore contains guidelines for the assessment of strength and power for athletes involved in elite strength training programs. Before proceeding into these protocols, it is important to realise that this is a working document that outlines the desired protocols for the assessment of strength and power based on current theory. It is expected that these protocols will be updated with the discovery of new and pertinent information and the development and acquisition of new innovative testing equipment.

Although great care has been taken in the selection of tests and testing procedures, the following issues must be considered during data interpretation:

- training adaptations are specific and may not be detected if the training and testing exercises are dissimilar or the test is insensitive to small training gains;
- the tests measure a specific strength quality during a specific task. Care must be taken when reporting what influence and importance these changes have on sports specific performance unless this relationship has been reported previously.

1.1 OBJECTIVES OF TESTING:

The assessment of strength and power is of critical importance in exercise science to:

- generate a profile of the athletes strengths, weaknesses and potential problems;
- generate a profile of a sport and the relevance of strength and power to it;
- monitor the effects of training, detraining and rehabilitation;
- provide motivation and encouragement to the athlete through the use of feedback and goal setting;
- increase the athletes accountability by using testing to monitor their compliance to training;
- monitor the athletes skill/technique acquisition under maximal load.

1.2 APPLIED DEFINITIONS FOR STRENGTH AND POWER ASSESSMENT TESTS:

The following ‘applied’ definitions and classification system have been employed for strength and power assessment tests detailed in this manual.

1.2.1 Strength / Power:

Maximum strength is the peak external load that can be moved in a specific dynamic task without reference to time. It is considered to be the basic quality that influences power [Schmidtbleicher, 1992]. Strength can be measured/expressed as a given number of repetitions (1 RM, 3 RM, 6 RM), where 1 RM is the maximum load an athlete can lift for one repetition. Three RM and six RM are the heaviest loads an athlete can lift in a given exercise with good technique and no external assistance three or six times, respectively. Strength and power assessment protocols included in this manual include variations of multiple RM tests.

The benefits of a multiple RM test compared to a maximal 1 RM test are:

- most athletes are not accustomed to using 1RM in training therefore multiple repetitions provide greater familiarity to training sets;
- multiple repetitions allow for assessment of technique during performance of test and allow for the early detection of technique deterioration;
- multiple repetitions can provide for greater reliability in the assessment of strength and power.

Predictive equations have been shown to be influenced by the muscle group tested, exercises performed [Morales, 1996] and training level [Braith, 1992; Baker, 1995]. Due to the large variability recorded ($\pm 10\%$) using sub-maximal repetitions to predict maximal strength [Braith, 1992], predictive equations are not used when presenting strength testing data.

1.2.2 Strength Endurance:

Strength endurance (SE) is measured as the maximum number of continuous repetitions completed at a designated load. SE can be classified as either absolute or relative to maximum strength [Young, 1995]. Relative SE relates to the muscles ability to work at a given percentage of maximum strength (ie. 75% of 3RM). Absolute SE is the muscles ability to work at a predetermined load, irrespective of maximum strength (ie. 50 kg or 100 kg).

2. ATHLETE PREPARATION:

A primary objective of testing is to assess changes in performance as a result of prescribed training loads. Many physiological capacities can be influenced by variables such as diet, fatigue, medications, illness, injury and environmental conditions. Athletes who present themselves for testing sessions should be in a similar state with regard to nutrition and fatigue for every testing session [Fricker and Fallon, 2000]. Therefore a standardised pre-test protocol is strongly recommended for reliable testing.

When performing tests over an extended training period such as a scholarship year it is unpractical to standardise literally all aspects of athlete preparation prior to each test. However, the following issues should be monitored and standardised as much as possible.

2.1 TRAINING:

Subjects should have no training induced severe physiological or neural fatigue in the 72 hours prior to testing [Abernethy, 1995]. This will exclude athletes from participating in any maximal physiological testing or physical training prior to strength testing.

No unaccustomed exercise should be performed 72 hours prior to strength testing that may result in sarcomere damage and/or decreased activation of motor units. Unaccustomed exercise includes: a change in resistance exercise selection; increases in training volume (number of sets, exercises or resistance sessions) or the performance of high volume eccentric contractions [Nosaka 2001; Byrne, 2001].

To ensure task familiarisation, the strength measures (e.g. bench press) should be incorporated into the usual training routine prior to testing.

An equivalent volume of training should be performed prior to all test sessions. At least three days prior to testing, a decrease in strength training volume of up to 50% should occur with training intensity remaining the same.

2.2 DIET AND SUPPLEMENTS:

Meal Content and Timing:

When using testing as a monitoring tool to evaluate athlete progress as opposed to an investigative research design, individual comfort levels should dictate actual meal size/volume and timing. However, in the research setting, many researchers are now utilising a dietary log prior to the day of investigative testing. Common practice is to record three days of food intake prior to the day of testing to ensure consistency across treatment interventions by replicating the respective meals prior to all subsequent tests.

Alcohol:

The effect of ethanol on a conditioning program over a number of weeks or months requires study. Kozoris (2000) found intoxication after resistance exercise had only a minor effect on the neuro-endocrine system. The consumption of alcohol prior to testing should be ethical grounds for exclusion from strength testing.

Stimulants:

Stimulants such as nicotine and caffeine should be controlled prior to high power neuro-muscular assessments. The specific impact of smoking on strength and power assessment has not been examined.

Jacobson (1992) et. al. reports that caffeine ingestion of 7 mg.kg^{-1} significantly increased knee extensor torque (isokinetic) at low and high speeds (30 and 300 degrees per second) by 22.6 % and 11.4 % respectively. The author states that the subject's fibre type, motivation and caffeine sensitivity need to be elucidated as part of further research. Tarnopolsky (2000) demonstrated that habitual users (771 mg.d^{-1}) do not differ to non-habitual consumers (14 mg.d^{-1}) of caffeine. Both groups with an ingestion of 6 mg.kg^{-1} , had a significant effect (on muscle force of contraction at low frequency (20HZ) muscle stimulation. Bond (1986) reports that low dosages of caffeine (5 mg.kg^{-1}) and Jacobson (1991) dosages of 300-600 mg absolute exert no ergogenic effect on isokinetic anaerobic measures.

