

Guide to performing 1 repetition maximum strength assessment

This guide is an accompaniment to the ACI video series on strength assessment/resistance training for individuals presenting with, or at risk of, frailty.

The aim of this guide is to:

- highlight important aspects of the testing processes
- monitor intensity during resistance training.

Background

Definition

A one repetition maximum (1RM) is the highest load an individual can lift for a single repetition through their full range of motion with good form. It is the gold standard for measurement of maximal dynamic strength.

Applicability

The 1RM is used as an objective means of determining the appropriate intensity for resistance training and load (described as a percentage of 1RM), and as a repeat measure to evaluate relative changes in muscle strength over time.

Screening, contraindications and safety – know who you are testing

1RM testing is a safe means of strength assessment in older adults when performed correctly and when the appropriate pre-screening is conducted.

A clinical history should always be taken to uncover any potential contraindications or precautions of which the tester may need to be aware.

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Screening and contraindications

Comorbidity history

Individuals presenting with a history of hernia, prolapse, haemorrhoids, previous retinal detachment, diabetic retinopathy, recent cataracts removal, aneurysms (particularly abdominal aortic) or uncontrolled hypertension (systolic blood pressure >200mmHg) may need specialist review and clearance prior to 1RM testing.

Musculoskeletal issues

Particularly, any recent (less than three months) fractures or joint replacements, bony metastases, muscle or tendon tears (especially rotator cuff injury or disease) and severe joint degeneration may need orthopaedic or surgical clearance prior to 1RM testing of involved areas.

Skin integrity

Skin integrity also needs to be considered if conducting exercises which may produce high pressures or shear forces on the skin (for example pressure on lower leg during knee extension and knee flexion or plantar surface of feet during leg press). Conditions such as cellulitis, pitting oedema, clotting disorders, diabetic foot ulcers, dry or thin skin, presence of sutures, recent wounds (lacerations or abrasions) skin cancers or other raised lesions should be screened for prior to conducting 1RM testing, with consideration given to selection, or adjustment, of exercises to avoid pressure on sensitive areas.

Orthostatic hypotension

Orthostatic hypotension is a common condition affecting older adults and presents an increased risk of falls. Orthostatic hypotension may be present in those with:

- neurological disorders (e.g. Parkinson's disease or Lewy-body dementia)
- cardiovascular disease (e.g. congestive heart failure, arrhythmia or myocardial infarction)
- endocrine disease (e.g. diabetes or adrenal insufficiency)
- taking certain classes of medications
- hypovolaemia (e.g. blood loss, dehydration), or
- non-pathological age-related autonomic insufficiency.

The assessor should closely monitor for, and ask about, symptoms of dizziness or light-headedness during testing, particularly on standing. Blood pressure should be taken if symptoms are experienced. Take care to ensure that symptoms have resolved before attempting to walk or transfer to the next machine or exercise.

Impaired cognition

Impaired cognition, particularly where executive function (such as processing information, problem-solving, multitasking or short-term memory) is compromised, may present challenges to instruction. The assessor may need to modify the delivery of information by further simplifying demonstration and verbal instructions. Use frequent repetition of cues immediately prior to execution, and provide additional assistance during transfers and positioning on machines or equipment.

Poor eyesight and hearing

Poor eyesight and hearing deficits are other issues which require consideration and adaptive communication for safe and effective 1RM testing.

Safety

Importance of correct breathing

Lifting a load whilst performing a Valsalva manoeuvre (breath holding) transiently increases intra-abdominal, intraocular and systolic blood pressure. The magnitude of these rises in pressure is reduced with exhalation during the lifting or pushing phase of the repetition. It is vital that clear and concise instruction and demonstration of the correct breathing pattern be given and repeated as needed to ensure competency prior to advancing the load during 1RM testing.

Protocol for 1RM testing

1. Explain the purpose of the test and which muscle groups will be targeted during the exercise.

Recommended dialogue for step 1

"This is a test of your maximum muscle strength. It will determine the most weight you can lift through your full range of motion for one time only with good form. This exercise is the knee extension. It involves the quadriceps muscles at the front of your thighs. The weight will start very light, then I will increase the weight after each repetition until I find a weight you can no longer lift through your full range of motion while maintaining good form".

2. Demonstrate the exercise, emphasising aspects of good form and movements to avoid.
3. Demonstrate correct breathing technique, emphasising the importance for safety.
4. Position the patient correctly for the exercise. Assistance may be required during transfers if the individual has impaired mobility or cognition. If using machines, record the seat, leg and arm settings. Use these same settings for subsequent testing for comparison of strength against baseline.
5. Measure unloaded range of motion (ROM) and set the criteria for successful completion of repetition. As load progresses during testing, achieving a full ROM will become more difficult. Measuring unloaded ROM on range limited exercises such as knee extension and seated row will allow the assessor to observe any inherent ROM limitations in the individual and establish a baseline ROM before the test begins. This can be done simply, by visually matching ROM in subsequent repetitions to that observed when unloaded, to determine success or failure of the attempt.

