CHAPTER 7

Alternatives to Manual Muscle Testing

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Introduction

Manual muscle testing is a foundational measure of strength that is widely used across the health professions for both diagnosis and rehabilitation. Yet manual muscle testing has specific limitations, as discussed in Chapter 2. Consequently, alternative strength measures are needed in certain cases. Examples include: when strength exceeds a functional threshold, strength of the patient is greater than that of the therapist, subtle differences exist between sides or between the agonist and antagonist, or power or endurance need to be measured. Equipment-based tests are the most commonly used alternatives to manual muscle testing.

There are many options for equipment-based testing, and each has its advantages and disadvantages. Choosing the best option depends on clinic space constraints, available budget, the type of patient, the goals of treatment, and how comprehensive the evaluation needs to be. For example, in a small outpatient clinic where most patients have low back or neck pain, the approach to equipment-based testing will differ substantially from that required in most acute care settings. Strength-testing instruments that can be used effectively for children and older adults will differ from those used for a sports team. The equipment-based tests presented in this chapter represent the more popular approaches, are appropriate for adults regardless of age, and have demonstrated reliability and validity.

General Testing Considerations

It is presumed that any therapist conducting a strength-testing session, particularly one requiring maximal effort from a large muscle group, will perform a prescreening exam for red flag conditions. Maximal strength testing for the trunk flexors in a patient with severe osteoporosis or a recent compression fracture, for example, may not be appropriate. Likewise, patients with unstable blood pressure may have an adverse reaction while exerting maximum effort on a leg press, particularly if the patient—incorrectly—holds his or her breath. It is also presumed that muscular strength will be assessed after the patient has warmed up the muscle before testing. The typical warm-up includes completing three to five submaximal contractions at 40% to 50% of maximum using the muscle or muscle group that is being tested.[1] Active range of motion should be assessed to determine if adequate joint range and muscle length will allow maximum effort in the correct test position.

Tips for Achieving Optimal Results in Alternative Muscle Testing

Before starting any of the alternative muscle tests described in this chapter, have all the tools and data collection materials ready so recording proceeds smoothly. Efficiency in testing will grow with clinical experience.

1. Calibrate the device (if appropriate). Any device that records force or torque will drift away from accuracy over time. All testing devices should be routinely calibrated at least once a month, sometimes each session if deviations are suspected.
2. Provide a conducive test environment. The more diversions there are (such as radio noise or crowding), the more unlikely it is that an optimal effort will be made.
3. Once the patient is in the clinic, the first thing to do is educate the patient. Explain and demonstrate each test. Allow the patient to practice using light weights. This practice could be incorporated into the warm up (see below). Patient cooperation is critical for achieving accurate results.
4. Provide a warm-up of some sort. Some therapists will have their patients walk on a treadmill or pedal a stationary cycle for 5 min before muscles are tested. It is also feasible to warm up cold muscles by performing the test with three to five submaximal contractions at 40% to 50% of maximum using the muscle or muscle group that is being tested, as described previously.
5. If there is suspected asymmetry in muscle performance, test the uninvolved side first. Side-

to-side comparisons are critical, and testing the uninvolved side also permits the patient to "feel" what the test is going to entail on their weaker limb.
6. Stabilize the body part and patient. Depending on the test, each patient may need a seat belt, a stabilizing belt across the pelvis, or towels to position the arm or leg. After a part or extremity is stable, the test can be performed easily and accurately.
7. Standardize therapist commands to ensure that the test is performed the same way each time.
8. Allow patient to rest between efforts. No one can duplicate a maximum effort without at least 30 s of rest before the next repetition.
9. Provide feedback on the test. It is part of human nature to desire knowing if side-to-side differences exist, if test 1 is different from test 2, and so forth. Including the patient in the testing procedure optimizes their participation.

One-repetition Maximum Test

The one-repetition maximum (1-RM) test is regarded as the "gold standard" of standardized muscle strength testing. The 1-RM refers to the amount of load a patient can move 1 time (and 1 time only) through full range in a controlled manner with good form.[1] It is a safe technique, perhaps safer than a submaximum strength test, even though muscle soreness may occur and blood pressure may spike during a maximum exertion test.[2] 1-RM tests are highly reliable when specific procedures are followed, more so than any other type of strength assessment.[3] In addition, the fundamental method for establishing 1-RM is the same for each muscle group and thus the 1-RM test is more precise than most.

One-repetition maximum testing serves several functions. Obtaining a patient's maximum strength ability may serve to establish the amount of resistance needed for an exercise prescription; it may help to determine the progress of a progressive, resistive exercise program; or it may be used to compare a patient to established norms. Many normative values for men and women of all ages exist for movements such as bench press, latissimus dorsi pull-down, leg press, and knee extension and are included throughout this chapter.

Technique

There are several methods that can be used to determine a 1-RM. For patients with health conditions, especially known cardiovascular disease, or pulmonary or metabolic diseases, a conservative approach is recommended, such as a multiple RM, described later in this section. The technique described below is chosen because it works well in the clinic and is recommended by the American College of Sports Medicine (ACSM).[1] The basic steps for performing a 1-RM are as follows[1]:

1. Warm up by completing 3 to 5 submaximum repetitions. This warm-up also allows the patient to become familiar with the movement and the therapist to correct the form, if needed.
2. Select an initial weight that is within the patient's perceived capacity (~50%–70% of capacity).
3. Determine the 1-RM within four trials with rest periods of 3 to 5 minutes between tests.
4. Increments of weight should be increased by 5 to 10 lb until the patient cannot complete a repetition.
5. All repetitions should be performed at a constant and consistent rate of speed.
6. All repetitions should be performed through full range of motion (or the same range of motion if full range is not possible).

The final weight that the patient can move successfully 1 time only is recorded as the definitive 1-RM.

Selecting the Starting Weight

Selecting the amount of the starting weight is crucial because the fewer repetitions to reach 1-RM the better, to avoid muscular fatigue and to prevent an underestimation of the true 1-RM. It is helpful for the tester to have knowledge of norms. For example, standing from a chair requires quadriceps strength of nearly half a person's body weight, no matter what the age. Therefore, when performing a 1-RM using a leg press to test the quadriceps of a person who can successfully, but with difficulty stand from a chair without using one's arms, a starting weight might be 60% of patient's body weight. Alternatively, norms exist for the leg press based on age. These norms might present a starting point for establishing a 1-RM. Other variables that can be factored into the clinical decision of initial load are body size (muscular versus thin), fitness level, the presence of pain, and patient's self-perception of ability.

Other considerations that should be attended to during 1-RM testing include breathing, form, and pain. First and foremost, patients should *not* hold their breath during the test. Thus breath control should be practiced during the warm-ups. Second, the patient should maintain correct form throughout the test. For example, the patient should not be permitted to pitch the trunk forward during the knee extension test, to avoid muscle substitution or the use of momentum. Joint movements during the test should be executed smoothly and consistently throughout the entire concentric and eccentric phase, in a controlled manner without jerking the bar or weight. If the test causes pain, an alternative to the 1-RM test should be selected, such as a multiple repetition maximum test.

Multiple-repetition Maximum Test

A multiple-RM test is based on the principles of a 1-RM test. The multiple-RM test is the number of repetitions performed using good form and proper breath technique at the point of muscle failure. Although not as exact as a 1-RM, a multiple-RM test may be desirable for certain situations. For example, some untrained adults are not comfortable exerting the kind of effort necessary for a true 1-RM. A multiple-RM test may be a safer option when joint or soft tissues are compromised (e.g., connective tissue disease, rotator cuff tear, ligamentous injury, post surgery). For individuals without an exercise history and for patients who cannot tolerate high joint compression forces, such as those with osteoarthritis and rheumatoid arthritis, or with systemic weakness, the multiple-RM test, such as an 8- or 10-RM test is safer than the 1-RM test. Also, as mentioned above, a multiple-RM test is preferred if the patient has a health condition such as cardiovascular disease, or a pulmonary or metabolic condition.[1]

A 1-RM test can be estimated from a multiple-RM test (Table 7.1), although this estimation has been shown to be quite variable (Table 7.2).[4] The general principle is as the percentage of 1-RM increases, the number of repetitions decreases (Table 7.3). Large muscle group exercises allow the completion of more repetitions than small muscle groups at the same relative intensity.[5] Because the volume of work is greater with a 10-RM than a 1-RM, fatigue will be a factor. The 1-RM and multiple-RM tests can be performed using the same equipment.