From a practical perspective, habitual coffee drinkers are unlikely to report a marked improvement in test results and normal daily intakes can be maintained (Note - caffeine content of retail coffee beverages range from 60-120 mg of caffeine per serve). The use of caffeinated sports or commercial beverages in amounts greater than 6 mg.kg^{-1} two hours prior to testing should be discouraged.

Creatine Monohydrate:

Creatine Monohydrate (CM) may have short-term effects on maximal strength testing results. Maximal 1RM leg press strength has been significantly increased from 7-15 % over 5-7 days in older adults (Gotshalk, 2002) and up to 25.2 % in young males over 21 days when 20 g.d^{-1} for 7 days followed by 10 g.d^{-1} for 16 days is ingested (Vukovich, 1998). Although other activities (e.g bench press) have shown no statistically significant difference to control groups, short-term CM use to boost 1RM test results should be discouraged.

Longer-term CM use over 12 weeks will result in greater strength gains in 1RM bench press and squat compared to controls (24 % and 32 % compared to 16 % and 24 %) if a dosage of 5 g.d^{-1} is maintained after an initial loading phase (25 g.d^{-1} for 7 days) [Volek, 1999]. Untrained subjects may experience up to 64.9 % greater gains in 1RM leg press strength with use of CM (6 g.d^{-1}) over 12 weeks of twice weekly strength training [Willoughby, 2001]. CM use to achieve greater rates in 1RM results should be noted in testing records.

When 20g of CM and 80g dextrose for 5 days is ingested by subjects, Stout (2000) reports a reduced onset of neuromuscular fatigue (as measured by PWC Fatigue Test). CM also significantly enhances repetitive power performance in squat and bench press measures [Izquierdo, 2002]. This may indicate the need for caution when examining measures of explosive strength and power over a number of trials.

Of more importance is the effect of CM on strength endurance (max repetition tests). Significant difference of 13.5 % and 18.8 % has been reported for max reps achieved with 70 % and 60 % of 1RM for the squat and bench press exercises respectively over controls by CM users (20 g.d^{-1} for 5 days) [Izquierdo, 2002]. CM use to boost strength endurance test results should be noted in testing records.

Prescribed and Non-Prescribed Medications:

The effects of banned substances (as listed by ASDA or the International Sports Federation) and stimulants found in common medications should be recorded (flu medications or asthma sprays). Temporary use of stimulants to manage pain or viral symptoms should also be recorded and interpreted with caution.

Where an athlete presents with illness or injury test results should be interpreted with caution if performed at all.

2.3 FREQUENCY AND SCHEDULING OF TESTING:

A planned testing schedule should be outlined in an annual plan and should be reflective of the specific targets established for each phase of training. Annual planning of testing will enable the strength and conditioning coach to address issues highlighted in section 2.1.

While feedback can be attained from each session based on training loads, the recommended minimum time period for scheduled testing to evaluate athlete progress is 6 weeks. Recognised significant improvements should be greater than the error of measurement (or variation in maximum results between testing trials).

2.4 TIME OF TESTING:

While strength has been reported to peak in the early evening (1400-1900 hours) [Atkinson, 1996] athletes should be tested at the same time of day in subsequent tests to avoid fluctuations in performance due to circadian rhythm [Winget, 1985]. Therefore strength testing should occur at the same time of day as regular training.

2.5 TEST ORDER:

It is imperative that strength and reactive power testing be coordinated with other physiological assessment during the annual training cycle and within a given testing week. Testing power should be performed at different time to endurance and field testing due to the effects of potentiation. The time span needs to be greater than 1 hour to avoid this phenomenon.

A weekly testing/training plan needs to be developed at the start of an annual cycle to ensure that physiological assessment of the athlete is coordinated with training. This ensures that testing conditions (day, time, etc) are maintained throughout the year. This plan needs to be distributed to the athlete prior to their initial assessment and the athlete educated of the rationale and importance of adhering to this plan.

Tests should be completed in an order whereby fast and explosive tests (reactive power) are completed prior to slower strength and strength endurance tests. Furthermore, multi segment or multi body part exercises should be completed prior to single segment exercises. The following list is an example of suggested test order. However, as has been stated earlier the main consideration is that test order should be maintained between test sessions.

Suggested Test Order:

Reactive Power →	Strength →	Strength Endurance
Counter Movement Jump Squat Jump Drop Jump Vertical Jump	① Snatch ② Power Cleans ③ Squats <u>Other:</u> Leg Press Bench Press Bench Pull Chins	

Strength Tests

- complete more “explosive” tests prior to less “explosive” tests
- complete “complex – whole body” tests prior to “simple – single” tests

3. PRE-TEST PREPARATION:

Physiologically, the result of a “general warm up” or aerobic preparation is an increase in circulation, an increase in oxygen delivery to muscle tissue, and an elevation in body core temperature. Therefore, muscle temperature rises and viscosity is reduced resulting in greater efficiency of muscle contraction, whilst also reducing the potential for muscle pulls and skeletal muscular injury [Burke, 1977].

Physiologically, a “specific warm up” results in a spectrum of advantages. An increase in muscle and blood temperature results in improvement in both contractile force and contractile speed because muscles contract and relax faster and contract with greater efficiency due to lower viscous resistance [Burke, 1977]. A specific warm up also warms and circulates lubricating fluid within the joints (synovial fluid), which enhances freer movements of the associated joints, increases full range of motion (ROM) and decreases the potential for injury [Harris & Elbourn, 2002]. Completing the combination of advantages of the specific warm up is the psychological preparation for the activity to follow which prepares the athlete mentally for a maximal effort whilst also enhancing the transmission of nerve impulses for the specific movement and or exertion [Burke, 1977; Harris & Elbourn, 2002].

In summary, advantages of an effective warm up include:

- increases the heart rate and blood circulation gradually;
- increases body core temperature and muscle temperature;
- permits freer movement in joints;
- prepares the joints and associated muscles to function through their full range of motion;
- improves the efficiency of muscular actions;
- reduces risk of injury;
- improves the transmission of nerve impulses;
- aids psychological preparation.