Additionally, use of environmental markers such as having a visual target (e.g. markers on a mirror or object to raise toes to during knee extension) can aid in improving task objectivity and motivation in the individual.

Devices such as inclinometers or pluriometers can also be attached to machines to obtain a more accurate ROM and criteria for successful completion of the repetition (e.g., within five degrees of unloaded ROM), and comparison to previous testing.

6. Introduce the Borg Rating of Perceived Exertion (RPE).

Recommended dialogue for step 6

"This is a standardised perceived exertion scale. It is a self-assessment of how heavy you perceive the weight to be ranging from 6 being light to 20 being maximal. After each repetition I will ask you to give me a number which reflects how hard you felt your effort was. This will help guide the increments in load throughout the test".

7. Set the load to what you estimate will be a light weight for the individual and ask them to perform one repetition. Cue correct breathing: "Take a deep breath in and breathe out as you push!"
8. Evaluate form and range of motion, provide feedback as necessary, and ask for an RPE.
9. If the RPE is below 15, keep increasing the load after each successful repetition. Aim to reach an RPE of 15 within about 4-5 repetitions.
10. Once an RPE of 15 or greater is reported, allow 1 minute rest between repetitions to recover.
11. During rest periods, enquire about any symptoms such as pain or other discomfort, gain further insight into health issues, and provide feedback and encouragement.
12. Failure of a repetition is determined when a lift is short of full range of motion, or the individual deviates from correct form (which includes incorrect breathing), following the 60 seconds of rest given since the previous repetition. When a repetition is failed, the weight can be repeated or slightly reduced to a load between the failed attempt and the last successful repetition.

End the test when failure occurs on the same weight twice. The 1RM is recorded as the last successfully lifted load.

Points to consider when conducting 1RM

The Borg Rating of Perceived Exertion

The Borg Rating of Perceived Exertion ('Borg' or 'RPE') is widely used as a reliable indicator to monitor and guide exercise intensity. The standardised scale provides individuals to subjectively rate their level of exertion during exercise or exercise testing on a scale from 6-20.

Figure 1: Borg Rating of Perceived Exertion

STRENGTH TRAINING RPE SCALE (Rating of Perceived Exertion)	
6	Light/Easy
7	
8	Easy to lift. Can perform 15 repetitions or more without fatiguing
9	
10	
11	Moderate/Somewhat Hard
12	
13	Feels somewhat heavy. Can lift between 11 to 15 repetitions, but no more
14	
15	Vigorous/Very Hard
16	
17	Very heavy. Can perform no more than 10 repetitions
18	
19	MAXIMAL
20	Extremely heavy. Can perform no more than 3 repetitions

Using RPE during 1RM Assessment

For many older adults, undergoing a maximal strength assessment is a novel experience. Obtaining an accurate evaluation of perceived exertion may present a challenge in those with high anxiety or low self-efficacy (they will tend to over rate), those who are overly self-confident (will tend to under rate) or individuals with cognitive impairments or communication difficulties. Translated RPE scales can be used for individuals of non-English speaking background.

While the individual's RPE is indicated to make decisions regarding rest periods and load increments during testing, the assessor also needs to observe the individual during each repetition and make their own judgement on the level of exertion. Cues such as facial expression, muscle exertion, and speed of movement can all give information about the degree of effort. The assessor should use their clinical judgement to guide their testing where significant discordance exists between the individual's RPE and that observed.

Determining the 1RM

Progression of loads during testing may not always follow an upward linear trajectory to the 1RM, but rather a repeated zig-zag pattern of increasing and decreasing loads after alternating successful and failed repetitions. Early failed lifts may be a consequence of unfamiliarity with the movement or progressing the load too quickly prior to warming the muscles up with a few successive light or moderate loads, rather than due to a true limit of strength. These loads are often surpassed later during testing with regressing the load and then progressing more gradually. **Thus, it is important to note that one criterion for determining 1RM is not simply two failed repetitions, but rather two failed repetitions at the same load.**

To ensure the most accurate 1RM, the difference between the load of the failed repetition to that of the last successful repetition should be as close as possible. That is within 1-2% for large muscle groups, (e.g. failing at load of 202-204kg of a 200kg leg press), or minimum weight increment, or at 0.5kg weight pole in ankle cuffs.

Effects of fatigue

Consideration of the order of exercise and the number of repetitions is important to minimise fatigue. When testing multiple exercises in one session, begin with the largest muscle/multi-joint exercises and alternate lower and upper body exercises and/or agonist/antagonist muscle groups. **The assessor should also aim to determine the 1RM within 8-12 repetitions to reduce the effect of fatigue on strength.**

Monitoring for increases in pain

Chronic pain is a common condition in older adults, with lower back, hips, knees, neck, shoulders and hands most often affected. Sources of pain include:

- rheumatologic conditions (e.g. osteoarthritis, rheumatoid arthritis, gout, polymyalgia rheumatica, spinal stenosis, degenerative joint disease, tendonitis and bursitis)
- neurologic conditions (e.g. neuropathies, radiculopathies and post-stroke pain)
- other causes (e.g. post-herpetic neuralgia, cancer, joint replacement or depression).