Table 7.1

ESTIMATING ONE-REPETITION MAXIMUM FROM A MULTIPLE-REPETITION MAXIMUM TEST

GIVEN A 1-RM OF 100 POUNDS:										
	1-RM	2-RM	3-RM	4-RM	5-RM	6-RM	7-RM	8-RM	9-RM	10-RM
Multiple-RM loads are:	100	95	93	90	87	85	83	80	77	75

RM, Repetition maximum.

Table 7.2

NUMBER OF REPETITIONS PERFORMED AT 80% OF THE ONE-REPETITION MAXIMUM[4]

Exercise	TRAINED		UNTRAINED	
	Men	Women	Men	Women
Leg press	19	22	15	12
Lat pull-down	12	10	10	10
Bench press	12	14	10	10
Leg extension	12	10	9	8
Sit-up	12	12	8	7
Arm curl	11	7	8	6
Leg curl	7	5	6	6

Table 7.3

MAXIMUM WEIGHT THAT CAN BE LIFTED DECREASES WITH THE NUMBER OF

REPETITIONS

Given:	1-RM	2-RM	3-RM	4-RM	5-RM	6-RM	7-RM	8-RM	9-RM	10-RM
The load would be (lb)	100	95	93	90	87	85	83	80	77	75
Number of repetitions	1	2	3	4	5	6	7	8	9	10

RM, Repetition maximum.

The number of repetitions performed at a given percent of 1-RM is influenced by the amount of muscle mass available. For example, more repetitions can be performed during the back squat than either the bench press or arm curl.[5] The 4- to 6-RM is more accurate than the 10-RM. Variability in RM increases with decreased loads.[6]

Definition of Terms

The *kinetic chain* refers to all the muscles and joints that are involved in producing a given movement. For example, in gait, the kinetic chain consists of the trunk, hip, knee, and ankle. Most exercises and tasks involve more than one muscle group and joint, which work simultaneously to produce the movement. Exercises in the kinetic chain can be performed two ways, open and closed, referred to as open chain and closed chain.

Open chain exercises are performed such that the distal end of the kinetic chain is free to move. An example of an open chain activity is quadriceps knee extension sitting on a plinth where the leg moves from 90° of flexion to full extension.

Closed chain exercises are performed with the distal end of the kinetic chain fixed. An example of a closed chain exercise for the quadriceps is squatting. The knee is again moving through 90° of movement, but the leg is fixed in place and the thigh is moving over the fixed leg.

Equipment-Based Strength Testing

Because practice patterns have changed extensively since the advent of manual muscle testing, methods to identify muscle weakness have also evolved. The days of poliomyelitis are behind us, and the need to identify deficiencies related to sports-related injuries, trauma, aging, and a host of other clinical conditions has resulted in the development of new and more specific testing techniques for the characterization of muscle weakness. This chapter segment will present an overview of some of the more popular approaches.

Equipment-based strength tests offer many advantages. The main advantage of using equipment (such as a strength-testing device) for repetition maximum testing is that the stability afforded by the device is far greater than in manual muscle testing and thus allows for highly controlled, single-plane movements and increased patient safety. In addition, normative data for many movements are available with equipment-based testing. The disadvantages of using equipment for testing are they take up space and may not be readily available, can test only one plane of movement, and can test only a finite number of muscle groups.

Interpretation of Equipment-Based Strength Testing Data

Equipment-based strength testing data are informative only if used in context with other clinical findings. For example, if the therapist identifies side-to-side strength differences for shoulder flexion in conjunction with difficulty lifting or the presence of pain on the weaker side, the therapist's clinical decision-making is enhanced and treatment can be confidently and competently applied. If gait speed is slow and there is evidence of gait deviation, equipment-based strength testing will help to inform the therapist about the reasons for the deviation and thus enhance treatment planning. Equipment-based strength testing, as with manual muscle testing, is only as good as the technique applied and is useful only in conjunction with other important functional findings. Clinical competence develops with practice, practice, and more practice, which includes all testing procedures, particularly those that provide information about strength deficits. Investing the time to learn correct testing procedures results in improved treatment planning, more targeted goal setting, better documentation of the patient's status and rate of improvement, and greater success in receiving reimbursements from health care providers.

Sitting Unilateral Knee Extension Test

Purpose:

The sitting unilateral knee extension test is used primarily to determine quadriceps strength when the strength of the patient exceeds the strength of the therapist. If manual muscle testing reveals Grade 4 or better strength with the therapist's maximum resistance, the test cannot discriminate whether strength is greater than Grade 4 or Grade 5 and manual resistance is insufficient to elicit a maximum patient effort. Therefore the sitting unilateral knee extension test can be used to distinguish side-to-side differences in quadriceps force output and elicit a true maximum effort.

Position of Patient:

Seated comfortably on a knee extension machine that has been adjusted for leg length. If necessary, padding may be placed beneath the thigh being tested, for patient's comfort.

The resistance pad should be positioned at distal third of tibia. A seat belt may be placed around the patient's pelvis, if needed, to provide stability (Fig. 7.1; seat belt not shown in figure).

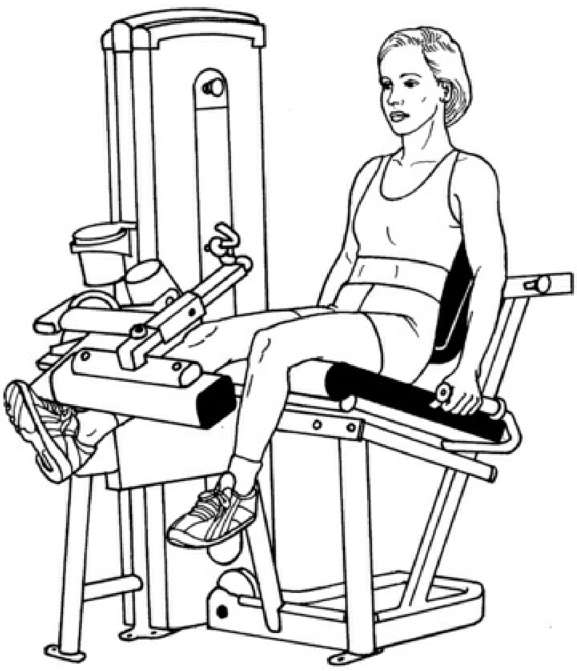

FIGURE 7.1

Instructions to Therapist:

To achieve a 1-RM, select an initial weight from the weight stack, based on the screening exam. A good place to start is approximately 25% of body weight if the screening exam verifies the patient can stand unassisted. Note that the weight lifted will be less than on a leg press machine. Standing at the side of patient, with patient sitting and arms at sides, holding the handles, have patient completely extend the knee through full range of motion with the selected weight. If successful, after a minimum 60-second rest, another repetition with a higher weight is performed through full range of motion. After the load cannot be moved through full range or patient loses form, patient is asked to perform another repetition at that weight, after the appropriate rest period, to verify muscle failure and confirm that patient cannot complete another repetition.

Instructions to Patient:

"Lift the weighted bar, completely straightening your knee."

Scoring

Record the highest weight the patient lifted 1 time to reach full knee extension for a 1-RM. The multiple RM is recorded as the weight lifted at last repetition and the number of repetitions the patient performed at that weight to achieve muscle failure. (Note: Knee extension through full range of motion, particularly the last 15° to 0°, must be achieved for a successful test.)

Helpful Hints

- A patient will move less weight on a single-joint machine, such as a unilateral knee extension machine, than on a multiple-joint machine, such as a unilateral leg press, because of the amount of muscle mass involved (e.g., quadriceps-only versus quadriceps, gastrocnemius/soleus, and gluteals combined).

Leg Press Test

The leg press machine is one of the most useful devices in a clinic as it is a closed chain activity, thus mimicking a common aspect of function such as standing, walking, and rising from a chair. The force output generated by a patient will tell the therapist whether a patient has enough strength to be functional in activities of daily living or with sport activities requiring a large amount of strength, such as soccer.

Purpose:

The leg press assesses the force output of all extensor muscles in the lower extremities (hip and knee extensors and plantar-flexors).

Position of Patient:

Seated comfortably on leg press machine, with head and spine in contact with seat back, both feet on the foot plate, approximately 12 in. apart, knees bent approximately 90° over the hips and in line with feet (avoid knees dropping toward each other in hip adduction), and hands on grab bars (Fig. 7.2). Feet on the footplate in either the low position (Fig. 7.3) or the high foot position (see Fig. 7.2).

