Training College-Age Women to Perform the Pull-Up Exercise

S. P. Flanagan, P. M. Vanderburgh, S. G. Borchers, and C. D. Kohstall

The purpose of this investigation was to determine the effect of a combined strength and aerobic conditioning program on the ability of college-age women to perform the pull-up exercise and to identify the characteristics of women successful in performing a pull-up at the end of the program. Participants significantly increased upper body strength and fat-free mass and decreased fat mass and percentage of body fat. Participants successful at performing a pull-up had significantly greater 1 repetition maximum strength, strength to mass ratio, and strength to fat-free mass ratio. A two variable equation (% body fat and strength to fat-free mass ratio) was developed to predict which women would be successful at completing a pull-up at the end of a similar training program.

Key words: body composition, periodization, prediction, strength training

The pull-up is a widely used test for measuring the strength and endurance of the arm and shoulder girdle. The pull-up has been deemed a reliable test (test-retest reliability, \( r = .82 \); Engleman & Morrow, 1991) and requires minimal skill and equipment to perform. Additionally, the need to lift one’s body mass is obvious in certain occupational settings, such as law enforcement, military, and fire fighting, and correlates well to certain physical performance measures, listed below.

Davis, Dotson, and Santa Maria (1982) found that chin-ups were a major predictor of physical work capacity in fire fighters on performance tasks such as the ladder extension, standpipe carry, hose pull, simulated rescue, and simulated forcible entry. Willford, Ducy, Olson, Howard, and Wang (1999) found that climbing, pushing, pulling, lifting, and chopping were critical to job importance and that the ability to perform pull-ups was significantly correlated to these tasks. Additionally, they found the following performance tasks were significantly correlated with the ability to perform pull-ups: forcible entry, hoist, hose advance, victim rescue, stair climb, and total time to perform all these tasks in a circuit fashion (physical performance assessment). Of all the fitness parameters tested, the model with the best ability to predict the time to complete the physical performance assessment included pull-ups, a 1.5-mile run, and fat-free weight \( (r = .73, M = 303.54 \text{ s}, SE = 96.19 \text{ s}) \). Therefore, it is reasonable to conclude that not only is the pull-up a reliable test, it is also valid for occupations that require one to manipulate his or her own body weight.

A potential problem arises, however, if the pull-up test is administered to women in law enforcement, fire fighting, and the military. The pull-up has not been recommended when testing women (Baumgartner, 1978; Baumgartner & Jackson, 1991; Cotten & Marwitz, 1969) because of the assumption that most are unable to accomplish one repetition. Since the 1970s, the United States Marine Corps has required men to perform the pull-up/chin-up and women to perform the flexed arm hang based on this belief. Attempts by the Marine Corps to investigate
use of the pull-up for women as part of its physical fitness test failed, because too few were able to execute even one repetition. Other organizations, such as the Chrysler-AAU Physical Fitness Program, also substitute the flexed arm hang for pull-ups when testing women (Baumgartner & Jackson, 1991; Safrit & Wood, 1995).

In accounting for what appears to be women’s inability to execute one pull-up, at least two factors must be considered. The first is that, in general, women do not have the upper body strength of men. In a review of the literature, Laubach (1976) found that women had an average mean percentage difference in absolute measures of dynamic upper body strength that was 55.8% (range, 35–79%) of men. When comparisons are made across gender with respect to body mass and lean body mass, the differences in strength between men and women narrow (Holloway, 1994; Ricci, Figura, Felici, & Marchetti, 1988).

The pull-up requires one to move his or her body weight against the force of gravity, and, thus, there is a negative correlation between this test and body weight (Baumgartner & Jackson, 1991; Safrit & Wood, 1995). However, Vanderburgh and Edmonds (1997) reported that, for the pull-up in men, experimental alterations in excess body weight (simulating body fat) greatly altered one’s ability to execute a pull-up, suggesting that body fat, more than total body weight, affects the ability to perform the pull-up. Because it is generally accepted that women, on average, have a higher percentage of body fat than men (Heyward & Stolarczyk, 1996), which could exacerbate a woman’s inability to do pull-ups, it should be considered a second factor.

