CHAPTER 3

TESTING OF MUSCLE STRENGTH, ENDURANCE AND FLEXIBILITY

OUTCOME OBJECTIVES

Following successful completion of this exercise, the student should be able to:

1. Define muscle strength, endurance, and flexibility, understand the reasons for testing these variables, and the bases for the tests performed.
2. Administer and interpret common tests of muscle strength, endurance, and flexibility.

INTRODUCTION

A very important part of whole body fitness is fitness of the musculoskeletal system. As we age, musculoskeletal fitness becomes increasingly important for acts of daily living (ACSM, 2014). Typically this fitness can be divided into three portions: muscular strength, muscular endurance, and muscle and joint flexibility. Muscular strength refers to the ability of a person to generate maximal force using a muscle or group of muscles. Muscular endurance emphasizes the ability to maintain repeated contractions or force generation for a prolonged period of time. This force can be generated without movement (isometric), or through a range of motion (variously referred to as isotonic, dynamic, concentric, or eccentric). Characteristic tests of muscle strength and endurance for specific muscle groups can be performed under either isometric or isotonic conditions with nearly equal ease. Isometric testing is often simpler conceptually and easier to quantify, but has the disadvantage of only testing muscle strength or endurance at one specific muscle length, while strength or endurance in the real world is needed through a range of lengths. Isotonic testing involves movement through a wide range of muscle lengths, so it may better mimic everyday activities. But to obtain maximal efforts sometimes requires more than one attempt, since the testing generally uses only one specific force during an individual effort. The tests to be described in this exercise will encompass certain aspects of both isometric and isotonic contraction of different muscle groups. We will not attempt to provide an exhaustive battery of tests for all muscle groups that can be tested. For that, the reader is referred to one of a number of testing books listed in the additional readings.

Muscle and joint flexibility encompasses elements within the muscle itself, in the connective tissue and tendon, and in the joint capsule and ligament. Therefore, flexibility may be decreased by muscle events such as spasms or tears, loss or damage of connective tissue or ligament elasticity, or by joint irregularities (Nieman, 2011). Flexibility can further be divided into static and dynamic flexibility (Fox, Bowers, and Foss, 1993). Static flexibility is the range of motion of a joint. This is what we typically think of as flexibility and can be measured easily with a goniometer at a joint or estimated by measurements

of stretching. Dynamic flexibility is the resistance to movement of a joint. This is difficult to measure and so has not been dealt with to a great extent. It may be important, however, in that if a joint has little dynamic flexibility, the joint is more difficult to open and close, and the muscles surrounding that joint have to do more work in order to create the movements desired. In this exercise, we will measure only static flexibility and will not concentrate on the measurement or estimation of dynamic flexibility.

All of the variables discussed here, with the possible exception of dynamic flexibility, are readily adaptable to training. While it is not the purpose of this manual to discuss training programs, improvements in strength, endurance, and flexibility of muscle groups and joints are readily apparent following appropriate training programs. Estimating this improvement is one aspect of training that is easily measured, and thus one of the principal reasons for the advent of muscle strength, endurance, and flexibility testing. The tests described in this chapter represent but a small portion of the tests devised for measuring muscle strength, endurance, and flexibility. The exercise is designed to provide instruction on how to perform several of the most widely used tests that are readily adapted to either the laboratory or the field.

MUSCLE STRENGTH TESTS

Any test of muscle strength needs to be one that is simple to perform, rather than requiring the subject to master a new skill. It also needs to be replicable because only a few efforts can be made prior to fatigue unless ample recovery is given. The three tests described here meet those requirements.

ISOMETRIC HANDGRIP TEST

This is one of the simplest and most common of the muscle strength tests available. It is widely used, so there are many reports with which to compare the data gathered. The reliability of the measurement is good, with reliability coefficients of 0.9 or higher (Beam and Adams, 2011), also making this a good test to compare training responses as well as population differences. This test has the disadvantage, as discussed earlier, of only testing the strength of the muscle group at one length, without movement. It is also specific to one, relatively small, muscle group. However, because of its widespread use, reliability and ease of use, the isometric handgrip test merits a description and demonstration. See Figure 3.1.

