2017

Muscle strength, endurance and power testing

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Muscle strength, endurance, and power testing

Contributed by: Daniel Hackett, University of Sydney

Project: Physique traits, muscle performance, and health status of natural bodybuilders and powerlifters
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1 Introduction/Background

The assessment of muscular strength, power and endurance are commonly used to inform researchers as well as coaches/trainers of progress with an athlete’s training. Due to resistance exercise making up the major component of a bodybuilder’s and powerlifter’s training, changes in these muscular capabilities throughout a training cycle is of particular increase to both researchers and individuals involved in these respective sports.

1.1 Terminology and abbreviations

- 1RM = one repetition maximum; muscle strength is defined as the maximal weight that can be lifted in good form, one time only

2 Key papers / theoretical basis for the method

Muscular fitness testing is shown to be valid and reliable with strong correlations found for 1RM (0.72-0.90; Verdijk et al., 2009; Seo et al., 2012), muscular power (>0.74, Schroder et al., 2007) and muscular endurance (> 0.79; Pereira et al., 2003).

2.1 References


3 Ethical considerations

Please see the accompanying documents:

Consent Form: http://epublications.bond.edu.au/crn_physique/2/
4 Facility and equipment

4.1 Equipment

4.1.1 Laboratory-based equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Photo/description</th>
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<tr>
<td>Keiser pneumatic-resistance training equipment with K400 electronics</td>
<td><a href="https://www.keiser.com">https://www.keiser.com</a></td>
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<tr>
<td>(Keiser Sports Health Equipment, Inc., Fresno, CA) is used for muscle</td>
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<tr>
<td>strength, power and endurance testing.</td>
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<td>For assessments, 1RM testing is carried out on the following equipment:</td>
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<tr>
<td>• seated leg press</td>
<td></td>
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<tr>
<td>• seated chest press</td>
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</tbody>
</table>

4.1.2 Smaller equipment/instruments

Not applicable

4.1.3 Consumables

Not applicable

4.1.4 Personal Protective Equipment (PPE)

Not applicable

5 Training/qualifications/competencies

This section should provide details of any training and inductions that must be completed prior to undertaking this method.

Please indicate (check the box) to indicate which of the following is required prior to undertaking this method:

<table>
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<th>Yes</th>
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| ☒   |    | Health and Safety training
| ☒   |    | Laboratory induction
| ☒   |    | Current First Aid / CPR
|    | ☒ | Immunisation
| ☒ | ☒ | Method-specific training
| ☒ | ☒ | Formal qualification required
| ☒ | ☒ | Other specific requirements
6 Restricted access

The use of this method does not require specific qualifications.
7 Workflow

7.1 Overview of testing protocol

- The testing session incorporates three types of testing:
  - Strength testing (1RM)
  - Endurance testing
  - Power testing

7.2 Equipment preparation

- The Keiser compressor should be turned on at both the power point and the distribution box 2-3 hours prior to use.
- Record the settings for each piece of equipment positioning on data sheet.

7.3 Participant preparation and instructions

- Before initiating EACH session, you should ask the participant if he/she needs to use the toilet. As strength testing may provoke incontinence, this is particularly important in older women.
- Before initiating EACH session, you should ask the participant if he/she has any injuries or pain anywhere that you should know about before starting the exercise.
- As applicable, distance vision corrective lenses and hearing aides must be in working order and in place.
- Ensure that proper footwear, such as jogging shoes with non-slip soles, are worn by the participant, in addition to loose pants. It is helpful to be able to visualise the knee if capris or stretch pants are worn by women and sweat pants by men.
- Prior to beginning the test, demonstrate to the participants the correct technique for performing each of the exercises, which muscle group it isolates, and where this muscle group is located. This may be another opportunity to ask – “do you think you will have any difficulty performing this exercise due to any pre-existing pain/injury?”
- You should explain to the participant why emphasis is placed upon proper breathing technique and avoidance of the Valsalva manoeuvre.
- Demonstrate proper breathing technique (i.e., breathe in before lifting/pushing the weight; breathe out during the “concentric” or lifting/pushing phase).
- Reinforce correct form and breathing during the rest period between repetitions.
- Inform participants that this (the 1RM testing) is a test of maximum muscle strength. Explain that the objective of the exercise is to find the greatest amount of weight he/she can lift with good form for the whole range of motion one time only. Instruct the
participant to push/pull against the footplate or arm of the machine until it is in the fully extended position, as you demonstrate the action.

- Once the movement has been performed, the weight should be lowered carefully.
- Strong verbal encouragement should be given throughout the test.
- Probe for any symptoms such as pain or other discomfort during the rest periods between attempts and document these in the source document.

7.4 Strength (1RM) testing procedure

7.4.1 Purpose

- The objective of the exercise is to find the greatest amount of weight that can be lifted with good form for the whole range of motion one time only.

7.4.2 Protocol

1. Allow participant to familiarise with the equipment with 2-3 unweighted repetitions.  
   
   ➔ **NOTE:** for the leg press, add only the amount of resistance required to hold the footplates up against the weight of the legs, if necessary. For most participants, the lowest available resistance holds the footplates up against the weight of the legs. Make sure the bar connecting the two footplates is engaged so that both footplates move as one.