3.1 SUGGESTED WARM UP PROTOCOL:

The warm up process should be broken into two sections. Firstly, the “general warm up” consisting of a light aerobic format. This should be then followed by a test “specific warm up” in which the action of the particular test is mimicked at a gradual increase of weight and decrease of repetitions. Examples of both formats are detailed in the following tables.

The intensity and duration of the warm up should be adjusted to the individual’s level of strength/fitness and or training age. This is to be known as the tester/coach’s duty of care. It is at the athlete’s discretion as to whether they utilise stretching of any form as part of a general warm up and in recovery periods of the specific warm up.

As a minimum, all athletes are required to perform an initial trial at ~ 90% of specified repetition maximum for each test to be performed.

General Warm Up:

Action	Duration
Ergometers (Mixed)	5 minutes minimum

[Burke, 1977; Harris and Elbourn, 2002]

Exercise Specific Warm Up:

Action	Duration
≤ 40-60% of specified RM	≤ 10 Reps
Recovery	≥ 2 minutes
≤ 60-80% of specified RM	≤ 5 Reps
Recovery	≥ 2 minutes
<i>90% of specified RM</i>	<i>≤ 3 Reps</i>
<i>Recovery</i>	<i>≥ 5 minutes</i>

[Burke, 1977; Maud and Foster, 1995]

4. STRENGTH/POWER TESTS:

All of the following tests must be supervised by an accredited strength and conditioning coach/scientist. All exercises are to be performed in a controlled manner. Any noted technical violations will result in the trial being invalid and a 2nd attempt at the same weight will be provided.

The following general guidelines must be adhered to for all tests:

- Ensure that athlete has performed appropriate warm-up (section 3.1). As a minimum, all athletes are required to perform a trial at ~ 90% of specified repetition maximum for each test. If first test, athlete should perform an initial trial at ~ 90 % of weight lifted in training.
- Lowering and lifting actions must be performed in a continuous manner. A single rest of no more than 2 seconds is allowed between repetitions.
- A maximum of 5 minutes recovery between trials is allowed.
- Minimum weight increments of 2.5 kg should be used between trials. However increments should be guided by ease of each trial.
- Ideally, specified RM test should be completed within 4 trials (not including the warm-up).
- If athlete is unable to complete tests as per protocol then this should be noted on testing results information, and values should not be included any mathematical calculations (eg. average, TE).
- It is recommended that a spotter, other than supervising coach, should be used where possible.
- If athlete is unable to adequately complete one rep within a set, then set/test should be recorded as a fail. If tester is unsure as to successful completion, or athlete believes that they can complete successfully, allow athlete a 2nd attempt with 2-3 minutes of initial trial.
- Athlete body mass for each test session should be recorded as body mass including clothes and shoes.

4.1 BENCH PRESS:

Test Procedure:

Preparation/Test:

- Athletes may choose the width of grip that they prefer initially but this should remain consistent over consecutive attempts and tests. In the bottom position, the forearms should be perpendicular to the floor.
- Foot position should be recorded (either both feet on the floor or on the bench).
- Record RM result on recording sheet.
- Recommended assessor position – 45° to front of athlete level with hips to facilitate observation of feet, shoulders and buttocks and bar contacting chest.

Technique:

- A valid repetition is one in which the athlete lowers the bar to the highest point of the chest (above the bench) in a controlled movement prior to completing the lift to full elbow extension.

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Failing to make contact with or excessively bouncing the bar off the chest;
- Lifting the shoulders or buttocks off the bench;
- Raising either foot off the bench/ground;
- Excessive deviation of bar from 'normal' position (observed in warm-up);
- An uneven bar during the lift (shoulder elevation or uneven extension of arms during lift);
- Having greater than 2 seconds rest between repetitions.

4.2 BENCH PULL:

Test Procedure:

Preparation/Test:

- Set bench height so that the athlete can comfortably take the desired grip whilst the weight is off the ground in the hang position.
- Start position – athletes must start all lifts from hang position.
- Athletes may choose the width of grip that they prefer initially but this should remain consistent over consecutive attempts and tests.
- Record RM result on recording sheet.
- Recommended assessor position - 45° to front of athlete level with hips to facilitate observation of feet, knees, shoulders and head and bar contacting underside of bench.

Technique:

- A valid repetition is one in which the bar touches the underside of the bench (no bar pad) and the bar is lowered in a controlled manner to the hang position without touching the ground. Feet should remain off the ground throughout lift and in the same position throughout lifts.
- Use of abducted or adducted bench pull technique should be noted on testing results information. Abducted Bench Pull – bar is lifted towards chest; Adducted Bench Pull – bar is lifted towards navel.

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Movement of the head and/or legs from chosen start position (ie. athlete can start with head down or to the side but it must remain in this position and in contact with the bench at all times);
- Movement of trunk away from bench, and/or any hip flexion/extension;
- Failing to make contact with bar on the bench;
- Excessive deviation of bar from 'normal' position observed in warm-up (ie. maintain abducted or adducted position);
- An uneven bar during the lift (shoulder depression, uneven flexion of elbows during lift);
- Having greater than 2 seconds rest between repetitions.

4.3 CHIN UPS:

Test Procedure:

Preparation/Test:

- Chin ups should be performed with a medium width pronated grip. The grip should be no wider than 1 hand width outside the shoulders whilst in the hang position. Athletes may choose the width of grip within limits but this must remain consistent over consecutive attempts and tests.
- Record RM result on recording sheet. Results should be recorded as body mass + external mass lifted.
- Recommended assessor position – side on to athlete at eye level with bar.

Technique:

- Starting from a fully extended elbow position (hang position) the athlete is required to pull body up in one smooth action so that the chin touches the top of the bar with the head in a neutral position (head should remain in neutral position to point above the bar). Legs can be held in semi-flexed position or extended, however they must not move during the exercise.

• Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Failing to get chin over the bar with head in neutral position;
- Breaking of the hips and/or knees from start position during the lift;
- Body swing during lift;
- Not going to full elbow extension between repetitions;
- Having greater than 2 seconds rest between repetitions.