FIGURE 3.1 — Handgrip test.

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Equipment Needed

Handgrip dynamometer

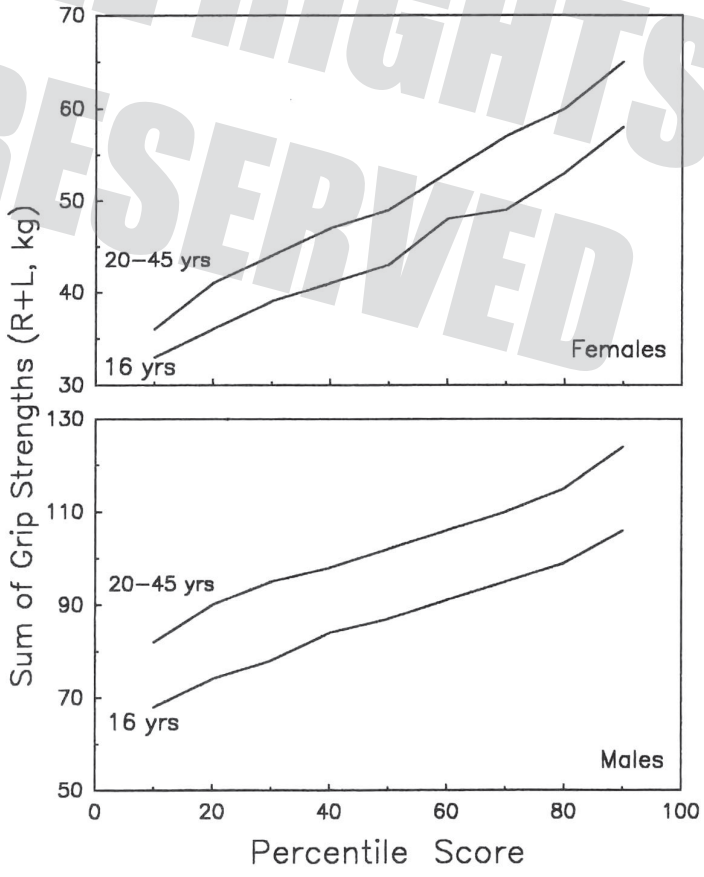
Scale with stadiometer to measure subject weight and height

TECHNIQUES AND PROCEDURES

1. Preparation for this test, as with many field type tests, simply consists of gathering the equipment and making sure that the handgrip dynamometer fits the hand of the subject. Adjust the size so that when the subject grips, the middle knuckle of the middle finger is bent to about 90°.
2. Measure the subject's body weight, age, height and gender, and record these numbers in the appropriate space on your data sheet.