2. Using the SETUP key from any mode will bring up the SETUP SCREEN.

3. Measure the unweighted range of motion twice by noting the arrow head position on the left side of the display panel. Ensure that good form is used during these repetitions, or the range will be too high and unreachable in good form once the load is increased.

4. PRESS position mode and use the arrows to adjust the load. Add a small amount of weight and ask participant the level of difficulty (use Borg RPE Scale).

5. For each repetition, record the force in Newtons or Newton-metres from the BOTTOM of the display panel, the BORG rating and whether successful or not (i.e. the range of motion was full and good form was maintained).

6. Attempt to reach a BORG rating of 15 in 3-4 lifts, resting 20-30 seconds between each lift.

7. Ensure 1 minute rest between each repetition once the BORG rating is > 15.

8. Failure is defined as a lift short of the full range of motion (determined in the unweighted position) on at least 2 attempts at least 60 seconds apart. Therefore, if a repetition is failed, either repeat again or lower weight slightly and repeat, depending on the degree of failure.

9. On machines with 2 cylinders (i.e., leg press, chest press), note maximum weight for both limbs and write down both on the data sheet.

10. To minimise risk of injury, carefully position the participant on each piece of
equipment, taking extra care with mounting and dismounting as well as correct exercise position.

7.4.3 Seated leg press (bilateral)

7.4.3.1 Machine setup

1. Assist the participant onto the machine by backing up towards the seat and sitting down first; then assist or observe as the legs are lifted up onto the footplates.

2. Move the seat to a position where the hips and knees are bent at approximately 90°. The seat may be moved while the participant is seated, as long as they are stabilised by you and warned that the seat is going to move slowly.

3. If participants cannot flex hips to 90° due to hip pain or abdominal girth, move the seat back to a tolerable position.

4. Record the final seat position from the numbered plate in the source document.

7.4.3.2 Movement performance

1. Participants’ feet should be placed at the bottom of each foot plate, with the heel resting on the rubber “lip” at the bottom of the foot plate; or if joint pain is encountered, a position allowing pain free movement.

2. Extra caution should be used for those participants who have chronic lower back discomfort, ensuring that they are not twisting the spine and are keeping their back, neck, and head against the padded seat.

3. The participant may stabilise the upper body by using handgrips on each side of the seat, making sure that his/her thumb is not touching the force control knob accidentally. The participant’s shoulders and neck should be relaxed.

4. The participant should then be instructed to push both legs forward simultaneously and to control the return of the weight back to a resting state.

5. It is important that you communicate to the participant that the knees travel in line with the toes, and that they do not drift medially (which is common in participants with arthritis or weak ligaments around the knee).

6. The push should be generated through the whole foot, particularly the heel, not through the forefoot/toes, to ensure activation of the gluteus and hamstring muscles, not just the plantar flexors/quads. You may show the participant where the active muscle area.

7. The participant should push until the knees are just short of being “locked” in full extension; that is there should be a very slight bend at the knee.

8. Participants who have osteoarthritis may have limited extension and may not achieve this full range of motion. A participant whose knees are correctly positioned (not locked) will have to use muscle force to keep the footplate out. When the knees are locked, no muscle force is being used, and the bones of the leg are keeping the footplate up. This should be explained and demonstrated explicitly.
so the participant knows what it feels like to perform the exercise correctly (versus incorrectly).

9. Excessive movement of the buttocks completely rising up off the seat is not considered good form but slight movements are tolerated.

7.4.4 Chest press

7.4.4.1 Machine setup

1. Adjust the height of the seat such so the grip setting is lined at the participant’s xiphoid process and the forearms run parallel with the floor. Record this setting in the source document.

2. Range of motion should be determined in the unweighted position.

3. Adjust arm levers to the comfort level of the participant and note position. This may depend on the joint limitations and ROM of the rotator cuff. The range has 4 settings (1 to 4).

7.4.4.2 Movement performance

1. Participant should sit upright facing forward with the back pressed against the back pad.

2. The position while gripping the handles with thumbs under the grip should avoid excessive extension of the wrist throughout the range.

3. Participant should push to full range without locking the elbows and then slowly control the return of the weight back to resting position.

4. The shoulders should not be elevated to compensate for the effort.

5. There is to be no excessive arch of the back and no separation of the back bench throughout the test/exercise.

7.5 Muscle endurance testing

7.5.1 Purpose

- Muscle endurance is a test of sub-maximal muscle performance. Analogous to a sub-maximal aerobic capacity test, the same workload is used at baseline and final testing, and the performance relative to this fixed workload is used to determine adaptation to the intervention.

7.5.2 Protocol

1. Muscle endurance will be assessed using the Leg Press and Chest Press exercises.

2. 60% of the subjects previously determined 1RM will be used as the workload.

3. Keiser Machine display should be set on “Position Mode” so that the range of motion bar can be seen to evaluate the completeness of lift.
4. The subject will be instructed to perform as many consecutive repetitions as possible through their full range of motion using good form.

