2007

Correction Factors for Body Mass in Military Physical Fitness Tests

Paul M. Vanderburgh
University of Dayton, pvanderburgh1@udayton.edu

CORRECTION FACTORS FOR BODY MASS BIAS IN MILITARY PHYSICAL FITNESS TESTS

Accepted for Publication, Military Medicine

Paul M. Vanderburgh, EdD, FACSM
Chair and Associate Professor
Department of Health and Sport Science
University of Dayton
Dayton, OH 45469-1210
TEL: 937.229.4213
FAX: 937.229.4244
vanderburgh@udayton.edu

Abstract

Recent research findings combined with the theoretical laws of biological similarity make the compelling case that all physical fitness test items for the Army, Air Force, and Navy impose a 15-20% physiologic bias against heavier, not fatter, men and women. Using the published findings that actual scores of muscle and aerobic endurance scale by body mass raised to the 1/3 power, correction factor tables were developed. This correction factor can be multiplied by one's actual score (e.g., push-ups, sit-ups, abdominal crunches, or curl-ups repetitions or distance run time) to yield adjusted scores that are free of body mass bias. These adjusted scores eliminate this bias, become better overall indicators of physical fitness relevant to military tasks, are easily applied to the scoring tables used in the present physical fitness tests, and do not reward body fatness. Use of these correction factors should be explored by all military services to contribute to more relevant fitness tests.

Introduction

Recent research evidence suggests that each of the physical fitness tests of the U.S. Army, Navy and Air Force imposes a 15-20% penalty on heavier, not fatter, service members. The strategies for reducing or eliminating these penalties, however, have not been investigated. The objective of this paper, then, is to detail the derivation and illustrate the use of one practical strategy: a system of correction factors that can be applied to the present physical fitness test scoring systems of the primary services of the U.S. military.

The importance of routine physical fitness testing in the military services is undisputed. In fact, all servicemembers of the Army, Air Force, and Navy are required to take physical fitness tests on a regular basis. Norm-based comparisons are often used for performance evaluation and criterion-based assessments are used to ensure minimally acceptable standards of performance. Each event of these tests measures some form of relative fitness, or the ability to move one's body mass. The two types of relative fitness assessed are aerobic power and muscle endurance. Aerobic power is traditionally defined as VO_{2max}, the maximum rate of oxygen consumption expressed per unit of body mass ($ml\ O_2 \cdot kg^{-1} \cdot min^{-1}$). Timed distance runs are the primary index of aerobic power in military testing because they have apparent occupational relevance and are conducive to mass testing. Furthermore, run time is moderately correlated with aerobic power (1). Muscle endurance is assessed via timed maximal repetition tests such as push-ups, sit-ups, abdominal crunches, or curl-ups, all conducive to mass testing and accepted as demonstrating "face validity" in the absence of a criterion standard of muscle endurance. The physical fitness test events for these three military services are shown in Table 1 (2,3,4).

Table 1. Muscle Endurance and Aerobic Capacity Tests of the Three Primary Armed Services (2,3,4)

	Upper Body Muscular Endurance	**Trunk Muscular Endurance**	**Aerobic Capacity**
Army	2 min Push-ups	2 min Sit-ups	2 Mile Run
Air Force	1 min Push-ups	1 min Abdominal Crunches	1.5 Mile Run
Navy	2 min Push-ups	2 min Sit-ups	1.5 Mile Run

Recent research literature, however, offers compelling evidence that each of these physical fitness tests imposes a systematic bias against heavier servicemembers (5). One might think that such a bias is not surprising given that that heavier people tend to be fatter and, therefore, disadvantaged in events that require one to move his/her body mass. Several studies, however, have applied laws of biological similarity and allometry to suggest that the bias is independent of percent body fat (5,6,7). These laws, well-documented in zoological research where animal sizes are quite variable, are useful to explain why various indices of physiological function, including physical fitness, do not change at the same rates as certain measures of body size. Since fitness indices often do not change linearly with body mass, then fitness tests that assume they do will impose a penalty against either lighter or heavier individuals.