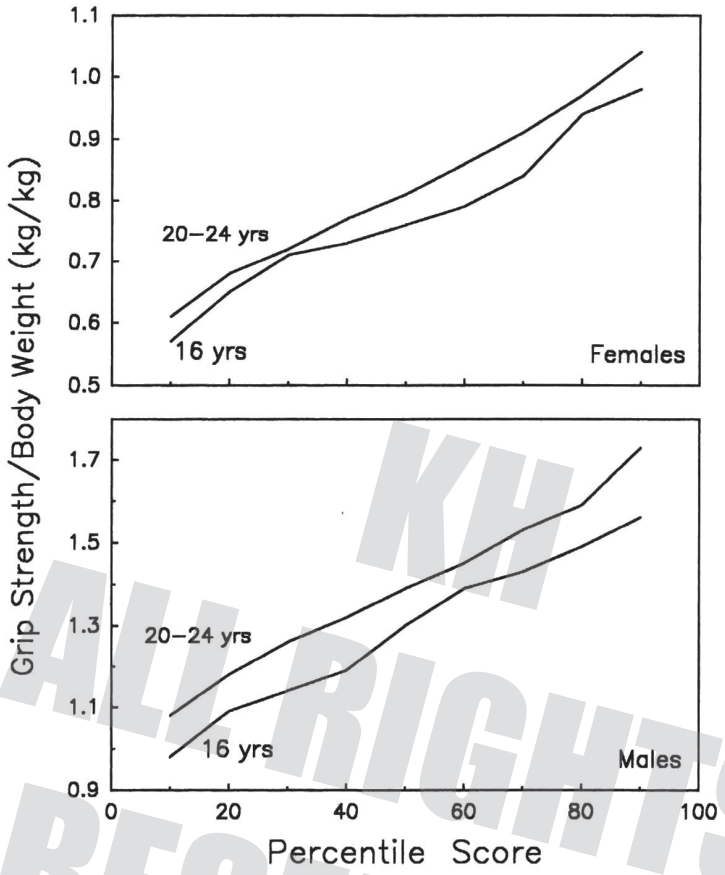
3. The subject may either stand, with the upper arm perpendicular to the floor, or sit with the forearm resting on a bench or table. Record the position from which the subject works so that you have a basis for comparison with other tests. If standing, the subject may also have the elbow bent to an angle of 90°.
4. Instruct the subject to exert a maximal handgrip. Record this number in your data sheet.
5. Repeat this procedure with the other hand until you have obtained at least three maximal handgrip efforts with each hand.
6. Add together the best effort from each hand and record this number. This is your raw score. If your dynamometer records force in pounds, divide the result by 2.2 to obtain the result in kilograms.
7. Divide the sum by the subject's body weight in kilograms. The result is the handgrip in kg of force per kg body weight. Record this number in your data sheet. Note here we use kg instead of the more proper SI unit for force, since values in the various references are in kg.
8. Compare the results to those in Figures 3.2 and 3.3 to find a percentile score. Record this number in your data sheet.

FIGURE 3.2 — Graph showing handgrip sum against percentile rank. To calculate your score, find the sum of handgrips (right + left) on the Y axis for your gender and age group, then draw a vertical line to the X axis and record the number. For other age groups, refer to the original study.



(From data by Montoye and Lamphiear, 1977)

FIGURE 3.3 — Graph showing the ranking for grip strength divided by body weight. Calculate the ranking as in Figure 3.1.



(From data by Montoye and Lamphiear, 1977).

MAXIMAL BENCH PRESS AND LEG PRESS

The bench press is an example of an isotonic muscle strength measurement. The bench press primarily tests the strength of the arms, chest, and shoulders. We will also employ the maximal leg press to assess lower body strength. Similar tests can be employed for other muscle groups if the same principles are applied to the testing protocol. To find some of these tests, the reader is referred to the additional readings. These tests are often referred to as one-repetition maximum, 1-rep max, or 1-RM tests. Since this test requires a maximal effort, the subject can seldom complete more than 3 to 5 lifts, and even then, ample rest is needed between efforts to ensure a successful test. Since this is a maximal test, care must be taken to prevent injury to the subject. See Figure 3.4.

Equipment Needed

Weight bench

Barbell and weights totaling at least 1.5 times the weight of the subject, or weight machine such as Universal Gym

Scale with stadiometer to measure subject height and weight

FIGURE 3.4 — Bench press in two positions.

