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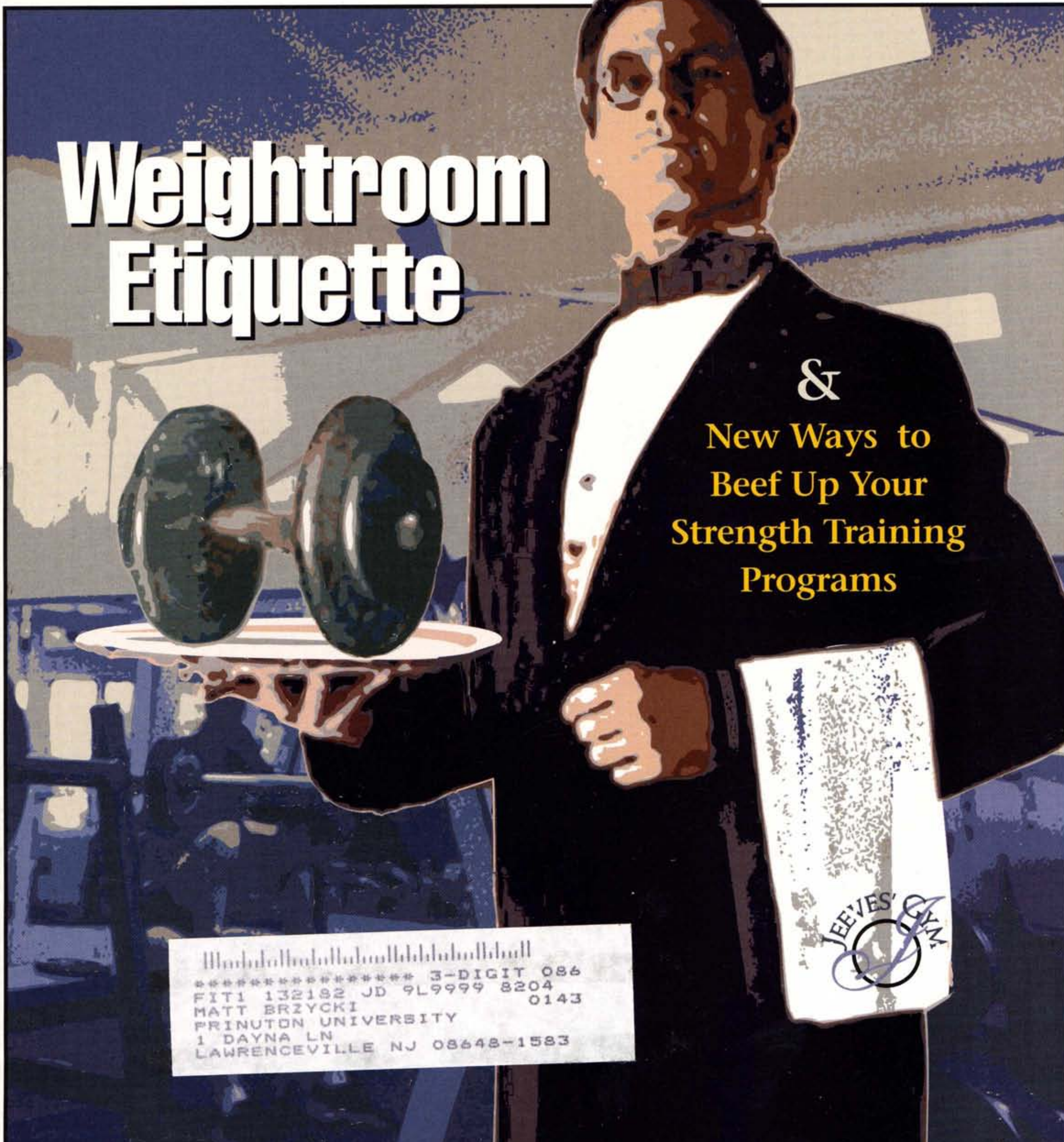

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Assessing Strength

You can assess muscular strength in a safe, efficient manner by using formulas that do not require clients to attempt maximum lifts.

By Matt Brzycki

STRENGTH TESTS ARE used for a variety of populations, from professional athletes to recreational fitness enthusiasts. The main reasons for performing strength tests are to evaluate initial strength levels and to assess changes in strength. Regardless of the reason for testing muscular strength, trainers and other staff need to perform testing in a safe, efficient manner. Examined here are some traditional forms of strength testing, as well as some alternate ways to test to ensure accuracy and the test's safety.