It is unclear if other differences between men and women can account for the traditional belief in the inability of women to perform a pull-up. According to Gray’s Anatomy, “the female clavicle is generally shorter, thinner, less curved, and smoother than the male” (Gray, 1977, p. 137). Because heavy contractions of the muscles attached to the clavicle will make it thicker, rougher, and more curved (Gray, 1977), it is unknown whether these differences are more the outcome of society relegating women to less active roles with regard to upper body usage or training than they are anatomical. In other words, the increased muscle mass of the upper body in men could account for this difference in internal architecture. Additionally, Hoppenfeld (1976) reported that the valgus angle at the elbow is greater in women (10–15° in women as opposed to 5° in men) but did not discussed whether this increased angle impacts on the ability to generate force in forearm flexion. Irrespective of these differences, Ricci et al. (1988) found no difference between electromyographic signals and biomechanical aspects of pull-up performance between men and women.

Using the above data and anecdotal information (female rock climbers can perform several repetitions of pull-ups), one could reasonably argue that a woman could perform a pull-up, provided she had adequate training and conditioning, sufficient upper body strength, and an acceptable level of body fat. Not presently known is the quantification of these qualities for women who can successfully execute one pull-up. Furthermore, while women have been shown to have similar relative gains in strength as men (Wilmore, 1974), the effect of a periodized strength training program on the ability of the average college-aged woman (which is the same age as those entering law enforcement, fire fighting, and the military) to perform a pull-up is unclear.

The purpose of this investigation was threefold. First, we wanted to quantify the effect of a combined strength and aerobic conditioning program on the upper body strength and body composition of college-age women. Second, we wished to determine if these changes would lead to an increase in the number of women who could successfully perform at least one pull-up. Finally, we desired to perform a retrospective analysis of common pretraining strength and body composition measures to identify the variables to predict which women would successfully complete at least one pull-up at the end of the training period. These variables could be useful in helping administrators establish minimum standards for women entering training programs for occupations that require them to complete a pull-up successfully.

Method

Participants

The participants were 20 female college students (M age = 20 years, SD = .82) recruited from a residential private university student population. None of the participants were collegiate athletes, and their activity level ranged from sedentary to very active. We felt that this sample was representative of the larger population of young women who would enter occupations such as the military or law enforcement. All were fully informed of the procedures and signed a consent form prior to participation in accordance with institutional review board procedures. Participants were enrolled in a strength training activity class and were monetarily compensated for successful participation of the study. Participants had to complete 33 of the 36 training days to be included in the results of the study. One withdrew before completion due to injury unrelated to the study.

Training

We also wished to design a training program that could be used by certain organizations in their entrance-level training programs. Therefore, we designed our
training program with certain delimitations. These delimitations resulted in a program that: (a) combined strength and aerobic endurance training, (b) was conducive to mass training (little to no individualization for the different participants), (c) was a whole body workout and not just a workout to improve pull-ups, and (d) was performed within a limited amount of time (three sessions per week, each lasting 50 min). These delimitations were considered to mimic a training program for law enforcement, military, or fire fighters.

**Strength Training.** The strength training component was a periodized strength training program as proposed by Bompa (1996a, 1996b). Participants performed sets with the loads designated below and performed repetitions until they could no longer execute the movement with proper form.

(a) Weeks 1–2—Testing and Teaching Phases: These 2 weeks were used to perform the initial testing, ensure that the participants were familiar with all the exercises, and establish a training load for each exercise.

(b) Weeks 3–7—Anatomical Adaptation Phase: This phase was designed to prepare the participants for the higher loads in the strength phase (Bompa, 1996a). Additionally, the volume was high during this phase, because the volume of work may be a primary factor in maximum strength gains during the initial weeks of a resistance training program (Kramer et al., 1997). Participants performed the following exercises for three sets of 9–12 repetitions: pull-up trainer, bench press, squat, hammer (forearm in the neutral position) curls, and abdominal crunches. They performed all exercises on Mondays, Wednesdays, and Fridays.

(c) Weeks 8–12—Strength Phase (see Table 1): After the initial training phase, intensity has been shown to have a greater effect on the rate of maximum strength gain than volume (Kramer et al., 1997). Therefore, the intensity of the load on all exercises was increased during this phase. Additionally, variation of the load has been shown to elicit greater gains than loads that were not varied over the course of a mesocycle (Kramer et al., 1997; Stone, O'Bryant, & Garhammer, 1981).