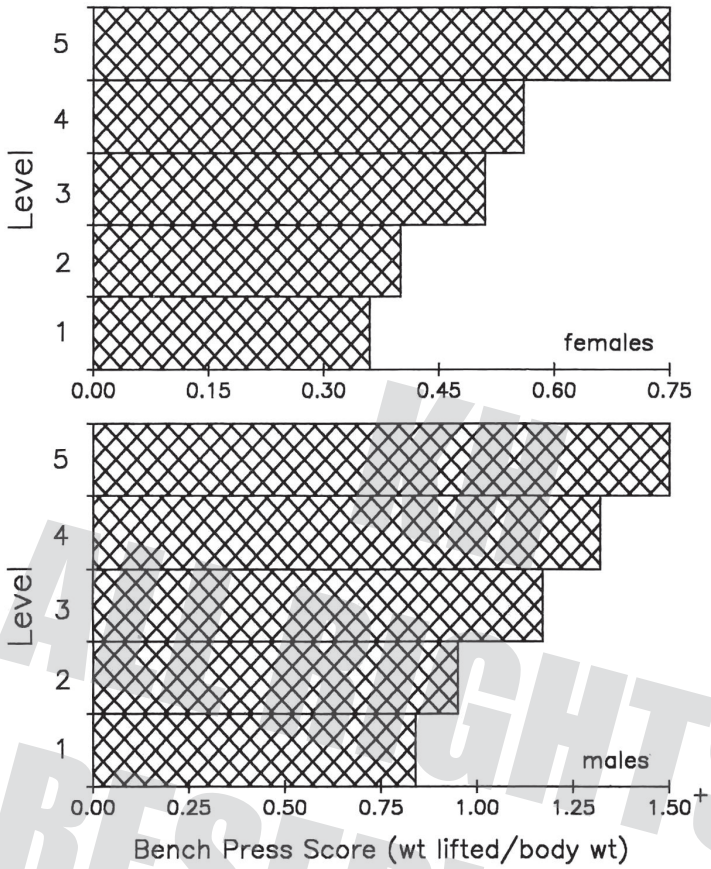
TECHNIQUES AND PROCEDURES FOR BENCH PRESS

1. Set up the test by putting weights on the bench or placing the bench at the weight machine.
2. Measure the subject's height and weight and record this in your worksheet.
3. Set the initial weight for the lift. Often the subject will know how much weight to place; however, if the subject does not know, a reasonable starting point is 40% to 60% of the body weight.
4. Instruct the subject to lift the weight. A successful lift is one that goes from a position with the bar at the level of the chest to one with the arms fully extended. If a barbell with weights is used rather than a weight machine, it is imperative that two assistants be present to "spot" at either end of the bar and prevent injury to the subject in the event of an unsuccessful lift.
5. Subsequent lifts will be lighter or heavier depending on whether the subject completed the previous lift. The amount of weight added or subtracted depends on the subjective impression of the subject's ease of completing the previous lift.
6. Record the weights successfully lifted. Do not have the subject try more than three to five attempts, as muscle fatigue will begin to be a factor in the subsequent attempts.
7. Divide the maximal weight lifted by the subject's body weight and record this number on your worksheet. Remember that body weight and the weight lifted must be in the same units e.g., Newtons, kilograms, or pounds.
8. Compare this number to Figure 3.5 for category ratings.

TECHNIQUES AND PROCEDURES FOR THE MAXIMAL LEG PRESS

1. This exercise should be done using a leg press machine. The maximal squat uses many of the same muscles, but is a lift requiring proper technique, and should not be employed for 1-RM tests unless the subject is proficient in the lift.
2. Set up the test by placing the leg press seat in the proper position according to the instructions for the machine and the size of the subject.

FIGURE 3.5 — Graph showing bench press categories for college-age males and females. To determine the ranking, find the maximal bench press/body wt on the X axis and draw a vertical line until it reaches a bar. This is the category ranking.



(Adapted from Johnson and Nelson, 1986, p. 113)

FIGURE 3.6 — Person performing a leg press showing both beginning and ending position.