FIGURE 7.2

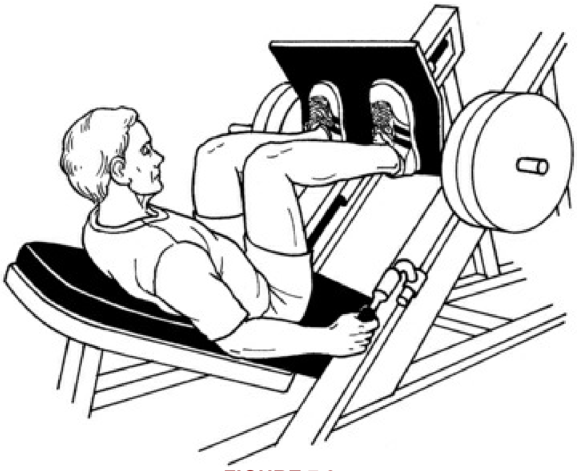

FIGURE 7.3

Instructions to Therapist:

Ensure the patient has painless and sufficient hip, knee, and ankle range to perform the test and is warmed up sufficiently. Select the initial weight that is 50% to 70% of capacity (see Table 7.4 for leg press norms), and ask the patient to fully extend the legs with feet against the footplate so that shins are parallel with the floor. The knees should be softly extended at the end of the push (avoid a "locked out" position). Note: Some leg press machines require therapist to place weights on either side of the footplate bar (e.g., two 25-lb weights) and lock the weights in place. Other machines will require the patient to sit upright. Obtain 1-RM.

Table 7.4

LEG PRESS NORMS FOR MEN AND WOMEN IN VARIOUS AGE GROUPS; VALUES REFLECT ONE-REPETITION MAXIMUM/BODY WEIGHT

Percentile	20-29 YEARS		30-39 YEARS		40-49 YEARS		50-59 YEARS		60+ YEARS	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
90th	2.27	2.05	2.07	1.73	1.92	1.63	1.80	1.51	1.73	1.40
80th	2.13	1.66	1.93	1.50	1.82	1.46	1.71	1.30	1.62	1.25
70th	2.05	1.42	1.85	1.47	1.74	1.35	1.64	1.24	1.56	1.18
60th	1.97	1.36	1.77	1.32	1.68	1.26	1.58	1.18	1.49	1.15
50th	1.91	1.32	1.71	1.26	1.62	1.19	1.52	1.09	1.43	1.08
40th	1.83	1.25	1.65	1.21	1.57	1.12	1.46	1.03	1.38	1.04
30th	1.74	1.23	1.59	1.16	1.51	1.03	1.39	0.95	1.30	0.98
20th	1.63	1.13	1.52	1.09	1.44	0.94	1.32	0.86	1.25	0.94
10th	1.51	1.02	1.43	0.94	1.35	0.76	1.22	0.75	1.16	0.84

Descriptors for percentile rankings: 90, well above average; 70, above average; 50, average; 30, below average; 10, well below average.

Data for men provided by The Cooper Institute for Aerobics Research, The Physical Fitness Specialist Manual. Dallas, TX, 2005; http://hk.humankinetics.com/AdvancedFitnessAssessmentandExercisePrescription/IG/269618.indd.pdf; and Data for women provided by the Women's Exercise Research Center, The George Washington University Medical Center, Washington, DC, 1998.

Instructions to Patient:

"Push the plate until your legs are straight. Don't hold your breath during the test or lock your knees out. Keep your knees in line with your feet."

Scoring

Record the highest weight patient can push 1 time (for 1-RM) or for a multiple RM, the weight achieved, and number of repetitions with the end weight that produced muscle failure.

Helpful Hints

- The leg press uses the closed chain approach (distal end of the kinetic chain is fixed).

- Foot position low on the plate (see Fig. 7.3) elicits greater muscle activity from the rectus femoris and gastrocnemius at 80% 1-RM than high foot position (see Fig. 7.2), suggesting that the feet should routinely be positioned low on the plate when using a 40% or 80% 1-RM.[7]
- The high foot position elicits gluteus maximus more than low foot position.[7]
- Not all patients can comfortably assume a low-foot position; in terms of importance, comfort should outweigh desired muscle activation.
- There are established norms for leg press for men and women ages 20 through early 60s, which is hardly comprehensive of all age groups. Nonetheless, it is important to understand what should be expected in terms of "normal" strength. Norms are expressed as a ratio of force output to body weight. Thus a typical ratio for a young woman in her twenties is 2.05, meaning that she should be able to generate force equivalent to twice her body weight. Normative data for the leg press compiled from hundreds of men and women that have been tested by the Cooper Institute are presented in Table 7.4.

Latissimus Dorsi Pull-Down Test

The latissimus dorsi pull-down test (lat pull-down test) is a general measure of bilateral scapular adduction and scapular downward rotation. The lat pull-down machine is commonly available in clinics, wellness centers, and workout facilities. The test is one of the safest and easiest to perform of all upper extremity exercises. This test is feasible for most adults without shoulder or neck problems.

Purpose:

To measure the collective force of the latissimus dorsi muscles, rhomboids, and middle and lower trapezius.

Position of Patient:

Seated, facing the weight stack, feet flat on floor. Arms overhead with hands on bar in overhand grip (pronation) (Fig. 7.4). Head position should be over shoulders, with attention to avoiding a forward head position. Forearms in supination (underhand grip) is easier (not shown).

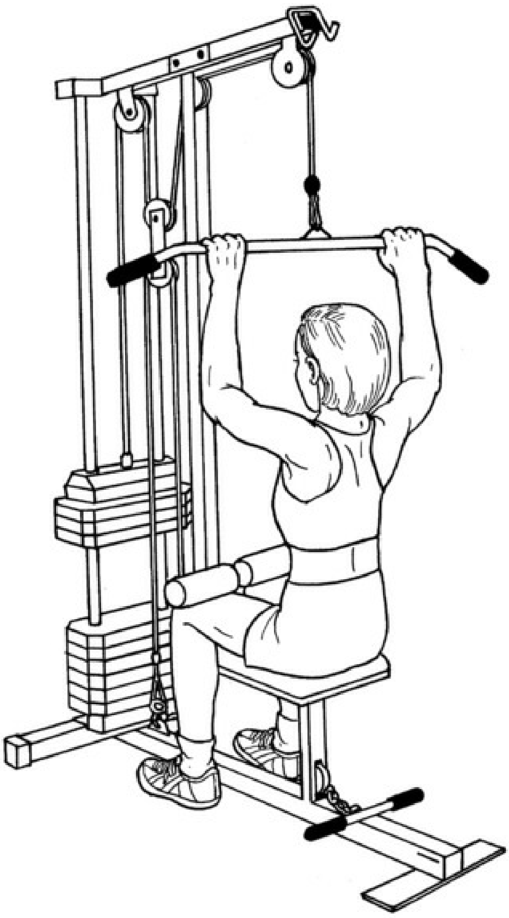

FIGURE 7.4

Instructions to Therapist:

Ensure the patient has no shoulder pain and sufficient elbow range to perform the test. Bring the overhead bar to the patient. Hands placed on the bar should be in an overhand grip with hands slightly wider than shoulders. Select a weight based on the initial physical therapy screening that is relatively easy (e.g., can patient pull against manual resistance easily?), such as 20 lb for a woman and 40 lb for a man. Adjust the soft pad above the thighs so that it is comfortable and contributes to stability. The therapist then stands behind the patient to monitor the position of the scapulae. Correct form is when the bar is pulled down to shoulder height in front of the body with shoulders retracted (scapular adduction and downward rotation) and leaning slightly backwards. The position of pulling down in front of the head provides the greatest activation of the latissimus dorsi.[8] Depending on performance of the first repetition, increase or decrease weight as indicated to achieve a 1- or multiple RM.

Instructions to Patient:

"In a smooth manner, pull the bar down in front of you level with your shoulders, while pulling your shoulder blades back and down. Don't hold your breath."

Scoring

Record the highest weight and number of repetitions the patient performs without losing form for a 1-RM or multiple RM. Norms for the latissimus pull-down activity are typically 66% of body weight for young men and 50% of body weight for young women.[9] Norms for men and women who are middle-aged and older have not been established.

Free Weights Testing

Free weights are the gold standard for reliability and validity of the 1-RM method because of their ease of application and specificity. They offer important advantages for muscle testing, such as permitting therapist to assess strength in both the concentric and eccentric modes. Free weights are readily available in any clinical setting and are readily accessible in the home, where household items can easily be substituted for weights. They can also be used through full range and through multiple planes.