Participants performed all exercises for the assigned number of sets. Note that loads were assigned based on repetition maximums (RMs) and not from a percentage of a 1-RM (Poliquin, 1988). For instance, if a RM of 3–6 was assigned for a week, the participants lifted a load in which they could perform at least 3 and no more than 6 repetitions. They performed primary exercises on Mondays and Fridays and performed assistive exercises on Wednesdays. Participants did not vary the assistive exercises in intensity and performed three sets of 8–10 repetitions.

**Aerobic Component.** Because fat mass has been shown to have a proportionately large and negative effect on the ability to perform the pull-up (Vanderburgh & Edmonds, 1997), we wished to decrease body fat by including an aerobic component to the program. Although a concurrent strength and aerobic endurance program has been shown to hamper improvements in strength and power (Bell, Syrotuik, Socha, MacLean, & Quinney, 1997; Dudley & Djamil, 1985), we hoped a decrease in fat mass would offset any decrements in strength improvements. Additionally, most entry-level training programs include an aerobic component. This program consisted of running or jogging between 1–1.5 miles each training day. Because we were only interested in the effect that jogging or running would have on body composition, we chose not determine its effect on aerobic fitness measures (such as maximal oxygen uptake).

<table>
<thead>
<tr>
<th>Training days</th>
<th>Exercises</th>
<th>8</th>
<th>9</th>
<th>Week 10</th>
<th>11</th>
<th>12</th>
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<tbody>
<tr>
<td>Monday &amp; Friday</td>
<td>Pull-up trainer</td>
<td>4 sets</td>
<td>4 sets</td>
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<td></td>
<td>Dumbbell bench press</td>
<td>6–9 RM</td>
<td>3–6 RM</td>
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<td></td>
<td>Squat</td>
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<tr>
<td>Wednesday</td>
<td>Upright row</td>
<td>3 sets</td>
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<td></td>
<td>Hamstring curls</td>
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<td>Hammer curls</td>
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<td>Super gripper</td>
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<td>Crunches</td>
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*Note. RM = repetition maximum.*
Testing

Testing was completed both prior to training and at the completion of 12 weeks of training. The percentage of body fat, fat mass, and fat-free mass was determined from the sum of skinfolds using the three-sided equation developed by Jackson, Pollock, and Ward (1980). For the triceps skinfold, a vertical fold was measured on the middle of the triceps midway between the acromial and olecranon processes. A diagonal fold was measured above the iliac crest along the anterior axillary line for the suprailiac skinfold. For the thigh skinfold, a vertical fold was measured on the anterior aspect of the thigh midway between the inguinal crease and the apex of the patella. An experienced investigator made three measurements at each site using Lange calipers (Cambridge Scientific Industries, Cambridge, MD). The average of the three measurements at each site was used for the equation.

Pull-ups were tested using a pronated grip with both hands. Although this is considered more difficult than the chin-up version performed with a supinated grip (Luttgenes & Hamilton, 1997), this investigation deemed the pull-up to be more occupationally relevant. After a warm-up, participants attempted to perform as many pull-ups as possible. To be considered successful, a participant had to raise his chin above the bar from a still-hang position without the assistance of body sway. Participants were encouraged to perform as many pull-ups as possible. If a participant was close to completing a pull-up, she was encouraged to repeat the test after a self-selected rest period.

Equipment

Most equipment used in this study consisted of free weights common to most gyms and fitness centers. However, two pieces of equipment were not. The Pull-Up Trainer® (Mini-Gym, Inc., Cleveland, OH) was used both as a training and a testing device. The Pull-Up Trainer® mimics the pull-up exercise but requires participant to lift themselves plus a sled on a guided track that can be adjusted to different angles. The Pull-Up Trainer® allowed participants to lift less than their body mass by adjusting the angle at which they performed the pull exercise. The greatest angle at which the participant could lift her own body mass was recorded and used to calculate the 1-RM on the Pull-Up Trainer® (1-RM PT) using the following equation: 1-RM PT (kg) = sin θ (body mass (kg) + mass of the sled (kg)). The mass of the sled was 25 lb (11.33 kg). If a woman’s mass was 62.36 kg, her mass plus the mass of the sled was 73.69 kg. If the angle of the sled was 30°, her 1-RM PT would be 36.85 kg. This method of evaluating 1-RM strength was favored over a pull-down exercise, because it is a closed-chain kinetic movement similar to the pull-up and is easy to quantify. The 1RM PT was tested pre- (Week 0), mid- (Week 7), and posttraining (Week 13).