The history of strength assessments

Strength tests and measurements began in the U.S. around 1860. At that time, the major focus was on anthropometric measurements, such as size and symmetry. Around 1880, physical testing shifted from anatomical proportions to muscular strength. Then, in the 1920s, new and more scientific test methods were developed, and statistical techniques for data analysis became available. Through the years, a few specific types of strength tests have become the most popular.

Traditional 1-RM testing requires skill, proper warm-up, instruction, supervision and practice.

Traditional test methods

Two basic types of strength tests have evolved: static and dynamic. In a static (or isometric) test, a muscle exerts tension against a fixed, nonmoving resistance. In a dynamic (or isotonic) test, one or more body parts moves against a resistance.

Strength testing has gradually become more sophisticated. Now tests can be conducted in a formal, scientific setting — such as a laboratory or sports medicine facility — with equipment ranging from relatively simple dynamometers and tensiometers to more elaborate isokinetic and motor-driven testing devices. Some equipment can even provide both static and dynamic tests that measure strength at different joint angles over a full range of motion, and then plot a "strength curve" with an incredible degree of accuracy. Unfortunately, such scientific testing can be expensive and involves a considerable amount of time. In addition, sophisticated scientific tests are usually not practical to assess a large number of individuals.

Fortunately, there is a more convenient way to assess muscular strength without the drawbacks of elaborate scientific testing. Since these easier assessments are performed outside of a formal scientific setting, they are referred to as "field tests." Field tests represent simple, convenient, easy-to-administer methods of measurement that require a minimum amount of time, cost and equipment. For these reasons, many strength and fitness professionals rely on field tests to assess muscular strength.

The most popular (and traditional) way to assess dynamic strength is to determine how much weight an individual can lift for one repetition. A one-repetition maximum (1-RM) is usually performed using three or four exercises that are representative of the body's major muscle groups. For example, a bench press or an incline press is typically used to assess the strength of the chest, shoulders and triceps, while a squat or a leg press is often used to measure the strength of the hips and legs.

Traditional 1-RM testing

The traditional way to test strength using a 1-RM raises a number of concerns. One reservation is that performing a 1-RM is a highly specialized skill, requiring proper warm-up, instruction, supervision and practice.[1] In addition, traditional 1-RM testing can be time-consuming, due to the number of warm-up sets that are required to prepare for the maximal attempt. These problems are magnified when evaluating a large group of people.[1,2]

Another concern with traditional 1-RM testing is an increased risk of musculoskeletal injury.[1,2,3,4] Attempting a 1-RM with a maximal or near-maximal weight can place an inordinate amount of stress on muscles, bones and connective tissues. Injuries occur when the stress exceeds the tensile strength of these structural components. The concern for safety increases when testing certain populations, such