Indeed, the evidence for this is mounting. Vanderburgh & Crowder (5) calculated that, for male and female service members at the body mass range limits of 60 – 90 kg and 45 – 75 kg, respectively, these physical fitness tests penalize the heavier personnel by 15-20%. Said differently, for *physiologically* equivalent performances, heavier personnel receive 15-20% lower scores. Of key importance is the fact that these penalties are based on "scale-modeling," such that a 90 kg man, an exact scale replica of a 60 kg man, would run slower or perform fewer repetitions of push-ups by a predictable percentage.

For distance run times, Vanderburgh & Mahar (6) reported that larger body mass was associated with slower two-mile run times for a sample of 59 lean, fit, service academy cadets. More specifically, because run times were directly associated with body mass raised to the 1/3 power, then the appropriate scaled score that eliminated body mass bias was run time$\cdot$(body mass)$^{-1/3}$. This finding suggests that larger men, independent of percent body fat, are generally slower distance runners than lighter men because laws of allometry dictate that they will not be capable of running at the same sustained speed. Indeed, Nevill's findings that VO_{2max} is proportional to body mass raised to the 2/3 power combined with the direct correlation between distance run speed and relative VO_{2max} (ml $O_2 \cdot kg^{-1} \cdot min^{-1}$), yield the result that distance run time should be proportional to body mass raised to the 1/3 power (details explained in ref. 5).

Besides their limitation of body mass bias, distance run times may not be as relevant for military tasks such as load carriage. In a sample of healthy males, Bilzon et al. (8) reported that run time to exhaustion while carrying an 18 kg backpack, was significantly correlated with lean body mass ($r = 0.71$, $p<0.05$) and that submaximal relative oxygen consumption was inversely correlated with lean body mass ($r = -0.87$, $p < 0.05$). In other words, increased lean body mass, and not relative aerobic power was an advantage for load carriage. They concluded that "fitness tests that determine aerobic power in units relative to body mass (e.g., timed distance run) incur a systematic bias against heavier personnel. Such tests are therefore inappropriate when predicting the ability of personnel to work in occupations that encompass load-carrying tasks." Vanderburgh & Flanagan modeled a two-mile backpack run test (9), with all servicemembers carrying the same backpack weight (gender-adjusted). The resulting run times were free of body mass bias and demonstrated face validity with regard to occupational relevance.

For tests of muscle endurance, empirical support suggests that push-up, sit-up, abdominals crunches or curl-up tests similarly penalize heavier personnel. In a study of 77 male physical education students, Markovic & Jaric (10) found that maximal repetition scores of common muscle endurance tests in which body mass was the primary resistance, were proportional to body mass raised to the -1/3 power. This relationship suggests that, as body mass increases, maximal repetitions in a scale model of the subject would decrease by a factor equal to the body mass ratio raised to the 1/3 power. In their review paper providing evidence-based recommendations on how to best scale various scores of physical performance, Jaric et al. (11) also concluded that muscle endurance repetitions, using body weight as the primary resistance, scale by body mass exponent raised to the 1/3. These findings indicate that muscle endurance scores (REPS), expressed in REPS$\cdot$(body mass)$^{1/3}$, are also free of body-mass bias. Said differently, the correlation, within a same-gender sample of subjects, between these scaled scores and body mass would be near zero.

The same argument regarding military relevance in testing aerobic power can be used for muscle endurance tests. That is, moving one's body mass, as in the push-ups, sit-ups, abdominal crunches or curl-ups tests, is an indicator of one's relative, not absolute ability because the force that must be exerted in each repetition is relative to one's body mass. Absolute ability, then, is based on a fixed resistance, independent of body mass. A good example of this would be a maximal repetitions bench press test against the fixed resistance of 175 lb. In a military context, then, one could execute many push-ups but, because of low body mass and, hence, total musculature, be incapable of heavy lifting absolute amounts of weight, as is typical in a military field setting. Therefore, the common push-up, sit-ups, abdominal crunches and curl-up tests not only impose an unfair body mass bias, but they may have limited occupational relevance as well.

While these problems, especially in a military context, have been well-documented, practical solutions are few. The backpack run test proposed by Vanderburgh & Flanagan (9) can eliminate the body mass bias and may be more relevant, but the military appears reluctant to incorporate physical tests that require equipment. Scaled scores for run times or muscle endurance yield scores that are difficult to calculate and interpret due to the non-integer exponents and the resulting strange units. One method that offers a practical solution is the use of a correction factor: a body-mass-based number multiplied by an actual fitness score to yield an adjusted score free of body mass bias. The purpose of this paper, then, is to derive these correction factors into tables that can be easily used by the military services to assess physical fitness in a way that is likely to be more physiologically and occupationally relevant.