We also wanted to improve our participants’ grip strength. Grip strength was trained using the Super Gripper (Ironman Products, Oxnard, CA). This device allowed for a wide range of resistances to be set in small increments and, therefore, the application of progressive overload that most other devices do not.

Statistical Analysis

All statistical analyses were conducted using the Statistica® software package, Dependent t tests (pre- and posttesting) were conducted on body composition measures. A 1-RM PT was analyzed with a one-way analysis of variance (ANOVA) using repeated measures. Significant differences were determined with Scheffe post hoc analysis. Independent t tests were performed retroactively at the completion of the training program on all of the initial testing variables between the women who were successful at completing a pull-up and those who were not.

Additionally, discriminant analysis was used to predict the women who would or would not successfully complete at least one pull-up by the end of this program (Gross Portney, & Watkins, 1993). This prediction was based on initial testing variables, which were then used to develop an equation to identify the physical characteristics of the woman who would be successful in a program similar to the one in the study. Alpha levels below .05 were chosen to be significant.

Results

Upper Body Strength

Participants significantly, F(2, 36) = 128.51, p < .001, increased upper body strength as measured by a 1-RM on the Pull-Up Trainer® from 40.66 (± 7.68) kg to 55.28 (± 8.46) kg, representing a mean increase of 35.95%. Repeated measures ANOVA with a Scheffe post hoc analysis revealed significant differences pre- to midtest (p < .0001), mid- to posttest (p = .0002), and pre- to posttest (p = .001).

Body Composition

Figure 1 shows the results on body composition measures between the beginning and completion of the study. Dependent t tests reveal participants significantly decreased sum of skinfolds, triceps, suprailiac, and thigh: pre = 93.47, post = 85.26, t(18) = 4.57, p = .0002; fat mass: pre = 21.26 kg, post = 19.73 kg, t(18) = 3.54, p =
.0002; and percentage of body fat: pre = 31.85%, post = 29.62%, \( t(18) = 4.63, p = .002 \), while significantly increasing fat-free mass, pre = 44.26 kg, post = 45.7 kg, \( t(18) = -3.52, p = .002 \), with no significant change in body mass, pre = 65.53 kg, post = 65.44 kg, \( t(18) = .17, p = .87 \).

**Pull-Ups**

At the beginning of the study, 2 participants (10.5%) successfully completed at least one actual pull-up (1 participant performed two and the other performed three). At the conclusion to the study, 6 of the 19 participants (31.6%) successfully completed at least one pull-up. The 2 original participants increased the number of pull-ups they could perform to 11 and 8, respectively. The 4 other participants performed five, three, two, and two pull-ups, respectively. Additionally, 2 other participants performed at least one pull-up during the course of the study but failed to complete at least one pull-up during final testing and were, therefore, categorized as unsuccessful for statistical purposes.

**Comparisons Between Women Who Could Perform a Pull-up and Those Who Could Not**

Table 2 lists the characteristics of the participants taken at the beginning of the training program. These characteristics differentiate between the women who were successful and unsuccessful at performing a pull-up at the end of the training program. Independent \( t \) tests reveal significant differences in 1-RM strength on the pull-up trainer, strength to mass ratio, and strength to fat-free mass ratio between the two groups.

**Discriminant Analysis**

Two variables, the percentage of body fat and strength to fat-free mass ratio, gave the best prediction for which of the two groups participants would fall into (eigenvalue, 2.19, \( p = .00009 \)). The canonical correlation was .83. Thus, 69% of the variability in group designation could be predicted by the two variables. The unstandardized coefficients were used to determine the participants' discriminant score and yielded the following empirical equation used to predict success of the pull-up: pull-up success = (10.4803 * strength to fat-free mass ratio) + (0.056302 * % fat) - 7.846636.