4.4 INCLINE LEG PRESS:

Test Procedure:

Preparation/Test:

- Set seat position at 90 degrees to the slide. If adjustable, set footplate angle to 110 degrees. If footplate angle is not adjustable ensure that angle is consistent between tests (ie. if using different machines for testing).
- Using heels as the reference, feet should be placed so that hips are flexed to 90 degrees. Whilst toes and knees should remain in line during lowering, athletes may choose foot width initially but this must remain consistent over consecutive attempts and tests.
- Record RM result on recording sheet. Results should be recorded as plates + mass of sled.
- Recommended assessor position – side on to athlete and at level of knees to assess depth.

Technique:

- A valid repetition is one in which the weight is lowered to a depth corresponding to 90 degrees of knee flexion and then extended to full leg extension. (The footplate should be referenced at 90 degrees knee flexion with tape or according to a pin position).

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Not achieving required depth during lowering of weight;
- Movement of hips/buttocks from start position (allowing hips/buttocks to come off the seat);
- Repositioning of feet from start position;
- Placing hands on thighs to assist lift;
- Having greater than 2 seconds rest between repetitions.

4.5 SINGLE LEG PRESS:

Technically, the single leg press test is completed as per incline leg press test (detailed above) but with each leg on separate occasions. Each set should be completed with both the left and right legs before moving to the next weight.

Test Procedure:**Preparation/Test:**

- Set seat position at 90 degrees to the slide. If adjustable, set footplate angle to 110 degrees. If footplate angle is not adjustable ensure that angle is consistent between tests (ie. if using different machines for testing).
- Using the heel as the reference, foot should be placed on footplate so that hip is flexed to 90 degrees. Whilst toes and knee should remain in line during lowering, athletes may choose foot placement.
- Record RM result on recording sheet. Results should be recorded as plates + mass of sled.
- Recommended assessor position - side on to athlete and at level of knees to assess depth.

Technique:

- A valid repetition is one in which the weight is lowered to a depth corresponding to 90 degrees of knee flexion and then extended to full leg extension (the footplate should be referenced at 90 degrees knee flexion with tape or according to a pin position).

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Not achieving required depth during lowering of weight;
- Movement of hips/buttocks from start position (allowing hips/buttocks to come off the seat);
- Repositioning of feet from start position;
- Placing hands on thighs to assist lift;
- Having greater than 2 seconds rest between repetitions.

4.6 SQUATS:

This test requires a high level of technical proficiency and is recommended for athletes with a solid training base. A qualified and experienced strength coach/scientist must supervise this test.

Test Procedure:

Preparation/Test:

- The safety bars should be set at the highest possible point without affecting the athlete's range of motion.
- Heel blocks should not be used unless anatomical structures limit the athlete's range of motion or prevent the exercise from being performed with correct technique. Use of heel blocks should be consistent between tests.
- The use of a weight belt is optional but should be consistent between tests.
- Athlete should assume a natural stance with feet approximately shoulder width apart.
- Bar should be held in a 'high' bar position on the trapezius during test. Hands should be held in a comfortable position as close to shoulders as possible.
- During the lowering action knees should travel forward over toes. Heels must remain in contact with the floor at all times during test.
- Athletes are required to lower to a designated depth where crease of hips is level with the top of the knee.
- Record RM result on recording sheet.
- Recommended assessor position – side on to athlete to facilitate observation of hip/knee angle, back posture and depth.

Technique:

- A valid repetition is one in which the weight is lowered to required depth and then extended to full leg extension with trunk as upright as possible.

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Excessive forward or sideways movement during test;
- Loss of controlled spinal position;
- Lifting of heels off the floor;
- Not lowering to required depth;
- Raising of hips prior to shoulder elevation;
- Having greater than 2 seconds rest between repetitions.

4.7 POWER CLEANS:

This test requires a high level of technical proficiency and is recommended for athletes with a solid training base. A qualified and experienced strength coach/scientist must supervise this test.

Test Procedure:

Preparation/Test:

- Start position – feet should be placed under the bar so as to have the bar directly above the balls of the feet. Grip should be slightly wider than shoulders. Shoulders should be forward of the bar and back should be held in a straight or concave set position. Initial movement of the bar should be generated from the legs by knee extension with no change to the back angle at the pelvis.
- Finish position - bar should be caught on the upper chest and shoulders of the athlete with the elbows in a position to allow the bar to rest on the upper chest and shoulders with no effort. Feet should be recovered to the position of the start and the body should be in an upright position.
- Upon catching the bar the athlete must not collapse into squat position where crease of hips drops below top of knees (vs. clean where there is no limit to depth of squat at catch position).
- Lateral movement of the feet is permitted during the catch.
- The weight must be caught and seen to be under control if the repetition is to be valid.
- The use of a weight belt is optional but should be consistent between tests.
- Repetitions should be completed as soon as possible after each other, however a single rest of no more than 5 seconds is allowed to re-position hands/feet etc if greater than 1RM is being used.
- Record RM result on recording sheet.
- Recommended assessor position – 45° to front of athlete to facilitate observation of posture and catch position.

Technique:

- A valid repetition is one in which the weight is caught on the shoulders without the crease of the hips dropping lower than top of the knee into a squat position.

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Failing to have the correct set-up, lifting and catching techniques (including back in convex set position);
- Failing to catch the bar in a controlled movement;
- Collapsing into a full front squat position after the catch;
- Uneven splitting of the feet forward or sideways during the catch;
- Having greater than 5 seconds rest between repetitions.

Note:

Power Clean vs. Clean – no limit to depth of squat at catch position in clean.

4.8 POWER SNATCH:

This test requires a high level of technical proficiency and is recommended for athletes with a solid training base. A qualified and experienced strength coach/scientist must supervise this test.