Moreover, movements with free weights require greater motor coordination and better balance (if standing), resulting in greater muscle recruitment. They use important stabilizing muscles to complete a lift, compared with machines, which do not emphasize the stabilizing musculature because movements occur in only one plane of motion. And they allow the therapist the freedom to test different movement variations that can inform an exercise prescription.

However, several disadvantages of using free weights exist. Greater control is required through all planes of movement because of the stabilization required. Free weights can challenge the entire kinetic chain, thus stressing the “weakest link” rather than the targeted muscle or movement, unless proper stabilization is provided. Maximum muscle loading occurs only at the weakest point in the range, thus requiring an attentive therapist. Proper positioning is critical for safety and test reliability. Spotting is necessary because the weight can be unexpectedly dropped, potentially causing injury.

Examples of Free-Weights Testing

Biceps Curl

The biceps curl is an example of using free weights to determine a 1-RM or multiple RM. In this instance the biceps, brachialis, and brachioradialis are the muscles that will be challenged, particularly the biceps and brachialis. This test can easily discern side-to-side differences and whether strength is adequate for lifting during work.

Purpose:

To determine maximum force capability of the biceps brachii and brachialis, as well as the brachioradialis and, to less extent, the pronator teres muscles.

Position of Patient:

Either standing or seated comfortably in a standard chair with no arms. Provide seat belt if needed. Elbow should be straight, with arm at the side, forearm supinated. Standing requires stabilization of the trunk, which may be a more functional position although more difficult.

Instructions to Therapist:

Based on prescreening, which may include questions such as “can you easily carry a bag of groceries” (approximately 10 lb) or “how much do you normally curl,” and determination that full range of motion can be achieved painlessly, the therapist should select a weight that is reasonably challenging, generally 50% more than what is routinely lifted. Standing next to the patient, place the weight in the patient's hand with the forearm supinated and ask the patient to flex the elbow through full range of motion in a supinated position (Fig. 7.5). After a rest of a minimum of 60 seconds, increase or decrease weight in appropriate intervals based on performance to achieve a 1-RM or multiple RM.

FIGURE 7.5

Instructions to Patient:

"While holding the weight, bend your elbow until the weight touches your upper arm."

Scoring

Record 1-RM or multiple RM. Normative strength is approximately 25% of body weight for women and 33% of body weight for men.[6]

Note: The incremental increase in weight lifted is far less for the upper extremity compared with the lower extremity because of the difference in muscle mass.

A hammer curl is performed in the same manner but keeping the forearm in a neutral position with hand towards body.

Bench Press Test

The bench press is one of the most popular tests of upper extremity strength because it provides a composite value for many muscles, similar to the leg press.

Purpose:

To achieve a repetition maximum while maximally challenging the larger anterior scapulohumeral muscles: pectoralis major, pectoralis minor, anterior deltoid, infraspinatus, serratus anterior, and upper and lower trapezius. In addition, the triceps brachii is critical to extend the elbow.

Position of Patient:

Supine on the testing bench, back flat against bench with feet flat on the floor. Nipple line is directly below the weight bar. Hand position is pronated (overhand grip) and slightly wider than shoulders (Fig. 7.6).

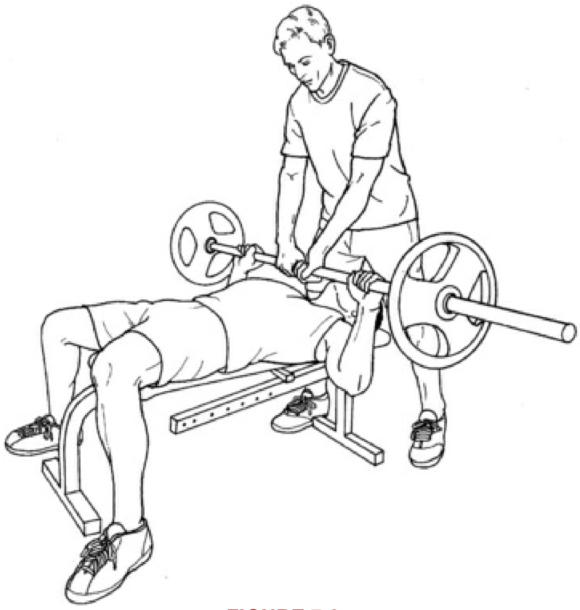

FIGURE 7.6

Instructions to Therapist:

Prescreen the patient to ensure the presence of full, painless range. Observe the patient's muscle bulk, and ask prescreening questions such as “Do you chest press regularly?” Then select two equal weight plates and place them at each end of the bench press bar, locking the weights in place. Provide for a warm-up period. Once warmed up, adjust weight to approximately 40% of body weight for women and 50% body weight for men. Be sure to consider the weight of the bar itself, which often is 40 lb.

Stand at the patient's head to “spot” the patient throughout the movement (see Fig. 7.6). Have the patient grasp the bar with a pronated grip. At a signal from the patient, assist the patient in moving the bar off the supports and lowering the bar directly over the chest. Release the bar smoothly after you are confident the patient is in control of the bar. Ask the patient to lower the bar to the nipple level, keeping head flat against bench. Then ask the patient to push the bar overhead until the elbows are fully extended. The back should not extend (come off the bench). The weight is either decreased (if first attempt is not successful) or increased if the patient indicates multiple repetitions can be performed. Provide the patient a minimum of 60 seconds of rest between lifts. Test failure is observed when the patient is unable to complete full range of motion. At test failure, grasp the bar with alternating overhand and underhand grips (see Fig. 7.6), and place it on the rack supports.

Instructions to Patient:

“Lower the weight slowly and smoothly, then push the bar straight up overhead until your elbows are completely straight. Do not hold your breath. Be sure to tell me if you need assistance with the bar.”

Scoring

Record 1-RM or multiple RM . The norms for men and women are listed in Table 7.5.

Table 7.5

BENCH PRESS NORMS BY GENDER AND AGE VALUES REFLECT ONE-REPETITION MAXIMUM/BODY WEIGHT (IN POUNDS)

Percentile	20-29 YEARS		30-39 YEARS		40-49 YEARS		50-59 YEARS		60+ YEARS		70+ YEARS
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Women
90th	1.48	0.54	1.24	0.49	1.10	0.46	0.97	0.40	0.89	0.41	0.44
80th	1.32	0.49	1.12	0.45	1.00	0.40	0.90	0.37	0.82	0.38	0.39
70th	1.22	0.42	1.04	0.42	0.93	0.38	0.84	0.35	0.77	0.36	0.33
60th	1.14	0.41	0.98	0.41	0.88	0.37	0.79	0.33	0.72	0.32	0.31
50th	1.06	0.40	0.93	0.38	0.84	0.34	0.75	0.31	0.68	0.30	0.27
40th	0.99	0.37	0.88	0.37	0.80	0.32	0.71	0.28	0.66	0.29	0.25

30th	0.93	0.35	0.83	0.34	0.76	0.30	0.68	0.26	0.63	0.28	0.24
20th	0.88	0.33	0.78	0.32	0.72	0.27	0.63	0.23	0.57	0.26	0.21
10th	0.80	0.30	0.71	0.27	0.65	0.23	0.57	0.19	0.53	0.25	0.20

Descriptors for percentile rankings: 90, well above average; 50, average; 30, below average; and 10, well below average.

Data for women are derived from the Women's Exercise Research Center, The George Washington University Medical Center, Washington, DC, 1998; and Data for men were provided by the Cooper Institute for Aerobics Research, The Physical Fitness Specialist Manual, Dallas, TX, 2005.

Helpful Hints

- Many bench press bars weigh up to 40 lb, and this must be taken into consideration when determining ultimate load.
- It may be necessary for the therapist to take the weight bar away from the patient at test failure, so the therapist should be sure (in advance) that he or she is physically capable of handling the weight bar being lifted.
- If there is no weight bench and the patient is lying on a plinth, the therapist must place the fully loaded lifting bar into position above the patient, again approximately 6 in. above the chest at nipple level. Help may be needed if the therapist is unable to handle the loaded weight bar. “Spotting” the patient is even more important in this adaptation of the bench press.