**Figure 1. Mean changes (+SEM) for pre (Week 0) and post (Week 13) body composition measures; * indicates a \( p \) value < .05.**

<table>
<thead>
<tr>
<th>Table 2. The characteristics of women successful and unsuccessful at performing a pull-up at the end of the training program</th>
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<tbody>
<tr>
<td><strong>Successful (N = 6)</strong></td>
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<tr>
<td><strong>M</strong></td>
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<tr>
<td>Age (years)</td>
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<td>Height (m)</td>
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<td>Weight (kg)</td>
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<td>Skinfold sum (mm)</td>
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<td>% Fat</td>
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<td>Fat mass (kg)</td>
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<td>Fat-free mass (kg)</td>
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<tr>
<td>Waist to hip ratio</td>
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<tr>
<td>Work (kg-m)</td>
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<tr>
<td>1-RM PT (kg)*</td>
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<tr>
<td>S to M ratio*</td>
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<td>S to FFM ratio*</td>
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</table>

Note. \( M \) = mean; \( SD \) = standard deviation; 1-RM PT = 1 repetition maximum on the Pull-Up Trainer®; S to M = strength to mass; S to FFM = strength to fat-free mass.

\( ^* \) \( p < .05 \), two-tailed.
A positive score predicts that a participant will be able to perform a pull-up at the end of a 12-week strength training program, while a negative score predicts that she will not. Larger numbers, positive or negative, indicate a greater or lesser chance of completing a pull-up, respectively. To examine the success of the equation, predicted pull-up success of each participant was determined and compared with her actual ability to perform a pull-up. The correct status was predicted for 18 of the 19 participants, or 94.7%.

**Discussion**

To train college-age women to successfully perform at least one pull-up, we felt it was imperative for them to undergo a training program that would both increase their upper body strength and decrease their fat mass. Our training program accomplished these two goals. Participants exhibited a significant increase in upper body strength as measured by a 1-RM test on the Pull-Up Trainer®, which we believe was primarily due to neuromuscular factors, such as improved intra- and intermuscular coordination. The 35.66% increase in strength was greater than the 28.6% increase found by Wilmore (1974) training a similar group of participants for 10 weeks on the bench press and could have been due to the periodized nature of the current study.

Repeated measures ANOVA with a Scheffe post hoc analysis revealed significant differences pre- to midstest, pre- to posttest, and mid- to posttests of upper body strength. The fact that there was significant upper body strength improvement between mid- and posttesting is important for two reasons. First, we suspect that any improvement due to initial learning would have occurred between pre- and mid-testing. Continued improvement should be considered strength gains. Second, continued improvement throughout the second half of the training program indicates that the participants’ strength gains did not plateau. We hypothesize that if we had extended the duration of the training program, participants would have continued to experience strength gains, albeit at a slower rate.

The theoretical accuracy of skinfold prediction equations is 3.3% (Heyward & Stolarczyk, 1996). This fact should be kept in mind when interpreting our results. However, this method was chosen because it is a more reasonable method to use in a field setting (as opposed to dual energy x-ray absorptiometry or underwater weighing).

Participants showed a significant change in the sum of skinfolds. Using skinfold prediction equations, participants also showed a significant change in body composition, with a significant decrease in fat mass and percentage of body fat, and a significant increase in fat-free mass, with no significant change in body mass. The change in both fat mass and fat-free mass without a significant change in body mass is indicative of muscle hypertrophy as a result of the program. These changes are similar to those found by Wilmore (1974), who reported the following percentage changes: fat mass -1.08 kg, % body fat, -1.86%, and fat-free mass, +1.06 kg. In that study, the participants performed only strength training exercises; they did no aerobic work. This leads us to believe that the aerobic training component of the current program was not of sufficient intensity or duration to elicit further alterations in body composition than those produced by a weight training program alone. Whether or not aerobic training negatively impacted potential strength gains is unknown.