Test Procedure:

Preparation/Test:

- Start position - feet should be placed under the bar so as to have the bar directly above the balls of the feet. Grip should be, as a minimum, at a point with elbows at 90 degrees of flexion if arms are held out at horizontal to the floor. Shoulders should be in front of the bar and back should be held in a straight or concave set position. The backside of the athlete is slightly higher in the set position for the Snatch than for the Power Clean. This position enables the athlete to have their shoulders in front of the bar before commencing the lift. The wider grip than the Power Clean necessitates this. Initial movement of the bar should be generated from the legs by knee extension with no change to the back angle at the pelvis.
- For taller athletes (> 190 cm) it is recommended that blocks of $\geq 2.5\text{cm}$ be used.
- Finish position – bar is caught on straight arms and held above the head. Feet are returned to start position and the body is in an upright position.
- Upon catching the bar the athlete must not collapse into squat position where crease of hips drops below top of knees (vs. snatch where there is no limit to depth of squat at catch position). Feet are to remain evenly spaced during the lift.
- The weight must be caught and seen to be under control if the repetition is to be valid.
- The use of a weight belt is optional but should be consistent between tests.
- Repetitions should be completed as soon as possible after each other, however a single rest of no more than 5 seconds is allowed to re-position hands/feet etc if greater than 1RM is being used.
- Record RM result on recording sheet.
- Recommended assessor position – 45° to front of athlete to facilitate observation of posture and elbow lock.

Technique:

- A valid repetition is one in which the weight is caught on fully extended arms and kept under control whilst returning the feet to the ‘natural’ standing position.

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Failing to have the correct set-up, lifting and catching techniques;
- Failing to catch the bar in a controlled movement;
- Having greater than 5 seconds rest between repetitions.

Note:

Power Snatch vs. Snatch – no limit to depth of squat at catch position in snatch.

4.9 DEADLIFT:

This test requires a high level of technical proficiency and is recommended for athletes with a solid training base. A qualified and experienced strength coach/scientist must supervise this test.

Test Procedure:

Preparation/Test:

- Start position - feet should be placed under the bar so as to have the bar directly above the balls of the feet. Grip should be slightly wider than shoulders. The grip can be of a reverse nature, meaning on hand can be over-grip and the other under-grip. Shoulders should be forward of the bar and back should be held in a straight or concave set position. Initial movement of the bar should be generated from the legs by knee extension with no change to the back angle at the pelvis.
- Finish position - the body should be in an upright position with the bar held with fully extended arms.
- During the movement little or no change in back position should be noted until the final extension of the hips occurs, bringing the back into line with the rest of the fully upright body.
- The back must not bend or show excessive flexion during the lift.
- The use of a weight belt is optional but should be consistent between tests.
- Repetitions should be completed as soon as possible after each other, however a single rest of no more than 5 seconds is allowed to re-position hands/feet etc if greater than 1RM is being used.
- The bar may be dropped to floor between repetitions.
- Record RM result on recording sheet.
- Recommended assessor position – side on to athlete to facilitate observation of posture.

Technique:

- A valid repetition is one in which the bar is lifted in one continuous motion to a point at which the body reaches a fully upright position with the knee and hip joints extended to a 'neutral' position (ie. the back in line with the rest of the fully upright body).

Technical Violations:

The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Failing to have the correct set-up, and lifting techniques;
- Failing to lift the bar in one continuous motion;
- Collapsing the back position during the lift;
- Having greater than 5 seconds rest between repetitions.

5. STRENGTH ENDURANCE TESTS:

ABSOLUTE STRENGTH ENDURANCE:

- Athlete is required to lift predetermined weight a set number of repetitions in the least amount of time.
- Cumulative repetitions per minute are recorded along with the time taken to complete the test. Any repetition not performed with the correct technique is not included in the cumulative total.

RELATIVE STRENGTH ENDURANCE:

- Athlete is required to lift a load corresponding to a given % of RM weight as many times as possible until volitional fatigue or technical violation.
- If an athlete performs a valid repetition following one failed attempt, the test continues with the failed attempt not recorded. Failing to complete two successive repetitions results in termination of test with the last successful repetition recorded as the performance.

TESTING STRENGTH ENDURANCE:

- All strength endurance tests must be completed with the same technical requirements and according to same technical violations as documented in strength/power tests.
- Reliability data for strength endurance tests is yet to be determined.

6. OTHER STRENGTH & POWER TESTS:

For explosive movements in which the external loads are low and force developed in a short period of time, the rate of force production (power) has been suggested to be the most important physical capacity [Schmidtbleicher, 1992].

Power can be classified into the following components. For example:

- Mechanical Power;
- Explosive Strength;
- Starting Strength/Power;
- Reactive Strength/Power.

The ability of the muscles to tolerate high stretch loads is considered important for success in jumping and other explosive movements that involve a stretch shorten cycle.

Stretch shorten cycle activities have been divided into long (>250 ms), low stretch loads or short (<250 ms), high stretch load activities [Schmidtbleicher, 1992]. The greater the stretch load, the more important reactive power is likely to be [Young, 1995].

Reactive power can be measured by using a combination of performance tests:

- Squat Jump (SJ)
- Counter Movement Jump (CMJ)
- Drop Jump (DJ)

The correlations in performance between these tests [Young, 1995] and maximal strength [Schmidtbleicher, 1992] and vertical jump with arm swing [Viitasalo, 1988] are fairly low, indicating that they measure independent muscular qualities.

The difference between CMJ and SJ is used to distinguish between the contractile and SSC contribution to performance during long, low stretch load SSC activities [Komi, 1978]. If the difference is small (<10%), it indicates inefficient use of the SSC, where as if the difference is large (>20%), it indicates ineffective use of the contractile mechanism [Baker, 1996].

Reactive strength during short, high load SSC movements can be assessed by comparing the differences in performance between the CMJ and DJ, and the differences in performance between the DJ heights.

The reactive strength index (height/contact time) during the DJ measures the optimum stretch load that an athlete can use to augment concentric performance. If this quality can be improved, an athlete can theoretically utilise higher stretch loads to enhance performance.