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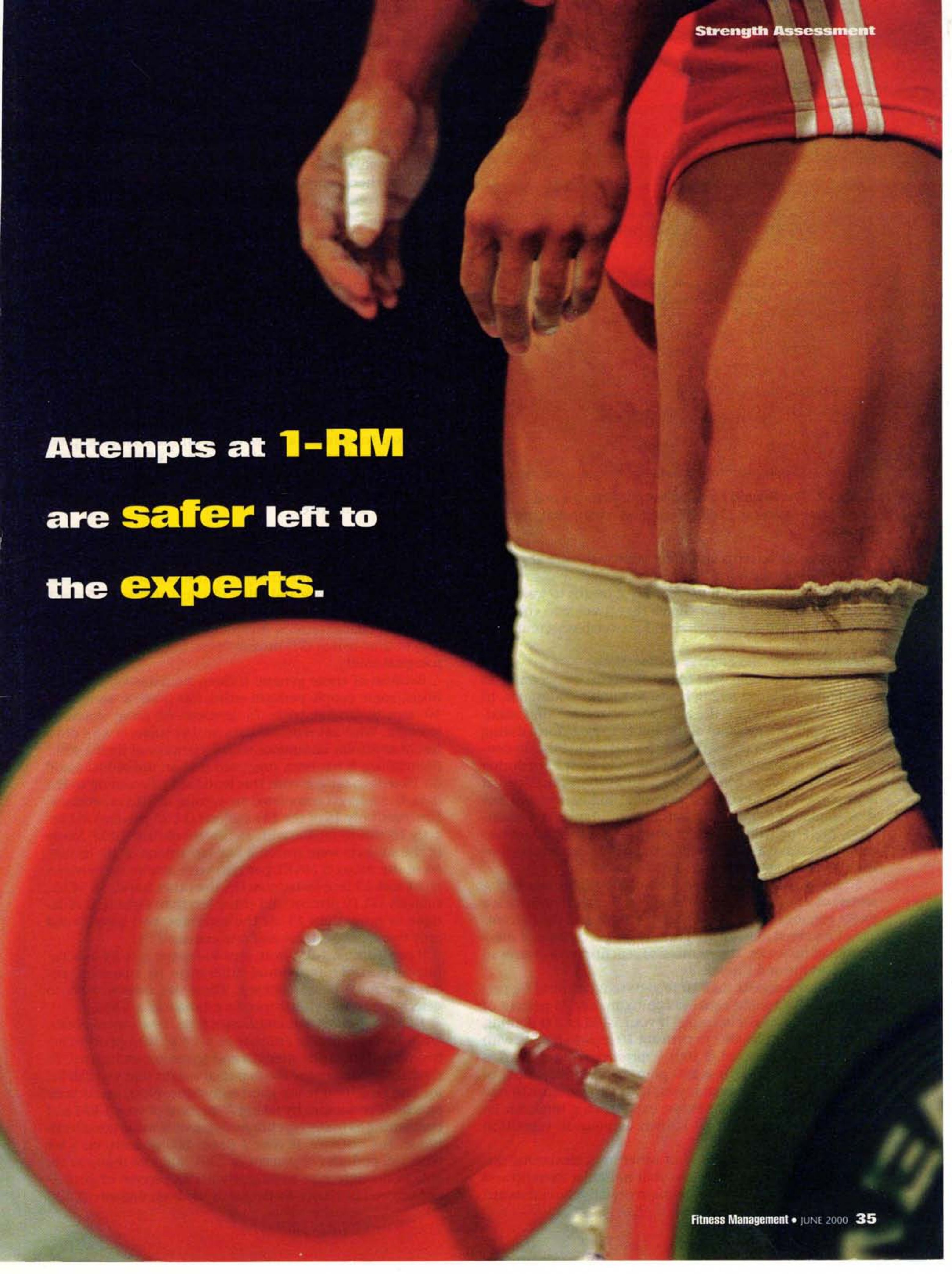

Attempts at 1-RM are safer left to the experts.

$$\text{PREDICTED 1-RM} = \frac{(X_1 - X_2)}{(Y_2 - Y_1)} \times (Y_1 - 1) + X_1$$

where X_1 = the heavier weight
X_2 = the lighter weight
Y_1 = the repetitions performed with the heavier weight
Y_2 = the repetitions performed with the lighter weight

Example

Suppose that an individual performs two sets to muscle fatigue: 5x165 and 10x135. Inserting these numbers into the equation would yield:

$X_1 = 165$
$X_2 = 135$
$Y_1 = 5$
$Y_2 = 10$

PREDICTED 1-RM =

$$\frac{(165 - 135)}{(10 - 5)} \times (5 - 1) + 165 = \frac{30}{5} \times 4 + 165 =$$

$24 + 165 = 189$

Figure 1. The Brzycki Formula for predicting a one-repetition maximum (1-RM) based on reps-to-fatigue in two sets.

as younger adolescents and older adults who are at greater risk for orthopedic injury.[1]

Fitness professionals must identify a means to assess the muscular strength of their clients that is safe and efficient, but also inexpensive, practical and reasonably accurate.

Strength and anaerobic endurance

To discuss alternate ways to test strength, it's necessary to distinguish between strength and anaerobic endurance. In basic terms, strength is the ability to exert force, and maximal strength is a measure of the ability to exert force during a single muscular contraction with a maximal load. In contrast, anaerobic endurance is the ability to exert force during successive muscular contractions with a submaximal load. It is important not to confuse anaerobic endurance with cardiovascular endurance. Anaerobic endurance is a short-term, high-intensity muscular effort — less than about two minutes; cardiovascular endurance involves muscular effort for a much longer duration.