Methods

The method for developing these correction factors was that used by Vanderburgh (12), who developed them for measures of maximal absolute strength. In the present study, the correction factor would be the number multiplied by the actual score (such as push-ups or sit-ups repetitions or distance run time) to yield an adjusted score. This adjusted score is what the subject would have scored, according to the aforementioned theoretical and empirical findings, had he/she been lighter in body mass. The "lighter mass" is chosen as the gender-specific mass below which no extra credit should be granted. Said differently, it is the mass above which performance tends to decline.

Computation of the correction factor starts with selection of the lower mass limits: 125 lb for women and 150 lb for men (U.S. Customary System of units chosen for ease of use and interpretation). These lower limits were chosen for a number of reasons. First, there are no published findings that suggest what the optimal body mass values should be for the combination of muscle endurance and distance run test tests. Vanderburgh and Laubach (13), in developing and age and body mass handicap system for a 5000m run, used lower body mass limits of 50 and 65 kg (110 and 143 lb) for women and men, respectively, because these were the mean body mass values for fairly large research samples of national-class runners. Such elite runners, however, would be expected to be lighter than the most elite performers of distance running *and* muscle strength/endurance tests, since the latter type of test is more dependent on lean body mass. Second, the present investigator's anecdotal observations of and experience in testing thousands of male and female service academy cadets and regular Army soldiers, suggests that these values are close to those optimal for military fitness test performance. Third, as body mass values diminish below the lower limits, subjects are likely to have too little lean muscle mass and, therefore, become disadvantaged. Conversely, body mass increases above the maximal limits will likely be due more to excess fat than lean body mass and, therefore, need not be credited with additional handicap. Lastly, different lower mass limits can be chosen and, using the procedures below, easily used to develop different sets of corrections factors as desired.

Next, the derivations begin with the body-mass (M) scaled scores for both distance run time (T) and repetitions of either push-ups, curl-ups abdominal crunches or sit-ups (REPS): $T \cdot M^{-1/3}$ and $REPS \cdot M^{1/3}$ (5,6,10,11). These are the scores that are free of body mass bias. The following identities, with baseline M values for men and women, are starting points:

$$T \cdot M^{-1/3} = T_{adj} \cdot 150^{-1/3} \text{ and } REPS \cdot M^{1/3} = REPS_{adj} \cdot 150^{1/3} \text{ for men and}$$
$$T \cdot M^{-1/3} = T_{adj} \cdot 125^{-1/3} \text{ and } REPS \cdot M^{1/3} = REPS_{adj} \cdot 125^{1/3} \text{ for women}$$

Rearranging each yields:

$$T \cdot \mathbf{(150/M)^{-1/3}} = T_{adj} \text{ and } REPS \cdot \mathbf{(M/150)^{1/3}} = REPS_{adj} \text{ for men and}$$
$$T \cdot \mathbf{(125/M)^{-1/3}} = T_{adj} \text{ and } REPS \cdot \mathbf{(M/125)^{1/3}} = REPS_{adj} \text{ for women}$$

where bolded values represent the correction factors.

Results

Calculating the correction factor for each body mass value above the lower mass limits yields Tables 2 and 3. As subjects become heavier, the correction factors become larger for REPS and smaller for T; this is the expected direction given the fact that larger REPS and smaller T are better, respectively. Subjects at or below the lower mass limits would have a factor of “1” since they would get no extra credit for body mass. The tables also indicate that those above 200 lb for women and 250 lb for men would receive no additional handicap than that received at these maximum body mass values. Establishment of this body mass range has not only the features previously described but is also practical in that the table size is not unwieldy. Furthermore, because these correction factors were derived, in part, from empirical findings, they should be valid because they would render the body mass bias essentially zero for the samples of subjects studied (6,10,11).