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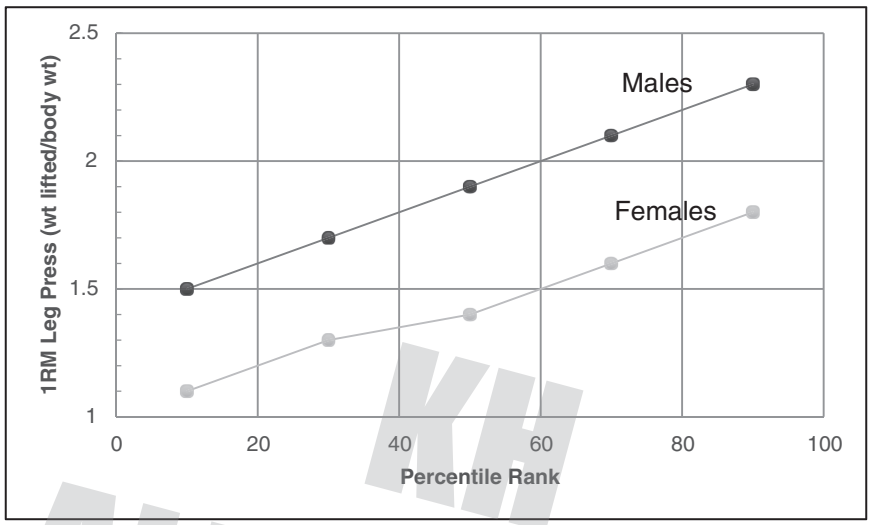
FIGURE 3.7 — Graph showing approximate percentile rankings for 20-29 year old males and females in the leg press. To find the ranking, use the maximal leg press weight/body weight on the Y axis. Extend the line horizontally to the appropriate graph line (male or female) and then extend a vertical line to the X axis to find the ranking. Based on data from ACSM, 2014. For other age groups see original data.



3. Record the subject's height and weight on your worksheet.
4. The initial weight for the lift should be set at approximately the body weight of the subject unless the subject knows an approximate weight with which to start.
5. Have the subject lift the weight, starting with the knees bent at about 90 degrees of flexion, until the legs are straightened at the knees, then let the weight down to the original position while maintaining control. This constitutes a successful lift.
6. Further lifts will be heavier or lighter depending on whether the subject completed the lift and the relative ease with which the lift was completed.
7. Record the weights successfully lifted. This should be completed in three to five attempts. To avoid fatigue, allow at least 3 minutes of recovery between attempts.
8. Divide the maximal weight lifted by the subject's body weight and record this in the data sheet. Make sure the lifted weight and the subject's weight are in the same units.
9. Compare this number to Figure 3.7 for category ratings.

MUSCULAR ENDURANCE TESTS

Tests for muscular endurance should not require a maximal effort on the part of the subject at the start of the test; this would place it in the category of a strength test. Instead, these should test the fatigability of a muscle or group of muscles. Most tests falling within this category require sustained efforts of one minute or less. However, they differ from the moderate term anaerobic capacity tests described in Chapter 2 in that they use a smaller group of muscles, thus eliminating most cardiovascular or other systemic input into the results of the test. As with the strength tests, these tests must be reproducible and reliable since they cannot be repeated even once without ample recovery. One other problem associated with muscular endurance tests is the motivation of the subjects. Since severe muscle fatigue comes into play in these tests it is important for the investigator to provide the same amount of encouragement to each subject and avoid the complications associated with extraneous motivational signals (Gettman, 1988).

FLEXED-LEG SIT-UPS

This is one of the few muscular endurance tests for which standards and rankings have been established for both males and females. Other tests are either standardized only for males or females (e.g., pull-ups or flexed arm hang) or are modified for testing males or females (e.g., push-ups or pull-ups) (Johnson and Nelson, 1986). For that reason the sit-up test will be described exclusively. This test assesses the endurance of the abdominal muscles and the hip flexors. Its use may be applicable to healthy lifestyle situations (in addition to strictly fitness assessment) because weak abdominal muscles are often associated with lower back pain in adults. See Figure 3.8.