Isokinetic Testing

Isokinetic testing was developed in the 1960s and has gained popularity, especially for research, because of its objectivity. The advantages of isokinetic testing for evaluating muscle strength and contraction speed include testing through a spectrum of movement speeds (e.g., 0° to 400° per second), providing highly reliable data, and providing safety in testing by ensuring movement control. Most importantly, isokinetic machines (e.g., Cybex, Biodex, KinCom) allow maximal resistance throughout the entire range of motion, something that no other testing method can provide. Eccentric strength can also be objectively assessed.

The disadvantages of isokinetic testing include:

- The prohibitive cost and space requirements of the oversized testing equipment
- The time required to set up the tests
- The fact that only single planes of movement can be tested
- The fact that many sports-specific movements are faster than any isokinetic machine
- The fact that isokinetic contractions are nonphysiologic

An isokinetic machine allows the speed to remain constant but the force generated through the range is not consistent, which means that muscle demand (percentage of force required) is highly variable throughout the range of motion. To use the knee extensors as an example, under physiologic conditions, quadriceps strength demand is greatest at the end of the range, where length-tension and the patella lever-arm are poorest.

Although the setup for isokinetic testing is protocol driven, the actual test execution requires skill, computer interaction, and know-how that is beyond the scope of this book. For complete instruction in isokinetic testing, the reader is referred to the remarkable amount of material on the internet and the instruction booklets from the makers of isokinetic machines and instrumentation.[10]

Elastic Band Testing

Elastic band testing is a common form of strength testing that uses elastic resistance that is color coded according to level of resistance. Resistance of the band is based on the amount and kind of material used in the band. Thicker bands provide more resistance. Some bands use a polymerized synthetic rubber, whereas others use a natural rubber latex (TheraBand) that may provide better elasticity and lower susceptibility to rupture. The force of elastic resistance depends on its percentage of elongation, regardless of initial length. The elastic band should be the same length as the lever arm being tested to ensure elongation remains less than 200%.[11] For example, if the length of the patient's leg, from hip to heel, is 50 in., then a band of 50 in. should be used. Force elongation in pounds for 100% elongation of TheraBand elastic bands is listed in Table 7.6.

Table 7.6

FORCE ELONGATION FOR THERABAND ELASTIC BANDS AT 100% ELONGATION (VALUE = FORCE IN POUNDS)

Elongation (%)	Yellow	Red	Green	Blue	Black	Gray	Gold
100 (twice the length of the band)	3	4	5 -4	5.8	7.3	10.2	14.2

The percentage of elongation (change in length) is calculated with the following formula:

$$\text{Percentage of elongation} = (\text{final length}) - (\text{resting length})/(\text{resting length}] \times 100.$$

http://www.thera-bandacademy.com/resource/x-showResource.aspx?id=5534.

In addition to elastic band availability in nearly all clinics and ease of application for home use, there are several other advantages to elastic band testing. Elastic bands produce a curvilinear length-tension profile, which can be used to challenge the end range, potentially producing a higher peak force than might be achieved with a free weight or machine.[12] Elastic bands increase the agonist-antagonist cocontraction, challenging stability. Eccentric contractions are especially challenged with elastic bands. Patients receive immediate feedback about their progress because the color of band changes according to strength increases. The cost of bands is low compared with other methods of strength testing. Any movement can be tested, with a little creativity.

Disadvantages of elastic band testing include the need for stabilization and the patient's muscle activation is at the weakest link in the kinetic chain, as mentioned with free weights. Greater force is required with elongation of the band, which may prohibit correct performance. There is difficulty standardizing elements of band elongation and the patient and/or extremity positioning, and quantifying test interpretation is dependent on the manufacturer. For example, if you have two patients and one patient abducts the hip only 10° against a gray elastic band (high strength demand) whereas another abducts the hip 20° against a green elastic band (low strength demand), which patient has more strength? Strength indexes help to standardize this issue; however, they are widely known only for TheraBand elastic bands.[13] Different manufacturers use different color codes, and published strength indexes are not interchangeable.

For safety, test positions can be adapted. For example, testing of the elbow flexors can be done with the patient sitting or standing. See Fig. 7.7 for an illustration of elastic band testing used to test shoulder abduction strength.

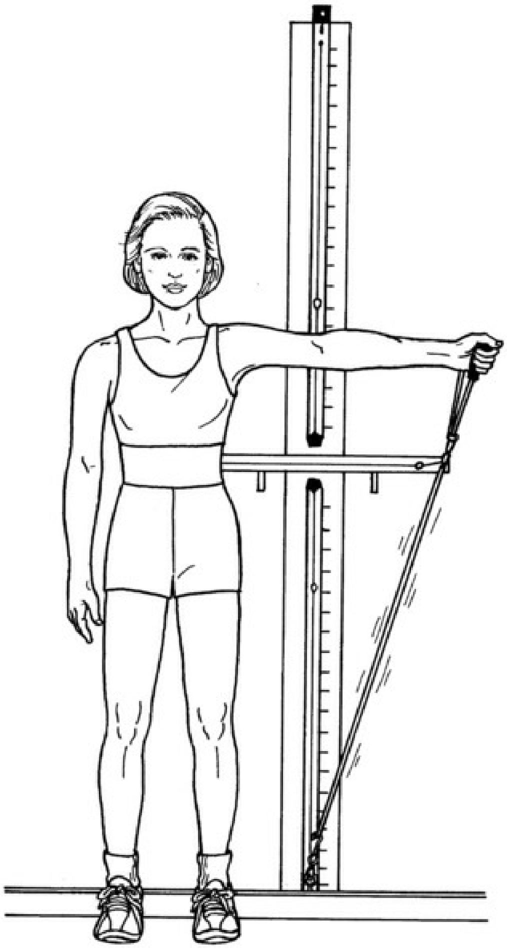

FIGURE 7.7

Example of Elastic Band Testing

Testing the Shoulder Abductors

Purpose:

To test the maximum strength of the shoulder abductors (deltoid and rotator cuff). Muscles also involved are the serratus anterior and upper/lower trapezius to upwardly rotate the scapula to support the humerus.

Position of Patient:

Standing. If patient cannot stand, the test can be performed in sitting.

Instructions to Therapist:

Before patient testing, shoulder abduction should be assessed for available range and the absence of pain. To assess strength, a color elastic band based on prescreening is selected for use. In general, a medium band is feasible for most trained patients who are without shoulder pain. Measure the band so that it is the same length as the length of the arm. Secure one end to an immovable object or knot the end and have the patient stand on the end of the band with knot on the inside of the foot. Stand to the side and slightly behind patient. Ask patient to hold the other end of band, with any slack in band removed. Ask the patient to lift the arm into 90° of abduction to height of shoulder, keeping the hand/forearm pronated and the elbow straight. At this position, the band should be elongated 2× (100%) its original length. Then ask the patient to slowly lower the arm (generally 3× slower than the lifting phase). Decrease the resistance color of the band if the patient is unable to complete full range or has discomfort, and increase resistance if the patient can perform multiple repetitions. Therapist should monitor form to include stabilization of the trunk, head and neck position, pronation of the forearm/hand, and scapular adduction and downward rotation.

Instructions to Patient:

"Lift your arm out and away from the side of your body to the height of your shoulder. Keep your elbow straight and hand pointed down. Don't hold your breath during the test."

Scoring

Record the color of the band used to complete a full 90° of abduction and how many repetitions were performed to muscle failure, if more than one repetition was completed. Consult appropriate chart for force in pounds (depending on manufacturer of band). Force elongation for 100% elongation of TheraBand elastic bands as described by the manufacturer is listed in Table 7.6.

Helpful Hints

- Some companies sell handles to attach to the end of the band, thus making it more feasible for patients to use the band.
- With repeated use and age of the band, elastic bands lose their elasticity and/or become brittle and should be replaced. Bands should always be inspected for small tears or holes that may weaken the band and cause it to break during elongation. Periodic calibration will determine if it is time to discard the original band.
- If the therapist underestimated the strength of the patient, the patient's force may overcome the elastic properties of the band and cause it to break, creating a potentially unpleasant and unsafe condition.

Isometric Cable Tensiometry Testing

A cable tensiometer is an objective and precise device that can be used to measure isometric muscle contraction. The cable gauge (dynamometer) is attached to a static object and to the distal end of the limb. No limb movement is allowed. Advantages of cable tensiometry include the numerical data that are produced from the patient's efforts and reproducibility of repeat tests and the isometric nature of the test, which makes this type of instrumentation safer than most. Disadvantages of cable tensiometry are its lack of availability and only one muscle group in one plane can be tested. Consequently, only a limited number of muscle groups can be tested using this method.