6.1 REACTIVE POWER TESTS:

Jump height is calculated by using a pressure sensitive mat to measuring the flight time during a jump (t_{air}), and using this to calculate the vertical take off velocity (V_i) and then height of rise of the centre of gravity (h) [Komi, 1978]:

$$V_i = \frac{1}{2} \times t_{\text{air}} \times g$$

$$h = \frac{V_i^2}{2} \times g$$

(where $g = 9.81 \text{ m}\cdot\text{sec}^{-2}$)

A comparison between jump height recorded using flight time calculations and changes in whole body centre of gravity computed from video analysis in six jumps gave an error of $\pm 2\%$ [Komi, 1978] indicating that this can be a reliable method of performance testing.

For this calculation to be valid, the body position at the instant of take off and landing are assumed to be the same. Landing with flexed knees, hips and ankles, and any forward lean of the trunk causes the centre of gravity to land at a lower level than the position at take off, therefore overestimating flight time [Young, 1994].

Young reported a 16 % overestimation in jump height following a flat foot landing. It is therefore crucial for the tester to control the landing position and eliminate “incorrect” trials so that results are reliable and repeatable.

All jumps require the athlete to jump keep their hands on their hips to eliminate the use of the arms, which have been reported to contribute up to 14 % and 27 % to performance during SJ and CMJ respectively [Harman, 1990]. By removing the arm action, it is intended to reduce the skill/coordination requirement of the test and focus the effort on the leg extensor muscles [Young, 1994].

Athletes should have a minimum of fifteen seconds and three minutes recovery between jumps and exercises respectively.

6.1.1 Squat Jump:

Test Procedure:

Preparation/Test:

- Ensure that athlete has performed an appropriate warm-up.
- Athlete should assume and maintain start position according to sport protocol (ie. technique may vary according to sport). Standard position is with hands up holding a 'broomstick' across the shoulders.
- Starting from an upright position the athlete slowly squats down to a depth corresponding to approximately 90 degrees of knee flexion.
- Following a slight pause (2-3 seconds) the athlete is required to perform a vertical jump for maximal height with no counter-movement of the upper or lower body.
- Athlete is required to keep upper body in an upright position throughout all phases of test and keep hands in start position (ie. either on hips or holding broomstick across shoulders).
- Athlete should land on the balls of the feet with full extension at the hip, knees and ankles; once ground contact has been made the athlete is allowed to flex to absorb the impact of landing.
- Record number and height achieved for each jump. Highest of all jumps performed should be recorded as maximum jump height.

Technique:

- A valid repetition is one in which athlete performs maximal vertical jump movement whilst maintaining an upright body position and lands on balls of feet in an extended position. Arms should remain in start position throughout test.

Technical Violations:

The following technical violations will result in the trial being invalid.

- Failing to achieve and/or hold squat position
- Allowing hands to move from start position
- Excessive forward lean of upper body

6.1.2 Counter-Movement Jump:

Test Procedure:

Preparation/Test:

- Ensure that athlete has performed an appropriate warm-up.
- Athlete should assume and maintain start position according to sport protocol (ie. technique may vary according to sport). Standard position is with hands up holding a 'broomstick' across the shoulders.
- Starting from an upright position the athlete is required to perform a rapid counter movement prior to executing a vertical jump for maximal height.
- Counter movement should be completed to a depth corresponding to approximately 90 degrees of knee flexion.
- Athlete is required to keep upper body in an upright position throughout all phases of test.
- Athlete should land on the balls of the feet with full extension at the hip, knees and ankles; once ground contact has been made the athlete is allowed to flex to absorb the impact of landing.
- Record number and height achieved for each jump. Highest of all jumps performed should be recorded as maximum jump height.

Technique:

- A valid repetition is one in which athlete performs maximal vertical jump movement whilst maintaining an upright body position and lands on balls of feet in an extended position. Arms should remain in start position throughout test.

Technical Violations:

The following technical violations will result in the trial being invalid.

- Failing to achieve squat position
- Allowing hands to move from start position
- Excessive forward lean of upper body

6.1.3 Drop Jump:

This test involves high impact forces and should not be administered with athletes at risk of injury or who have current lower limb injuries.

Test Procedure:

Preparation/Test:

- Ensure that athlete has performed an appropriate warm-up.
- Athlete should stand on edge of box and place hands on hips.
- Starting from an upright position athlete is required to step off the box and upon landing perform a vertical jump for maximal height.
- Emphasis should be placed on jumping for maximal height whilst minimising ground contact time
- Athlete is required to keep upper body in an upright position and hands on hips throughout all phases of test.
- The drop jump height should start at 15 cm and progressively increase by 15 cm until there is a decrement in performance as indicated by the reactive strength index.
- Record number and height achieved for each jump. Highest of all jumps performed should be recorded as maximum jump height.

Technique:

- A valid repetition is one in which athlete drops from box and performs maximal vertical jump movement with minimal ground contact time, whilst maintaining an upright body position and hands on hips.

Technical Violations:

The following technical violations will result in the trial being invalid.

- Incorrect technique when dropping from box
- Allowing hands to lift off hips
- Excessive forward lean of upper body
- Excessive ground contact time

6.2 VERTICAL JUMP:

Absolute and relative jumping ability incorporating arm swing is assessed using the vertical jump test. Where reactive power tests try and isolate leg power by eliminating the use of the arms, vertical jump tests are used to measure vertical power in a specific movement representative of a skill commonly performed in many sports.

Test Procedure:

Preparation/Test:

- Ensure that athlete has performed an appropriate warm-up.
- It is recommended that athlete's standing reach height be recorded by having athlete displace as many vanes on jump device as possible while standing flat-footed and side-on to the apparatus. Athlete should reach vertically with preferred hand.
- Starting from an upright position the athlete should stand side-on to the apparatus.
- Using an arm-swing and counter-movement the athlete is required to perform a vertical jump for maximal height; at the peak of the jump the athlete moves vanes on apparatus out of the way.
- Athlete should perform at least 3-5 trials.
- Record height achieved for each jump. Calculate vertical jump height by subtracting standing reach height from highest absolute jump height. Highest of all jumps performed should be recorded as maximum jump height.

Technique:

- A valid repetition is one in which athlete performs maximal vertical jump movement and moves vanes of apparatus at peak of jump.