Pain varies in severity.

It is important to understand a person's baseline acuity, severity, location and nature of pain prior to exercise to determine which exercises to prescribe and whether to terminate 1RM testing once commenced. For example, a baseline level of knee pain may rate as 4/10 and be dull in nature and not increase in severity with increases in load throughout the test. However, if pain increases with minimal increases in load early in testing and at low RPE, or the nature of the pain changes from dull to sharp, it would be best to not to continue with the test.

While an acutely painful, hot, red and swollen joint should not be exercised, there are ways of altering an exercise to conduct a 1RM in those with stable chronic pain. Limiting painful joint ranges of motion may allow a non-symptom limited 1RM. Methods to alter start or end positions to change range of motion include:

- setting the seat further back on the leg press
- setting the leg bar further out on the knee extension, or
- sitting at a higher seat setting on the seated triceps machine,

Use the time between repetitions during testing to monitor increasing levels of pain and look for cues indicating pain, such as facial expressions or changing body positioning during repetitions.

Providing some basic education on types of pain is also useful to reassure individuals who may be deterred by the feeling of an intense muscle contraction associated with the level of effort during 1RM testing, or mistake this feeling to be an injury or a cramp. **It is also good practice following completion of 1RM testing to educate on, and forewarn of, delayed onset muscle soreness, its time-course and methods to alleviate it if experienced.**

Reassurance and motivation

A 1RM assessment is an extremely effort driven test and many older adults may be unaccustomed to, and apprehensive about, performing at this level of exertion. Developing a rapport, being patient and reassuring, providing education and being professional will assist in instilling a level of trust and minimise barriers of fear and uncertainty, allowing the individual to give their best effort.

Motivation during 1RM testing is vital to elicit a maximal performance. You will not encourage anyone to give their best effort if you are flat and disinterested. Your body language, expression and tone of voice should be open and enthusiastic. Verbal encouragement should be tailored to suit the individual, varied, and increased dependent on the effort required. For example, not everyone wants to be yelled at or hear the same word "Go, go, go, go" on each and every repetition. Easy repetitions will not require any encouragement. The volume, tone and urgency in your voice should increase with the level of effort and proximity to the goal (i.e. as approaching the end ROM in a near maximal attempt), and you should vary the words used to provide information as well as encouragement (such as "keep going!", "nearly there!", "don't give up!").

When approaching a near maximal load, it may take a few seconds of effort to develop the required level of muscular force to overcome the inertia of the weight. **It is helpful to mentally prepare the individual for the required level of effort before the attempt.** For example, saying, "the next repetition should feel very hard. I need you to give it your best effort and push as hard as you possibly can. The weight may not move at first but keep pushing until I say to stop". If the load has not started to move within three seconds of sustained maximal effort, instruct the individual to stop.

Setting training loads and progression

Following the 1RM assessment, initial training sessions in an untrained individual should start at a lower intensity and progress each session to the 80% 1RM load. This serves to reduce muscle soreness and fatigue post-session and allows additional practice of technique and breathing prior to high intensity training.

A suggested progression is:

- session 1 at 50% 1RM
- session 2 at 60% 1RM
- session 3 at 70% 1RM
- session 4 at 80% 1RM.

Two to three sets of eight repetitions (taking at least one minute rest between sets) of each exercise should be performed 2-3 times per week on non-consecutive days. Concentric repetition speed will depend on whether conducting traditional strength training (three seconds) or power training (as fast as possible), however **the eccentric repetition speed should always be performed slowly over 3-4 seconds.**

In untrained individuals, adaptations to high intensity resistance exercise are greatest in the early stages of training. **Progressive resistance training, by definition, needs to be progressive with the aim of increasing training loads each session.**

The RPE scale should be used to gauge training intensity and progress loads to ensure relative training intensity is maintained as the individual increases strength from session to session. Correct use involves asking the individual to provide an RPE after **the first repetition** of the exercise. **A rating of 15-18 (hard to very hard) on this first repetition corresponds to approximately 80% 1RM and should allow the completion of eight repetitions with good form.**

Often there is a range of loads that the individual may rate at the same level of exertion. Just because an individual gives an RPE of 15 does not mean there is no scope for progression. You may find that increasing the load another few kilograms does not change the individual's RPE, and provided good form can be maintained, the higher load should be used. Again, the clinician should use their observation of the individual's level of exertion to judge any inconsistency with their RPE. **If form or ROM begins to deteriorate during the set, allow the individual to rest for 10-20 seconds to partially recover before continuing. This intra-set rest method is preferable to reducing the load or intensity which is key for optimal strength gain.** The use of a training diary to record loads is a valuable tool for planning for progression, tracking improvements and motivating the individual.