Strength and anaerobic endurance are highly related.[4] A review of strength-training literature indicates that there is a direct relationship between reps-to-fatigue and the percentage of maximal load (or weight): As the percentage of maximal load increases, the number of repetitions decreases in an almost linear fashion.[5]

Data also suggests that 10 reps-to-fatigue could be performed with a weight equal to approximately 75 percent of a maximal load.[5] For example, if your 1-RM is 200 pounds, then you should be able to perform 10 reps-to-fatigue with 150 pounds (75 percent of 200). Expressed in other terms, if your maximal strength is 200 pounds, then a measure of your anaerobic endurance is your ability to perform 10 repetitions with 150 pounds before experiencing muscular fatigue. This would also be known as your 10-repetition maximum (10-RM).

Unless you have an injury or other musculoskeletal disorder, the relationship between your muscular strength and your anaerobic endurance remains relatively constant.[4] Therefore, regardless of whether your strength increases or decreases, you should always be able to perform the same number of repetitions with a given percentage of your 1-RM. This also suggests that if you improve your 1-RM by 20 percent, then your 10-RM should also improve by 20 percent. Conversely, if you increase your anaerobic endurance, then you also increase your muscular strength. So, if you improve your 10-RM by 20 percent, then your 1-RM should also improve by 20 percent. Keep in mind, however, that the actual improvement in a 1-RM may be less if you haven't practiced the requisite skill in performing a 1-RM.

Implications for testing. Since there is a direct relationship between anaerobic endurance and strength, you can determine anaerobic endurance by measuring strength, and determine strength by measuring anaerobic endurance. Though it doesn't directly measure pure maximal strength, testing anaerobic endurance is much safer than attempting a 1-RM because it involves submaximal loads.

A number of prediction equations have been developed and used to estimate a 1-RM based on the relationship between strength and anaerobic endurance. While some of the equations have proven to be reasonably accurate, one problem with them is that they do not take into consideration individual differences.[2,3]

Genetic influences on testing

Each individual inherits a different potential for improving muscular size and strength, cardiovascular endurance, anaerobic endurance and other physical attributes. Indeed, a person's physical profile is largely determined by several inherited characteristics, including the ratio of fast-twitch (FT) to slow-twitch (ST) muscle fibers, limb length and neurological ability.

Because of these genetic influences, especially muscle fibers, some people perform either less than or more than 10 reps-to-fatigue with 75 percent of their maximal strength. Westcott reported data on 141 subjects who did a test of anaerobic endurance with 75 percent of their 1-RM.[6] (Remember, it has been suggested that an individual could do 10 reps-to-fatigue with this workload.) According to the data, the subjects completed an average of 10.5 repetitions. However, only 16 of the 141 subjects (11.35 percent) did exactly 10 reps-to-fatigue with 75 percent of their 1-RM. Many of the subjects were within a few repetitions of 10. In fact, 66 of the subjects (46.81 percent) were able to do between eight and 13 reps-to-fatigue. On the other hand, 75 of the subjects (53.19 percent) did either less than eight reps-to-fatigue or more than 13. At the extremes, two subjects did only five reps-to-fatigue and one managed 24.

If predicting a 1-RM from reps-to-fatigue is to be as accurate as possible, individual differences in anaerobic endurance must be considered. There are several ways to determine an individual-specific estimate of a 1-RM.

1-RM and anaerobic endurance tests. One way to obtain an individual-specific estimate of a 1-RM is to perform actual tests of muscular strength and anaerobic endurance. To do this, first determine the maximal weight that you can lift for one repetition using good technique. Next, assess your anaerobic endurance by taking 75 percent of your 1-RM and performing as many repetitions as possible using good technique. For instance, if your 1-RM is 200 pounds, do a set with 150 pounds (75 percent of 200). Suppose that you are able to do eight reps-to-fatigue with 75 percent of your 1-RM (instead of 10 reps-to-fatigue as has been suggested). You have just established an individual-specific relationship between your strength and anaerobic endurance based upon your inherited characteristics. More specifically, you now know that you can do eight reps-to-fatigue with 75 percent of your 1-RM. In the future, you can estimate your 1-RM based upon your inherited characteristics by dividing the most weight you can lift for eight repetitions by 0.75.

A two-set prediction equation. Another approach to attain an individual-specific estimate of a 1-RM is to use a prediction equation. The most frequently used prediction equations are based on the reps-to-fatigue done in one set.[2,3] However, a test using one set does not account for individual differences in anaerobic endurance. A better way to assess muscular strength from anaerobic endurance is to use a prediction equation that is based on the reps-to-fatigue obtained in two sets. A two-set prediction equation is shown in Figure 1.