Technical Violations:

The following technical violations will result in the trial being invalid.

- Holding of counter-movement squat position
- Excessive forward lean of upper body

Note: The yardstick® is the preferred equipment for VJ testing as it is a more familiar jumping action for athlete to perform; the athlete has no inhibitions about jumping into a wall; there are no space restriction, which can occur in vertical jump pits; and athletes reach directly upwards to displace the yardstick® veins and not to the side to touch the wall mounted board.

6.3 MULTI-STAGE ABDOMINAL STRENGTH TEST:

Test Procedure:

Preparation/Test:

- Starting position for all stages is lying supine on the floor with knees bent to 90 degrees. The feet, without shoes, should be comfortably apart, in contact with the floor, and not held.
- The athlete is allowed up to 3 attempts to pass each stage. All movements are to be completed in a smooth and controlled manner. The athlete's score is the final stage completed successfully.
- Stage 1 (Palms over knees) – arms straight with hands resting on thighs; move forward until the fingers are touching the knee (patella).
- Stage 2 (Elbows over knees) – arms straight with hands resting on thighs; move forward until elbows are touching the patella.
- Stage 3 (Forearms to thighs) – arms across and in contact with the abdomen with hands gripping opposite elbows; move forward until the forearms touch mid-thighs.
- Stage 4 (Elbows to mid-thighs) - arms across and in contact with the chest with hands gripping opposite shoulders; move forward until the forearms touch mid-thighs.
- Stage 5 (Chest to thighs) – arms bent behind the head with hands gripping opposite shoulders; move forward until the chest touches the thighs.
- Stage 6 (Chest to thighs with 2.5 kg mass) – arms bent behind the head with hands crossed and holding a 2.5kg mass; move forward until the chest touches the thighs.
- Stage 7 (Chest to thighs with 5 kg mass) – arms bent behind the head with hands crossed and holding a 5 kg mass; move forward until the chest touches the thighs.
- Following stage 7, additional stages can be included by adding 2.5 kg masses incrementally.
- Record athlete's final score/stage on recording sheet.

Technique:

- A valid repetition is one in which athlete completes required stage whilst feet remain in contact with the ground and body position is held throughout movement.

Technical Violations:

The following technical violations will result in the attempt being invalid and a further attempt provided.

- Lifts either feet partially or totally off the floor;
- Throws the arms and or head forward in a jerky manner;
- Moves the arms from nominated position;
- Lifts the hips off the floor;
- Fails to maintain 90 degrees angle at the knee;
- Inability to complete nominated sit-up.

6.4 CORE STABILITY TEST:

This test has been developed as a tool for assessing athlete 'core stability'. Core stability is a vital component in all-athletic performance and is often neglected. The 'core stability' test is a ten level test in which the athlete must satisfactorily achieve a level before moving directly into the next.

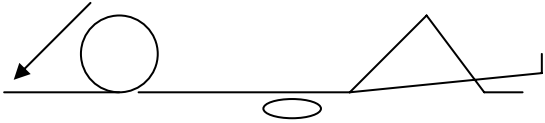
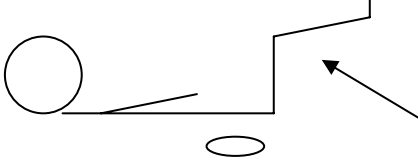
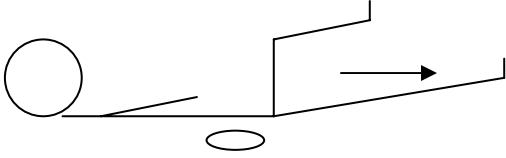

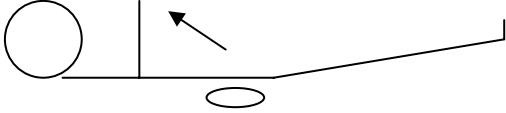
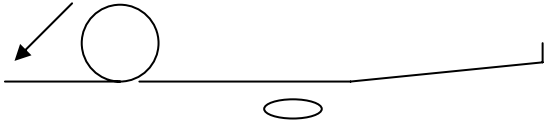
This test will be done as part of the normal range of strength tests which are carried out at the completion of a strength training block.

Test Procedure:

Preparation/Test:

- Starting position for stage 1 is lying supine on the floor with knees bent to 90 degrees. The feet, without shoes, should be comfortably apart, in contact with the floor, and not held.
- Athlete should be able to view the biofeedback stabiliser and mmHg at all times throughout the test.
- Biofeedback stabiliser should be placed so that lower portion of bag is at L2 (ie. middle of arch of back).
- The 'core stability' test is a continuous test, and there are no rest intervals between levels.

Level	Description	Diagram
1.	<ul style="list-style-type: none"> • Athlete to posteriorly tilt pelvis to reach 80 mmHg then return to 40 mmHg • Athlete to anteriorly tilt pelvis to reach 20 mmHg then return to 40 mmHg • Arms should be crossed across chest • Feet flat knees bent to 90° 	
2.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • Arms crossed across chest • Lift 1 leg until upper leg is perpendicular to floor 	
3.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • Arms crossed across chest • Straighten the bent leg and then lower until the heel is ~ 1cm off the floor 	
4.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • With one leg held straight ~ 1 cm from floor • Elevate arms to a straight position perpendicular to the floor 	

5.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • With one leg held straight ~ 1cm from floor • Move arms to a straight position above the head ~ 1cm from the floor 	
6.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • Arms crossed across chest • Return straight leg to a bent position as in level 2 • Lift the other leg till both upper legs are perpendicular to floor 	
7.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • Arms crossed across chest • Straighten 1 bent leg and then lower until the heel is ~ 1cm off the floor 	
8.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • Arms crossed across chest • Straighten the other leg until the heel is ~ 1cm off the floor 	
9.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • With both legs straight ~ 1cm from floor • Elevate arms to a straight position perpendicular to the floor 	
10.	<ul style="list-style-type: none"> • Keeping mmHg at 40 • With both legs straight ~ 1cm from floor • Move arms to a straight position above the head ~ 1cm from the floor 	

Technique:

- A valid repetition is one in which athlete completes required stage whilst maintaining required body position and is able to achieve required mmHg.