Unfortunately, these significant changes in both upper body strength and body composition did not translate into an impressive increase in the number of women who were successful at completing onepull-up. Only one third of the participants were able to perform a pull-up on completing the training period, although some did make dramatic improvements (1 participant increasing from 0 to 5 and another from 2 to 11 pull-ups). Several of the women were within 7.62–10.16 cm from successfully completing one pull-up, and we believe that if the training period was extended by 2–3 weeks, then over half the women would have done so. Additionally, 2 women were able to perform a pull-up during the training period but were unable to complete a pull-up at the final testing session. We believe that despite an unloading week prior to the final test, these women may have been overtrained, which led to a decrement in strength (Kraemer, 1994).

Finally, we considered the possibility that many of the participants may have started with a fitness level too low to reach the goal of successfully completing a pull-up in a 12-week period. Comparing the initial characteristics between the women who could complete one pull-up at the end of the study to those who could not, it is clear that initial strength levels are the most important variable separating the two groups. When initial strength is expressed as a ratio to either mass or fat-free mass, the differences between the two groups is even more apparent. For our participants, it was necessary to have an initial strength-to-mass ratio of 0.67 to be successful at completing one pull-up at the end of 12 weeks of training.

Discriminant analysis gave us the ability to predict success with a more powerful statistical tool. It also allowed us to analyze more than one variable simultaneously. Our results indicate that best predictor of pull-up success at the end of a 12-week strength and conditioning program included the participant’s initial percentage of body fat and strength to fat-free mass ratio. Percentage body fat has been shown previously to have
a detrimental effect on pull-up performance (Vanderburgh & Edmonds, 1997) and although there was no statistical difference between the two groups, it added to the predictive ability of our equation. It is interesting to note that strength to fat-free mass ratio was the single best predictor of success. This finding adds to our initial notion that participants had to be trained for maximum strength (Bompa, 1996a; Kramer et al., 1997) instead of hypertrophy, because programs emphasizing hypertrophy methods would have a concomitant rise in body mass with an increase in strength, which may not be beneficial to the strength to fat-free mass ratio.

When these two variables are plotted on a graph (see Figure 2), they show a rather clear pattern between those who were successful and those who were not at the end of our study. There is one obvious exception to this pattern, and it is interesting to note that this participant had completed a pull-up during the course of the study but failed to do so during the final test. As mentioned earlier, we believe that this participant was in an overloaded state on the final test day, and we believe the fact that she did perform at least one pull-up during the course of the study strengthens the predictive ability of our equation.

Administrators can use Figure 2 or our equation to set minimum recruiting standards for women whom they will require to perform a pull-up at the end of their initial training (i.e., law enforcement, military, firefighting). For instance, using Figure 2, they could require women entering their programs to have a maximum body fat of 35% and a minimum strength to fat-free mass ratio of .95. Alternatively, administrators could set a maximum body fat percentage (30% for example) and a discriminant level for success (1.0). Manipulating the equation, they could determine a minimum strength to fat-free mass ratio of 1.01. Or, administrators could simply set a discriminant level for success, and allow a variety of combinations between the two variables as long as this discriminant level was met or exceeded. Any of these options would give these women a good chance at being successful at the end of the program and save valuable resources.

### Conclusion

Although the pull-up has been found to be an occupationally relevant test of upper body strength, policy makers must exercise caution when mandating this test for women. Despite significant improvements in strength and favorable body composition changes over a 12-week training program, only one third of the participants in this study were successful in completing at least one pull-up at the end of the program. If performance of pull-ups was a critical element of an occupation, one would have to accept the possibilities that fewer women could join that occupation, a training period longer than 12 weeks would be required, and minimum screening requirements for upper body strength (as related to pulling movements) and percentage of body fat may be required. Further research with a large sample from the actual population under consideration should be undertaken to quantify the level of success and minimum requirements for that population.

### References


Note

1. The pull-up and chin-up exercises are similar; the only difference is the grip of the hands. A pull-up is performed with both hands in a pronated grip (palms facing away from the exerciser), while a chin-up is performed with both hands in a supinated grip (both hands facing the exerciser). A chin-up is usually considered to be an easier movement to perform, because the biceps have the most favorable line of pull in this position (Luttgens & Hamilton, 1997). However, we felt that the pull-up was a more occupationally relevant, because the forearms were in the same position as they would be to climb a ladder or pull oneself through a window.

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