Equipment Needed

Timer

Exercise mat

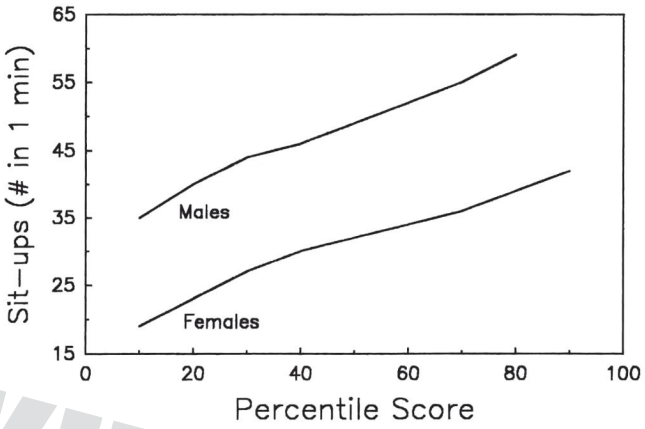
TECHNIQUES AND PROCEDURES

1. The site for testing can be any place with a flat surface. It is best to provide a mat on which the subject can lie or to perform the test in a grassy area. Sit-ups done on a hard surface can lead to abrasions or bruising.
2. Have the subject lie in the supine position with the knees bent so that the subject's heels are approximately 18 inches from the buttocks. The arms should be crossed in front of the chest with the hands on the opposite shoulders. Alternatively, the hands can be placed by the side of the head. They should not be clasped behind the neck to prevent possible injury.
3. A successful sit-up consists of rising from the supine to the seated position with the elbows touching the thighs. The investigator or an assistant may hold the subject's feet to the floor during the test. The subject must then return to the supine position with the back touching the floor.
4. Instruct the subject that he or she is to perform as many sit-ups as possible during a 1-minute period and that you will keep the subject informed as to the amount of time remaining.
5. From 5 seconds, count down the time and instruct the subject to begin doing sit-ups. Count each effort that meets the conditions set forth in number 3 above as one sit-up.
6. Each 15 seconds, inform the subject of the time remaining.

FIGURE 3.8 — Sit-ups in two positions.

7. At the end of the 1-minute period, tell the subject to stop. In the appropriate space in the worksheet, record the number of successful attempts performed during the test.
8. Compare the number of sit-ups performed with the graph in Figure 3.9 to characterize the fitness of the subject.

FIGURE 3.9 — Percentile rank for number of sit-ups for 17+ year old males and females. Calculate rankings as in figure 3.7.



(Adapted from Tables 2 and 8, AAHPER, 1975)

JOINT FLEXIBILITY TESTS

Flexibility is widely recognized as both an asset to athletic performance and to health (Mathews, 1978), although excess joint flexibility may be detrimental to certain types of performances, such as contact sports in which shoulder flexibility may increase the likelihood of injury (Powers and Howley, 2015). Greater flexibility has been associated with decreased pain on exertion and decreased muscle soreness, although a specific cause and effect relationship has yet to be determined. As with strength and endurance, muscle and joint flexibility is responsive to training.

SIT AND REACH TEST

This test evaluates the flexibility in the hips and lower back. It is also responsive to the tightness of the hamstring and shoulder muscle groups. The sit and reach test is easy to perform, is reliable, and assesses flexibility in a relatively large group of muscles and joints. For that reason it is widely used in fitness settings and exercise science laboratories, often as the sole measure of flexibility, and will be the exclusive test described here. Other tests that work effectively have been described for other joints or limbs. For these the reader is referred to the additional readings.