Discussion

There are several important features of these correction factors for both muscle endurance and distance run tests. First, they are simpler to use but yield identical results, in terms of relative comparisons. Scaled scores, as mentioned previously, require the use of non-integer exponents and result in strange currencies of fitness scores. For example, two women, 154 lb and 120 lb, both with 45 push-ups, would have scaled scores of 241.20 $REPS \cdot lb^{1/3}$, and 221.96 $REPS \cdot lb^{1/3}$, respectively. These units are difficult to interpret and require calculations not easily done by hand. Applying the correction factors from Table 2 to the raw scores, however, yields adjusted scores (in REPS) of 45 (120 lb woman, correction factor of 1.0) and 49 (154 lb woman, correction factor of 1.09). Both techniques produce the same relative result in that the heavier woman’s score is 9% better than the lighter woman’s, but the correction factor method preserves the original units. To score performances, then, one simply cross-references the adjusted score with the appropriate military service’s scoring table for that event. In the case of this heavier woman, she would use 49 push-ups instead of 45 for the appropriate service’s scoring table.

For distance run times, correction factors decrease as body mass increases because shorter time is better. Furthermore, multiplying a run time by a correction factor requires decimal-based units, either in seconds or minutes. For example, an actual score of 15:37 for a two-mile run time must be converted either to seconds (e.g., 937 sec) or minutes with decimals (15 + 37/60 or 15.62 min) before multiplying by the correction factor. For a 189 lb man with a 15:37 run time, his adjusted score would be 0.93 times 937 sec or 871 sec, or 14:31, over a one-minute handicap.

The idea of a handicap for increased body mass, may suggest that excess body fat is being rewarded – an unfavorable notion from a health and fitness perspective. Analysis of the modeling foundation of the correction factors, however, indicates otherwise. The previously discussed findings (5,6,9,10,11) suggesting the body mass exponent of 1/3 for the scaling of muscle endurance or distance run time scores, is based on the scale model assumption. That is, the adjusted score is equal to what the subject would have performed if he/she would have become an exact replica of him/herself, except lighter (120 lb for women or 150 lb for men). Becoming heavier by gaining excess body fat, then, creates a performance decrement that is larger in magnitude than the gain from the larger handicap. Empirical models of this using metabolic equations and scaling laws are provided and explained in detail elsewhere (13). In short, even with the handicap for being heavier, gaining fat mass leads to poorer adjusted scores.

Often, military physical fitness test results are used for promotion boards or even rewards. Fig. 1 can be used to illustrate the inequities of such practice for the Army Physical Fitness Test (APFT). Two women, 120 lb and 180 lb in body mass, respectively, with identical actual scores of 35 push-ups, 65 sit-ups and two mile run time of 19:28, would normally score 233 total points on the APFT. With the correction factors, however, the heavier woman would gain an additional 36 points for a total of 269 points. Likewise, for the 150 lb and 230 lb men, with identical test performances of 55 push-ups, 63 sit-ups and two mile run time of 17:00, the heavier man scores significantly more total points (265 vs. 216).

The resulting adjusted scores have occupational relevance as well. One way of characterizing this relevance is to examine the subjects in Fig. 1 in terms of body mass vs. actual and adjusted scores. The six men and women all performed the same actual scores, within each gender. This indicates that each was able to move his/her body mass equally well in tests of muscle endurance or aerobic power. The heavier men and women, however, would most certainly have more lean body mass than the lighter women. As Bilzon et al. (8) demonstrated, greater lean body mass is more advantageous than VO_{2max} for load carriage – clearly an essential task in a military environment. Quite simply, a 200 lb man who achieves a maximum score with any of the current service's tests, is more valuable, from an occupational fitness standpoint, than a 140 lb man with exactly the same actual scores. If military fitness were defined as having equal contributions of relative and absolute fitness, the heavier subjects in Fig. 1 *should* score more points with the same actual scores. The total points, then, can be considered a better indicator of total physical fitness, the combination of relative and absolute levels of fitness. This does not obviate the appropriateness of a minimal standard for *actual* scores for each gender (e.g., a minimal number of acceptable repetitions of push-ups or a maximally acceptable distance run time) but such a standard should be defensible.

Table 2. Correction Factors for Muscle Endurance Tests (Push-ups, Sit-ups, Abdominal Crunches). A 156 lb woman with an actual score of 59 sit-ups, for example, would go to the “150” column and down to the row corresponding to “6” to yield the correction factor of 1.08. This number would be multiplied by 59 to yield an adjusted score of 63.7 or 64 sit-ups.