To illustrate the equation, guesstimate a weight that will allow you to reach muscular fatigue in approximately four or five repetitions. On a later date, guesstimate a weight that will allow you to reach muscular fatigue in approximately nine or 10 repetitions. It doesn't really matter how many repetitions you do in the two sets, as long as you do not exceed 10. Now, suppose that you did five reps with 165 pounds in the first set and 10 reps with 135 pounds in the subsequent set. Inserting these values into the equation yields an individual-specific predicted 1-RM of 189 pounds.

1-RM graphing method. A final way to make an individual-specific estimate of a 1-RM is to use a graph and plot the reps-to-fatigue obtained in two sets. On a sheet of graph paper, draw a vertical line down the left-hand side of the page. Starting at the bottom of this vertical line, draw a horizontal line across the page. Label the vertical line "weight" and mark off five- or 10-pound increments; label the horizontal line "reps-to-fatigue" and mark off 10 increments, numbering them from one to 10. The intervals between the numbers on both lines must be equidistant.

Once the graph is set up, perform two sets with the same guidelines as previously stated. On the graph, plot the weight that you used and the number of reps-to-fatigue that you did in both sets. Using a ruler, connect these two points and extend this line to the left until it intersects the vertical line that designates one repetition. This extrapolation is an individual-specific estimate of your 1-RM.

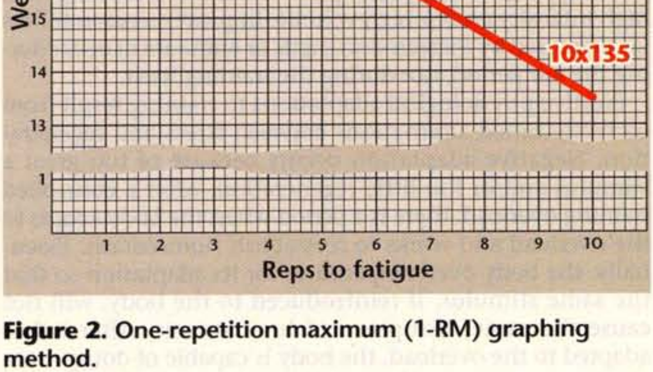

Figure 2. One-repetition maximum (1-RM) graphing method.

An application of the graphing method appears in Figure 2. In this instance, consider again that you did 5 reps with 165 pounds and 10 reps with 135 pounds. When these two points are plotted on the graph and the line is extrapolated to the left, it yields a predicted 1-RM of 189 pounds — the same maximum that was estimated by the two-set prediction equation.

Implications for training

There is not currently any consensus on the percentage of maximal weight that is necessary to stimulate optimal gains in strength. For the moment, however, imagine that it is 75 percent. According to the study by Westcott, this workload appears to allow an average of about 10 reps-to-fatigue.[6] Recall, though, that his data also showed that many individuals can do either less than or more than 10 reps-to-fatigue. These individual differences in anaerobic endurance suggest the need to customize repetition ranges to maximize the response to strength training. For example, those who cannot do more than 10 reps-to-fatigue with 75 percent of their 1-RM have a relatively low level of anaerobic endurance (and likely a high percentage of fast-twitch muscle fibers). These individuals would benefit more by training with slightly lower repetition ranges. Conversely, those who can do more than 10 reps-to-fatigue with 75 percent of their 1-RM have a relatively high level of anaerobic endurance (and likely a high percentage of slow-twitch muscle fibers). These individuals would benefit more by training with slightly higher repetition ranges. This is not to say that 75 percent is the optimal workload for stimulating increases in strength. The use of 75 percent of a 1-RM is only to illustrate the point about the need for individualized repetition ranges.

There are also implications for pre-planned or "periodized" workouts that demand specific numbers of repetitions with certain percentages of a 1-RM. For instance, a workout might require individuals to perform 10 repetitions with 75 percent of their 1-RM. Because of wide variations in anaerobic endurance, however, such a prescription might be far too easy for some and literally impossible for others. Therefore, pre-planned workout schedules that stipulate the same number of repetitions with a specific percentage of maximal load for everyone may be minimally effective, except for the segment of the population who have a particular level of anaerobic endurance that corresponds exactly to the specifications and parameters of the training prescription. **FM**

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