Equipment Needed

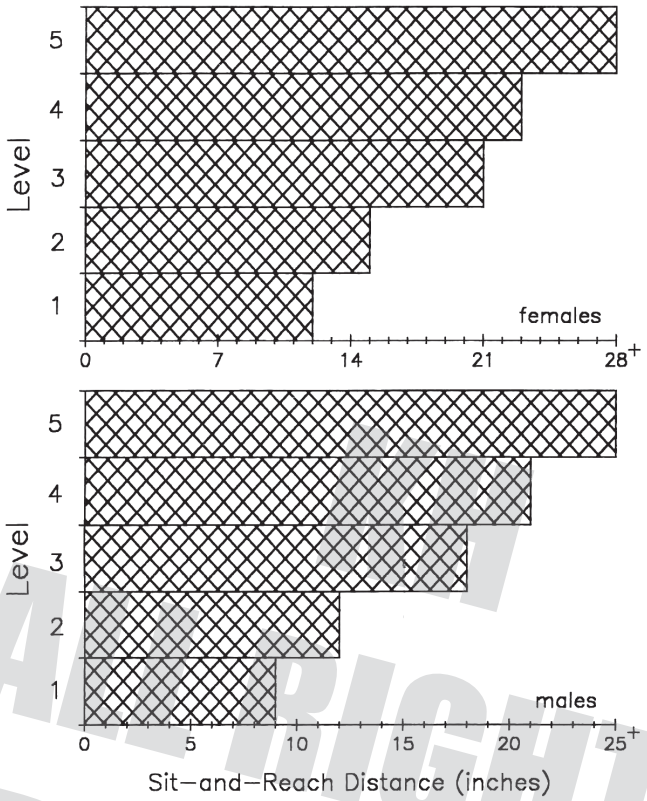
12-inch high box

Yardstick

TECHNIQUES AND PROCEDURES

1. The measurement device for the sit and reach test can be purchased ready made, or can be made by attaching a yardstick to a box. The box should be sturdy and approximately 12 inches in height. The yardstick is attached to the box so that the 15-inch mark is at the edge of the box and the lower numbers extend past the edge toward the subject.
2. The subject should be instructed and encouraged to participate in proper stretching and warm-up techniques prior to testing. These should include hamstring, back, and shoulder stretching.
3. To perform the test, have the subject seated with the legs extended so that the feet are placed flat against the edge of the box. The subject may either wear or not wear shoes. Since the heel height of most exercise shoes is rather small, any error induced will also be small.

FIGURE 3.10 — Category rankings for the sit and reach test for 20–29-year-old males and females. Calculate the ranking as in the bench press test.



(Adapted from Golding, Myers, and Sinning, 1982)

4. Have the subject then place the hands in front of the body with index fingers together and reach the farthest point possible on the yardstick. The number used is the farthest reach that the subject can hold for 1 second.
5. Allow three attempts. A successful attempt is one in which the subject's legs were kept straight and in contact with the floor, and in which the subject did not bounce to attain the best distance.
6. Record the three attempts. Compare the best attempt with the graph in Figure 3.10 to categorize the performance of the subject. Record the category in the appropriate space in the worksheet.

QUESTIONS AND ACTIVITIES

1. Make a table of subjects' age, gender and performance in each of the assessments made.
2. Rank yourself as well as the average male group and average female group in the class on each of the tests administered using the percentile scores or rank levels.
3. What is the difference between muscle strength and endurance? Could we reliably measure muscle endurance in a one-repetition test, or muscle strength from a test that took 1 minute?
4. What are the advantages and disadvantages of isometric and dynamic means of testing muscle strength or endurance?
5. Why should bouncing not be allowed in the flexibility tests?
6. Is there a difference between males and females in your group? Can you suggest a reason why?

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MUSCLE STRENGTH, ENDURANCE AND FLEXIBILITY WORKSHEET

Subject name: _____ Age: _____ Sex: _____

Height: _____ Weight: _____

Muscle Strength

Handgrip

Right Hand Trial 1: _____ Trial 2: _____ Trial 3: _____ Trial 4: _____

Left Hand Trial 1: _____ Trial 2: _____ Trial 3: _____ Trial 4: _____

Best Attempt

Right Hand:_____ Left Hand: _____ Sum (Rt + Lft): _____ Sum/Body Wt: _____

Percentile

Sum: _____ Sum/Body Wt: _____

Bench Press

Trial 1: _____ Trial 2: _____ Trial 3: _____ Trial 4: _____ Trial 5: _____

Best Attempt

Total Wt: _____ Total Wt/Body Wt: _____ Category: _____

Leg Press

Trial 1: _____ Trial 2: _____ Trial 3: _____ Trial 4: _____ Trial 5: _____

Best Attempt

Total Wt: _____ Total Wt/Body Wt: _____ Category: _____

Muscle Endurance

Flexed-leg Sit-ups

Number of sit-ups in one minute: _____ Percentile Rank: _____

Flexibility

Sit and Reach Test

Trial 1: _____ Trial 2: _____ Trial 3: _____

Best Attempt

Distance: _____ Category Rank: _____