Technical Violations:

The following technical violations will result in the attempt being invalid and a further attempt provided.

- Athlete fails to return biofeedback stabiliser to 40 mmHg after keeping reading between 30 and 50 mmHg when asked to perform given movement.
- Athlete is unable to maintain correct body alignment – lower limbs must remain parallel at all times throughout the tests and not ‘fall out’ laterally.
- Athlete fails to steady needle at 40 mmHg before attempting next level; a needle that is moving does not show control of core muscles.

7. REFERENCES:

- Abernethy, P., G. Wilson, et al. (1995). Strength and power assessment: Issues, controversies and challenges. Sports Medicine 19(6): 401-417.
- Atkinson, G. and T. Reilly (1996). Circadian variation in sports performance. Sports Medicine 21(4): 292-312.
- Baker, D. (1994). Improving vertical jump performance: The application of general, special and specific strength training. National Coaching Conference, Canberra, Australian Coaching Council.
- Baker, D. (1995). The use of submaximal repetitions to predict maximal squat and bench press strength in trained athletes. Strength and Conditioning Coach 3(4): 17-19.
- Baker, D. (1996). Improving vertical jump performance through general, special, and specific strength training: A brief review. Journal of Strength and Conditioning Research 10(2): 131-136.
- Bond, V., Gresham, K., McRae, J and Tearney, R.J. (1986). Caffeine ingestion and isokinetic strength. Brit. J. Sports Med. Vol 20, No. 3 pp 135-137.
- Braith, R. W., J. E. Graves, et al. (1992). Effect of training on the relationship between maximal and submaximal strength. Medicine and Science in Sports and Exercise 25(1): 132-138.
- Burke, E. J. (1977). Toward an Understanding of Human Performance. Ithaca, New York: Movement Publications.
- Byrne, C., Eston, R.G and Edwards, R.H.T (2001). Scand J Med Sci Sports. 11: 134-140.
- Fricker and Fallon (2000). Physiological Tests for Elite Athletes. Champaign, IL: Human Kinetics.
- Gotshalk, L.A., Volek, J.S., Staron, R.S., Denegar, C.R., Hagerman, F.C and Kraemer, W.J (2002). Creatine Supplementation improves muscular performance in older men. Med. Sci. Sports Exercise. Vol.34, No. 3, pp 537-543.
- Harris, J. and Elbourn, J. (2002). Warming Up and Cooling Down. 2nd edition, Champaign, IL: Human Kinetics.
- Izquierdo, M., Ibanez, J., Gonzalez-Badillo, J.J., and Gorostiaga, E.M. (2002). Effects of creatine supplementation on muscle power, endurance, and sprine performance. Med. Sci. Sports Exercise. Vol.34, No. 2, pp 332-343.
- Jacobson, B.H., Weber, M.D., Claypool, L and hunt, L.E (1992). Effect of caffeine on maximal strength and power in elite athletes. Brit. Journal Sport Med. 26(4), 276-280.
- Jacobson, B.H and Edwards, S.W (1991). Influence of two levels of caffeine on maximal torque at selected angular velocities. J Sports Med Phys Fitness. 31: 147-153.

- Kozoris, L.P., Kraemer, W.J., Gordon, T.I and Knutten, H.G. (2000). Effect of acute post exercise ethanol intoxication on the neuroendocrine response to resistance exercise. J. Appl. Physiol. 88:165-172.
- Maud, P. J and Foster, C. (1995). Physiological Assessment of Human Fitness. Champaign, IL: Human Kinetics.
- Morales, J. and S. Sobonya (1996). "Use of submaximal repetition test for predicting 1-RM strength in class athletes." Journal of Strength and Conditioning Research 10(3): 186-189.
- Nosaka, K., Sakamoto, K., Newton, M and Sacco, P. (2001). The repeated bout effect of reduced-load eccentric exercise on elbow flexor muscle damage. Eur J Appl Physiol. 85: 34-40.
- Schmidtbleicher, D. (1992). Training for power events. Strength and Power in Sport. P. V. Komi. Oxford, Blackwell Scientific: 381-395.
- Stout, J., Eckerson, J., Ebersole, K., Moore, G; Perry, S., Housh, T., Bull, A., Cramer, J and Batheja, A (2000). Effect of creatine loading on neuromuscular fatigue threshold. J. Appl. Physiol. 88: 109-112.
- Tarnopolsky, M and Cupido, C (2000). Caffeine potentiates low frequency skeletal muscle force in habitual and non-habitual caffeine consumers. J. Appl Physiol. 89: 1719-1724.
- Viitasalo, J. T. (1988). Evaluation of explosive strength for young and adult athletes. Research Quarterly for Exercise and Sport. 59(1): 9-13.
- Volek, J.F., Duncan, N.D., Mazzetti, S.A., Staron, R.S., Putukian, M., Gomez, A.L., Pearson, D.R., Fink, W.J and Kraemer, W.J (1999). Performance and muscle fibre adaptations to creatine supplementation and heavy resistance training. Med. Sci. Sports Exercise. Vol.31, No. 8, 1147-1156.
- Vukovich, M and Michaelis, J (1999). Effect of two different creatine supplementation products on muscular strength and power. Sports Med. Training and Rehab. Vol. 8(4), 369-383.
- Willoughby, D.S and Rosene, J. (2001). Effects of oral creatine and resistance training on myosin heavy chain expression. Med. Sci. Sports Exercise. Vol.33, No. 10, pp 1674-1681.
- Winget, C. M., C. W. DeRoshia, et al. (1985). "Circadian rhythms and athletic performance." Medicine and Science in Sports and Exercise 17(5): 498-516.
- Young, W. (1994). "A simple method for evaluating the strength qualities of the leg extensor muscles and jumping abilities." Strength and Conditioning Coach 2(4): 5-8.
- Young, W. (1995). "Laboratory strength assessment of athletes." NSA 10(1): 89-96.
- Young, W. (1995). "Strength qualities: What they are and what they mean to the coach." Strength and Conditioning Coach 3(4): 13-16.