Squat Test

Purpose:

To assess maximum isometric strength of the quads, hip, and back extensors (primary movers)

Position of Patient:

Stand facing the tensiometer with feet shoulder width apart. Knees should be bent approximately 110°. Arms should hang down naturally to grasp handle in an overhand grip (pronated). In this position the back should be bent slightly forward at the hips, the head should be held upright, and the patient should look straight ahead.

Instructions to Therapist:

Attach tensiometer to the floor or to an immobile object that can be stabilized on the floor. Reset the dial to zero. With the patient standing with arms hanging down, adjust the chain so that the knees are bent at approximately 110° with no slack in the chain. Ask the patient to grab the bar in an overhand grip and to pull it as hard as possible in a smooth motion (Fig. 7.8). The pull should be held between 3 and 5 seconds. Reset the needle on the tensiometer dial back to zero, and repeat the test a second time.

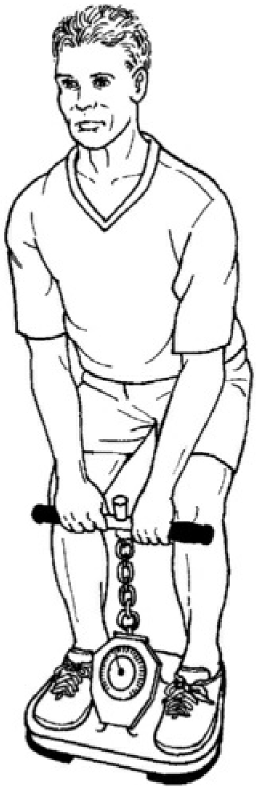

FIGURE 7.8

Instructions to Patient:
"Pull the bar up as hard as you can. Now pull a little harder."

Scoring
Average the two trials or record the highest value.

Summary
Except for the leg press, the procedures presented in this chapter are either isometric or concentric and patients are tested using the open chain approach. Day-to-day function requires performance of activities using a closed chain approach (e.g., sitting down or climbing stairs). Activities that include multiple joints are often multiplanar, require some degree of balance, and are speed dependent. There are few instrumented options available for specifically and accurately assessing strength using the closed chain functional approach, but change is likely on the horizon. Currently, power and functional tests are the best options for use in the clinical setting.

Power Testing
Power testing, also known as maximal anaerobic power testing, was initially developed to assess explosive strength in a sports setting. Maximal power is defined as force per unit of time, and thus a power measure includes not just muscular force production but the rate of force development. The specific formula for power is:

$$\text{Power} = \text{work}/\text{seconds}$$

Powerful athletes can accelerate rapidly with explosive force output (e.g., the Olympic 100-m dash). In addition, the rate of force development may be the critical determinant of a person's safety, especially in unexpected or emergency situations. For example, a patient must go from gas pedal to brake quickly enough to prevent a crash. Another important reason for rapid force development is to prevent a fall. Once a person loses balance, only the power of rapid limb movement can rescue the individual. Recently, power has been identified as a major determinant of functional impairment in the older adult and is now considered even more important than strength (e.g., in the chair rise).[14] Thus power is an important aspect of muscle performance.

Power testing is in its infancy. Although the concept of power determination has been around for half a century, actual tests for its measurement are limited. It is expected that more tests for power will be developed in the future or adaptations of existing tests will be made to include patients with muscular weakness and poor muscular endurance.

The power tests in the next section have been selected because they do not require special equipment or extensive preparation. In addition, these tests require maximum muscle power. Because maximal muscular activity is involved in performing power tests, they are anaerobic and are of short duration.

Margaria-Kalamen Stair Sprint Test[15]

Since the early 1960s, numerous adaptations of the original Margaria stair sprint test[15] have been made as the relevance and importance of power testing has become evident. Modified versions include running two stairs at a time and shortening the starting distance. Regardless, the test is of short duration (lasting less than 5 seconds). It is considered a standard test for determining peak power. A disadvantage of the test is that typically only the young and healthy can perform it.

Purpose:

To measure maximal anaerobic strength and power of the lower extremities.

Test Instructions[16]:

Ensure the patient can safely negotiate nine stairs, three steps at a time. Weigh patient in kilograms. Each stair should be 17.5 cm (~7 in.) tall. The therapist should stand at the bottom of the stairs to monitor the effort. A timer start switch mechanism is placed on the third step, and a stop switch mechanism placed on the ninth step. With the patient positioned 6 meters (20 ft) from the bottom stair, ask the patient to run towards stairs, taking three steps at a time at maximal speed. Repeat the test 2× with a 3-minute recovery period between each trial.

Scoring

The time from third- to ninth-step contact is determined to the nearest 0.01 seconds using the timing system. Power in watts is calculated according to the following formula:

$$\begin{aligned}\text{Power (in watts)} &= \text{Weight (body weight in kg)} \times 9.807 \\ &\times \text{Vertical height of six stairs in meters} \\ &\text{(step 3} - \text{step 9)/Time (seconds)}\end{aligned}$$

Example: Mark weighs 210 lb and scored a best attempt of 1.2 seconds when climbing six steps with a combined height of 49.5 inches.

$$210 \text{ lb} = 95.25 \text{ kg}$$

$$\text{Vertical height} = 17.5 \text{ cm stairs} \times 6 = 1.05 \text{ meters}$$

$$\text{Power} = (92.25 \times 9.807) \times 1.05)/1.2 = 831 \text{ watts}$$

Normative data are described in Table 7.7.

Table 7.7
MARGARIA-KALAMEN STAIR SPRINT TEST NORMATIVE DATA (WATTS)

Classification	AGE GROUPS (YEARS)									
	15-20		20-30		30-40		40-50		Over 50	
	M	F	M	F	M	F	M	F	M	F
Excellent	Over 2197	Over 1785	Over 2059	Over 1648	Over 1648	Over 1226	Over 1226	Over 961	Over 961	Over 736
Good	1844-2197	1491-1785	1726-2059	1383-1648	1383-1648	1040-1226	1040-1226	814-961	814-961	608-736
Average	1471-1824	1187-1481	1373-1716	1098-1272	1098-1373	834-1030	834-1030	647-804	647-804	481-598
Fair	1108-1461	902-1177	1040-1363	834-1089	834-1088	637-824	637-824	490-637	490-637	373-471
Poor	Under 1108	Under 902	Under 1040	Under 834	Under 834	Under 637	Under 637	Under 490	Under 490	Under 373

Data from Hoffman, J. (2006). Norms for fitness, Performance, and Health. Champaign, Ill.: Human Kinetics. Adapted from Fox, E., Bowers, R., & Foss, M. (1993). The Physiological Basis for Exercise and Sport (5th ed.). Dubuque, Iowa: Wm C. Brown, 676, with permission of the McGraw-Hill Companies; based on data from Kalamen, J. (1968). Measurement of Maximum Muscular Power in Man, Doctoral Dissertation, The Ohio State University, and Margaria, R., Aghemo, I., & Rovelli, E. (1966). Measurement of muscular power (anaerobic) in man. Journal of Applied Physiology, 21, 1662-1664.

Medicine Ball Throw Test

Purpose:

To determine the power of important scapulothoracic and glenohumeral muscles, particularly the pectoralis major and minor, anterior deltoid, supraspinatus, and infraspinatus.

Test Instructions:

With the patient seated, assess the ability of the patient to throw a medicine ball from the chest.[16a] Weight of the ball usually ranges from 1.5 to 4 kg. Athletes perform this test seated on the floor with legs extended in front and back against the wall. If the patient can perform the task, place a 1.5 to 4-kg ball in patient's hands close to the chest (like a basketball) (Fig. 7.9A). Ask the patient to push the ball forward as rapidly as possible. An alternate method is depicted in Fig. 7.9B. In this instance, the patient throws the ball using an overhead technique. Either technique is acceptable.