5. Repetitions will be performed at the cadence of approx. 3 sec concentric/3 sec eccentric.

6. Test is terminated when subject performs a lift that is not within 4 degrees or mm of their full range of motion (or when the marker is short of the lighted diode bar).

7. The total number of complete repetitions, the total work performed, as well as the velocity and power generated during the first and last repetitions for each exercise will be recorded on the data sheet. Note that the work, velocity, and power measurements are only obtained for Chest Press. For the Leg Press, only the number of repetitions is recorded.

7.6 Power testing

7.6.1 Purpose

- This test measures the ability of muscles to generate force (movement) quickly.
- Force, velocity, and power will be assessed using a single explosive contraction at 20, 40, 50, 60, 70, 80, 90, and 100 % of the subject’s most recently measured 1RM or, at baseline, the better of the two 1RM measurements using the Keiser Leg Press Machine.

7.6.2 Additional power testing at follow-up test periods

- To assess potential change in peak velocity capacity the subject will perform an ‘extra’ lift at the load during which peak velocity was demonstrated at baseline.
- Power testing must follow 1RM testing when performed at each timepoint, as the loads are set based on the results of the 1RM testing.
- Power testing should be done in an unfatigued state at each timepoint.

7.6.3 Protocol

1. Demonstrate movement (fast concentric/slow eccentric).

2. Prior to starting the test, explain the purpose of the test to the subject and how it will be achieved. E.g. “The purpose of this test is to measure how powerful muscles are in your legs. This means how quickly your muscles can generate force, so this time I will ask you to push the weight as fast as you can. However, I still want you to slowly return the weight to the starting position. Similar to the maximum strength test, you will start with a light weight and then move onto heavier weights.” (Avoid saying something like “You should be able to push the lighter weights faster than you can push the heavier weights”.)

3. Subject will be instructed to push the footplate as fast as possible and slowly return it for one time only at each of the workloads and will be verbally cued. “1, 2, 3, GO!!”

4. To improve coordination of breathing and exertion, subjects may be instructed to
inhale on the count of “1”, exhale on the count of “2”, inhale again on the count of “3”,
and exhale with rapid exertion on “GO!”

5. A rest period of 30-60 seconds will be taken between repetitions.

6. Ensure subject is in the correct starting position for the exercise (see 1RM testing).

7. Allow one ‘practice’ trial at 20% 1RM and record the results from the motion the real
time display on the computer panel. The force, work, and power will be available on
the time computer display panel. (Distance moved is also shown, but is not needed for
the POWER test). The velocity will need to be taken from of motion the data file
downloaded onto the computer at the conclusion of the test (see below for A420
software instructions), as it is not shown on the real time display window.

8. If the subject’s baseline 20% 1RM is less than the minimal resistance of machine, use
the minimal resistance possible on the machine. If the subject’s 1RM was so low that
the machine’s lowest resistance is greater than some of the lighter loads e.g. 20, 40%
1RM then you can only do those loads that the machine will allow. If the subject’s 1RM
is the lowest resistance that the machine allows then the subject can only be tested at
100% 1RM. Allow the subject 3 trials at this load, with 1-min rest between each one.
Record force, work, and power for each trial, (the highest power achieved out of the 3
attempts will be recorded as their peak power).

9. Next, set the machine resistance at 20% of the most recent 1RM and continue with
heavier loads.

10. Assess the subject at each %1RM (40, 50, 60, 70, 80, 90, and 100), right up to
100%1RM even if you think they achieved their peak power at a lighter load. For
subjects whose power is still increasing at 100% of the 1RM, additional loads must be
used at 10% increments (110%, 120%, etc.) until a drop in Power is seen. This will be a
very unusual, but possible occurrence.

11. Record the force, velocity, work, and power at each % 1RM on the source document
(record the attempt where the highest power was achieved out of the 2 attempts at
20% 1RM as the “20%” value when the source document).

12. Allow 30 seconds rest after the trial at 20%, and 60 seconds rest after each trial at
heavier loads (RPE scorings of 15+).

7.7 Post-test care

- Participants are to contact the study staff immediately if there are any unusual health
experiences, injury or adverse effects. This notification should take place whether or not
they believe that the problem is related to the study or from some other cause.

7.8 Data handling and management

- Data is written on record sheets and following testing are placed in participant folders and
locked in a filing cabinet in an office at The University of Sydney. Written data will later be
transferred to a computer file to enable data analysis and this file will be protected via
passwords. Data analysis will be conducted with the use of SPSS software.
7.9 Cleaning and equipment maintenance

All repairs and maintenance of the Keiser equipment are conducted by:

Mr Raymond Patton  
Senior Technical Officer  
University of Sydney

7.10 Reporting of information

Verbal feedback is provided to participants at the conclusion of the testing.
8 Supplier and ordering information

Complete the table with the list of items, the manufacturer, reference/order numbers, suppliers, alternative items, other notes to assist in re-ordering or sourcing items.

<table>
<thead>
<tr>
<th>Item description (with photo)</th>
<th>Product code</th>
<th>Supplier</th>
<th>Alternative supplier (if applicable)</th>
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9 Appendices