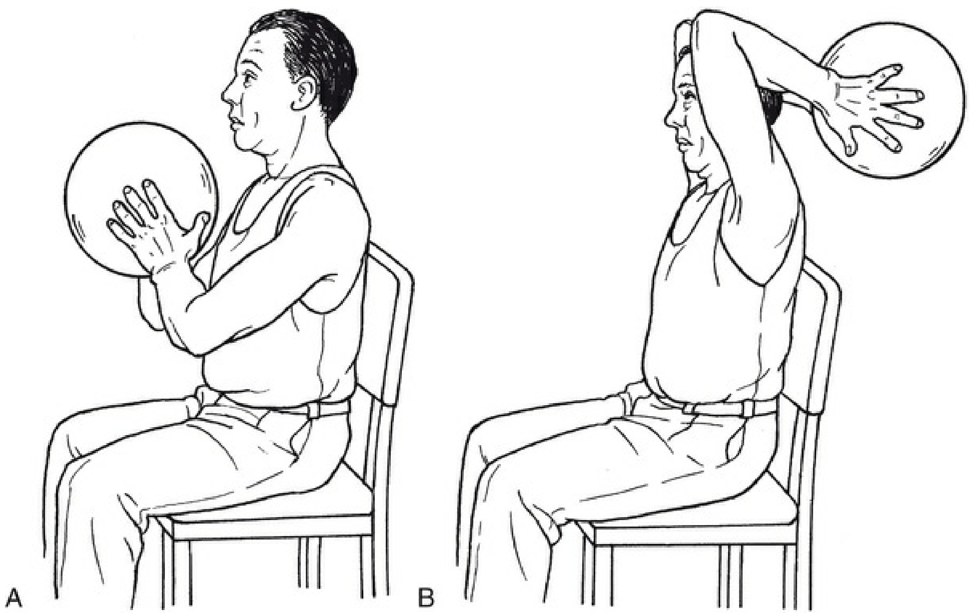

FIGURE 7.9A AND B

Scoring

The test is repeated 3 times. Record the maximum or average distance from the front of the chair to where the medicine ball lands. No normative data exist and scores depend on the weight of the ball. However, the top score in the 2013 NHL Combine using a 4-kg ball was 6.25 meters (sitting on the floor).[16b] Older men and women (mean age 72.4 years) threw a 1.5 kg ball a range of 2 to 6 meters and a 3-kg ball a range of 2 to 4.5 meters.[16a]

Shot Put Test

Purpose:

As with the medicine ball throw, the shot put test challenges the musculature of the glenohumeral and scapulothoracic muscles. However, the test is unilateral, which permits side-to-side comparisons. Because the test is done standing, it also challenges balance. The test can also been done sitting, similar to the two-handed medicine ball throw test.

Test Instructions:

Assess the patient's ability to throw a shot put from overhead. If the patient can perform the test, select a “shot” that is appropriate for patient (1–7 kg). The therapist then places the shot put in the patient's hand. Ask the patient to bring the shot put to the shoulder, then rapidly thrust the shot put away from body as far as possible. The technique requires the patient momentarily balancing the shot put on the shoulder and chin (Fig. 7.10). The trial is repeated 3 times and the furthest distance recorded.

FIGURE 7.10

Scoring

The trial is repeated 3 times and the furthest distance recorded. No normative data exist; however, distances of more than 20 meters have been recorded for female and male athletes.

Alternative Shot Put Test:

Standing and using two hands, the patient leans forward, brings the shot down between the legs, and throws the shot forward as far as possible. The throw is underhand instead of overhand and involves both arms instead of just one. This test is easier for the patient to perform. To score, record the distances of the effort.

Vertical Jump Test

Purpose:

The vertical jump test assesses maximum muscle power and strength. It specifically challenges the extensors of the lower extremity, particularly the gluteus maximus and minimus, the hamstrings, quadriceps, gastrocnemius, and soleus. Only those with adequate balance can perform the test.

Test Instructions:

Tape a yardstick or piece of paper with height markings onto the wall. The therapist chalks the patient's fingers on the dominant hand. Ask the patient to reach as high as possible with the dominant hand, touching the wall while keeping the feet flat. Note chalk mark that serves as starting position. Standing flat-footed without preparation, ask the patient to jump as high as possible, swinging arms backwards before reaching overhead, touching dominant, chalked hand to wall (Fig. 7.11). The patient may flex knees and hips with jump. Repeat test.

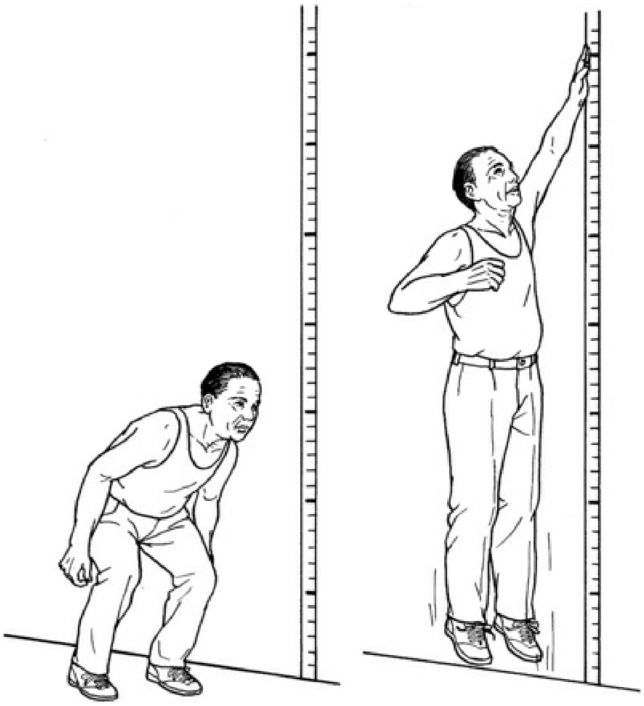

FIGURE 7.11

Scoring

The total distance jumped is recorded, which is the highest mark minus the initial mark. Score the best of the two trials. Normative data are listed in Table for athletes in various sports (Table 7.8).

Table 7.8

VERTICAL JUMP DESCRIPTIVE DATA FOR VARIOUS GROUPS

Group, Sport, or Position	Vertical Jump (in./cm)
NCAA Division I college football split ends, strong safeties, offensive and defensive backs	31.5/80
NCAA Division I college football wide receivers and outside linebackers	31/79
NCAA Division I football linebackers, tight ends, and safeties	29.5/75
NCAA Division I college football quarterbacks	28.5/72
NCAA Division I college basketball players (men)	28/71
High school football backs and receivers	24/61
College baseball players (men)	23/58
College tennis players (men)	23/58
17 year-old boys	20/51
NCAA Division I college basketball (girls)	17.5-19/44-48
18-34 year-old men	16/41
18-34 year-old sedentary women	8/20
17 year-old girls	13/33

NCAA, National Collegiate Athletic Association.

NSCA Essentials of Strength Training and Conditioning, ed 3, p. 278.

Hop and Standing Long Jump Tests

There are several variations on long jump power tests. As depicted in Fig. 7.12, the tests can be done on one leg, alternating from side to side or on both (Fig. 7.13). For a more challenging examination (done frequently in athletic training centers), the patient is required to clear an obstacle with each jump, with some obstacles being ≥18 in.

FIGURE 7.12

FIGURE 7.13

Purpose:

To test the power of the lower extremity extensors and pelvic stabilizers, particularly the gluteals, quadriceps, and plantar flexors. Patients require adequate abdominals and balance control.

Test Instructions:

For both tests, measure a 20-foot long area. Draw line on the floor as the starting position.

Single hop test: Ensure that the patient can balance easily on dominant leg. If able, ask the patient to stand on the line with feet just behind the line. Then ask the patient to leap upward and forward on dominant leg, completing three consecutive single leg hops (see Fig. 7.12). The total distance achieved in the three hops is measured and recorded.

Standing long jump: With both feet behind the starting line, ask the patient to jump 1 time, as far forward as possible (see Fig. 7.13). The patient must land on both feet for the jump to be scored. Measure from the starting line to the patient's heel. Repeat for two trials.

Scoring

Hop Jump: The cumulative total distance achieved in the three hops is recorded.

Standing Long Jump: Best of two trials is the score. Long jump scores for young athletes range from 1.88 m to 3.76 m. (1.2 to 2× body height for a 5- and 6-foot individual, respectively. For older adults, twice the length of patient's feet is considered "excellent."[17]

More difficult power tests are available, but it is rarely appropriate to use tests that are at the higher end of physical performance capacity in active rehabilitation. For more definitive work on this aspect of testing, the reader is referred to other sources.[18,19] Most power tests were developed for the young athlete. However, therapist judgment regarding the patient's abilities should be the key element, not age alone, in deciding whether a test is appropriate. Extreme care should be exercised in choosing a power test for those with significant weakness (Grade 3 or lower) or patients with painful conditions.

Body-Weight Testing

Using body weight as resistance provides important information about the ability of patients to use the strength they possess to move their bodies in space. These tests are also effective exercises for strengthening the core as well as specific muscle groups. Several functional tests presented in

Chapter 8 use body-weight resistance. Presented next are several other tests that use body mass as resistance. These tests are high demand and should not be used for patients with specific weakness.

Pull-ups (Chin-ups) Test

Purpose:

The pull-up test uses patient's body weight to challenge the shoulder extensors (latissimus dorsi, teres major, triceps brachii, and posterior deltoid). The middle and lower trapezius, pectoralis minor, and rhomboids pull the scapula down. To pull the body up to the chin-up bar, the biceps brachii, brachialis and brachioradialis are contracting vigorously at the elbow. The wrist and finger flexors must also contract to hold the body on the bar.

Test Instructions:

Assess the patient's ability to fully flex the shoulders and extend the elbows. If adequate range is present and no complaints of pain are presented, ask the patient to stand below an overhead bar that should be higher than the patient's outstretched arms. Have patient stand on a stool if unable to reach the bar. Ask the patient to grasp bar with an underhand (supinated) grip and hang from the bar with the elbows fully extended. Then, ask the patient to lift the entire body multiple times to muscle failure. For each repetition to count, the body must be raised so that the chin is brought above the bar. Subsequently, the body is lowered to the original starting position with each repetition.

Scoring

The number of pull-ups that can be performed successfully is recorded. Normative data for men and women are listed in Table 7.9.

Table 7.9

NORMS FOR ADULTS FOR THE PULL-UP BY GENDER

Gender	Excellent	Above Average	Average	Below Average	Poor
Male	>13	9-13	6-8	3-5	<3
Female	>6	5-6	3-4	1-2	0

Adapted from Davis, B. et al: Physical education and the study of sport, 4th ed, London, 2000, Harcourt, p. 124.

Helpful Hints

- Norms for young boys and girls can be found at http://www.exrx.net/Testing/YouthNorms.html#anchor581034
- Norms used by the Marine Corps can be found at http://www.military.com/military-fitness/marine-corps-fitness-requirements/usmc-physical-fitness-test

Push-up Test

Purpose:

A test of strength for the shoulder flexors, scapular stabilizers (especially serratus anterior), and triceps brachii. Push-ups are used not only as a test of strength but as a test of endurance, particularly in the US Armed Forces.

Test Instructions:

Ensure that the patient does not have shoulder or any upper extremity pain and that adequate range of the shoulder, elbow, and wrist is present. Then, on the floor or other low surface, ask the patient to assume the starting position or "up" position with the hands shoulder width apart, back straight, head up, and using the toes as the pivotal point. The patient then lowers the body until the arms are parallel to the floor (Army standard) or until the chest touches the therapist's fist held vertically against the ground (ACSM standard). The Army uses the same position on toes for men and women. The ACSM allows women to perform push-ups on bent knees with ankles crossed. For both men and women, the back should be straight at all times and the patient must push up to a straight arm position.[1]

Scoring

The Army standard is as many repetitions as possible within a timed 2-minute period. The patient may only pause in the up position. For the ACSM standard, as many repetitions as possible are performed until failure. Norms for the ACSM and Army personnel are listed in Tables 7.10 and 7.11.[2,20]

Table 7.10

CONVERTING THE PUSH-UP SCORE (NUMBER) TO A HEALTH BENEFIT RATING

Age	Zone	Male	Female	Age	Zone	Male	Female
15-19	Excellent	≥39	≥33	40-49	Excellent	≥25	≥24
	Very Good	29-38	25-32		Very Good	17-24	15-23
	Good	23-28	18-24		Good	13-16	11-14
	Fair	18-22	12-17		Fair	10-12	5-10
	Poor	≤17	≤11		Poor	≤9	≤4
20-29	Excellent	≥36	≥30	50-59	Excellent	≥21	≥21
	Very Good	29-35	21-29		Very Good	13-20	11-20
	Good	22-28	15-20		Good	10-12	7-10
	Fair	17-21	10-14		Fair	7-9	2-6
	Poor	≤16	≤9		Poor	≤6	≤1
30-39	Excellent	≥30	≥27	60-69	Excellent	≥18	≥17
	Very Good	22-29	20-26		Very Good	11-17	12-16
	Good	17-21	13-19		Good	8-10	5-11
	Fair	12-16	8-12		Fair	5-7	2-4
	Poor	≤11	≤7		Poor	≤4	≤1

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Table 7.11

PUSH-UP STANDARDS FOR U.S. ARMY PERSONNEL

Age Range	PUSH-UP STANDARDS FOR US ARMY PERSONNEL REPETITIONS IN 2 MINUTES																			
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
17-21	6		13		20	2	28	8	35	13	42	19	49	25	57	31	64	36	71	42
22-26			5		14		23	2	31	11	40	17	49	24	58	32	66	39	75	46
27-31			1		11		20		30	10	39	17	49	25	58	34	68	42	77	50
32-36					7		17		26	9	36	15	46	23	56	30	65	38	75	45
37-41					5		15		24	7	34	13	44	20	54	27	63	33	73	40
42-46							12		21	6	30	12	39	18	48	25	57	31	66	37
47-51							8		17		25	10	34	16	42	22	51	28	59	34
52-56									11		20	9	29	15	38	20	47	26	56	31
57-61									9		18	8	27	13	36	18	44	23	53	28
62+									8		16	7	25	12	33	16	42	21	50	25
Points Awarded	10		20		30		40		50		60		70		80		90		100	

60 points is passing, 90 points is excellent.

Men and women start in up position on toes.

http://www.military.com/military-fitness/army-fitness-requirements/army-physical-fitness-test-score-chart.

Cyriax Method of Testing Contractile Lesions

A common reason for strength testing in orthopedics is to diagnose the tissues contributing to musculoskeletal pain lesions. Because manual muscle testing typically requires completion of full range of motion to assign a grade, an alternative system is needed. James Cyriax developed a system to differentiate between painful contractile and noncontractile (inert) soft tissues.[21] Contractile tissues are parts of the muscle (belly, tendon, and their bony insertions). Inert tissues are those without the capacity to contract or relax, such as joint capsule, ligaments, nerve roots, and the dura mater. The therapist selects passive movements to specifically test inert tissue and resisted movements to specifically stress contractile tissue. If passive movement is painful, it may be that inert tissues are at fault. If resisted movement is painful, the contractile tissue may be at fault. Active movement stresses both inert and contractile tissue. As an example, if a patient has a biceps tendonitis (long head), then resisted flexion (isometric, mid-range) will provoke pain. Passive movement through the flexion range of motion should not provoke pain because the biceps is relaxed. Theoretically, after the specific tissue is identified, the therapist can provide the appropriate treatment.

To test a muscle and its components (e.g., a contractile tissue), the therapist uses an isometric force to an immobilized limb segment so that the joint does not move. The joint is held in mid-range to keep from compromising the inert tissue. No joint movement should occur to direct the tension on the contractile tissue. If a contractile lesion is present, the resisted movement may provoke pain or demonstrate weakness, occasionally both. Normal contractions are strong and painless.

Because of the inherent strength of a normal muscle, the therapist should stand in a position of maximum advantage with proper hand placement to exert the strongest possible force as appropriate. In addition, the following rules, similar to manual muscle testing, should be followed:

- Muscles must be tested in such a way that the therapist's and patient's strength are evenly matched.
- The therapist uses one hand for resistance, the other hand for stabilization.
- Muscles other than those being tested must not be included. Proper hand placement should help to isolate the muscle(s) (e.g., preventing supination when isolating the brachialis muscle).
- The joint that the muscles control must not move and should be held at near mid-range.
- The patient must be encouraged to try as hard as possible.

Only one study was found that has examined the reliability of the Cyriax selective tissue tension method.[22] In this small study of otherwise healthy individuals between the ages of 20 and 40 years, with either unilateral shoulder or knee pain of undiagnosed origin, intrarater reliability for the knee ranged from 0.74 to 0.82 and interrater reliability ranged from 0.42 to 0.46. Both intrarater and interrater reliability were highest for knee flexion. For the shoulder, intrarater reliability ranged from 0.44 to 0.67 and interrater reliability ranged from 0.00 to 0.45, with the highest values for shoulder abduction.[22] Nearly all the disagreements between therapists came from whether a contraction was painful or not. The authors concluded that intrarater reliability for the knee was acceptable, but for the shoulder it was not. Interrater reliability was not acceptable for either joint.

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