Women	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**	**200**
0	1.00	1.01	1.04	1.06	1.08	1.11	1.13	1.15	1.17
1	1.00	1.02	1.04	1.06	1.09	1.11	1.13	1.15	1.17
2	1.00	1.02	1.04	1.07	1.09	1.11	1.13	1.15	1.17
3	1.00	1.02	1.05	1.07	1.09	1.11	1.13	1.15	1.17
4	1.00	1.02	1.05	1.07	1.09	1.12	1.14	1.16	1.18
5	1.00	1.03	1.05	1.07	1.10	1.12	1.14	1.16	1.18
6	1.00	1.03	1.05	1.08	1.10	1.12	1.14	1.16	1.18
7	1.01	1.03	1.05	1.08	1.10	1.12	1.14	1.16	1.18
8	1.01	1.03	1.06	1.08	1.10	1.12	1.14	1.16	1.18
9	1.01	1.04	1.06	1.08	1.10	1.13	1.15	1.17	1.18

Men	**150**	**160**	**170**	**180**	**190**	**200**	**210**	**220**	**230**	**240**	**250**
0	1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.13	1.15	1.17	1.18
1	1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.15	1.17	1.19
2	1.00	1.03	1.05	1.07	1.08	1.10	1.12	1.14	1.15	1.17	1.19
3	1.01	1.03	1.05	1.07	1.09	1.11	1.12	1.14	1.16	1.17	1.19
4	1.01	1.03	1.05	1.07	1.09	1.11	1.12	1.14	1.16	1.17	1.19
5	1.01	1.03	1.05	1.07	1.09	1.11	1.13	1.14	1.16	1.18	1.19
6	1.01	1.03	1.05	1.07	1.09	1.11	1.13	1.14	1.16	1.18	1.19
7	1.02	1.04	1.06	1.08	1.09	1.11	1.13	1.15	1.16	1.18	1.19
8	1.02	1.04	1.06	1.08	1.10	1.11	1.13	1.15	1.16	1.18	1.20
9	1.02	1.04	1.06	1.08	1.10	1.12	1.13	1.15	1.17	1.18	1.20

Table 3. Correction Factors for Timed Distance Runs). A 186 lb man with an actual score of 15:05, for example, would go to the “180” column and down to the row corresponding to “6” to yield the correction factor of 0.93. This number would be multiplied by the actual time of 905 sec to yield an adjusted score of 841.7 sec or 14:02.

Women	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**	**200**
0	1.00	0.99	0.96	0.94	0.92	0.90	0.89	0.87	0.85
1	1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.87	0.85
2	1.00	0.98	0.96	0.94	0.92	0.90	0.88	0.87	0.85
3	1.00	0.98	0.96	0.93	0.92	0.90	0.88	0.87	0.85
4	1.00	0.98	0.95	0.93	0.91	0.90	0.88	0.86	0.85
5	1.00	0.97	0.95	0.93	0.91	0.89	0.88	0.86	0.85
6	1.00	0.97	0.95	0.93	0.91	0.89	0.88	0.86	0.85
7	0.99	0.97	0.95	0.93	0.91	0.89	0.87	0.86	0.85
8	0.99	0.97	0.95	0.92	0.91	0.89	0.87	0.86	0.84
9	0.99	0.97	0.94	0.92	0.90	0.89	0.87	0.86	0.84

Men	150	160	170	180	190	200	210	220	230	240	250
0	1.00	0.98	0.96	0.94	0.92	0.91	0.89	0.88	0.87	0.85	0.84
1	1.00	0.98	0.96	0.94	0.92	0.91	0.89	0.88	0.87	0.85	0.84
2	1.00	0.97	0.96	0.94	0.92	0.91	0.89	0.88	0.86	0.85	0.84
3	0.99	0.97	0.95	0.94	0.92	0.90	0.89	0.88	0.86	0.85	0.84
4	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.87	0.86	0.85	0.84
5	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.87	0.86	0.85	0.84
6	0.99	0.97	0.95	0.93	0.91	0.90	0.89	0.87	0.86	0.85	0.84
7	0.98	0.96	0.95	0.93	0.91	0.90	0.88	0.87	0.86	0.85	0.84
8	0.98	0.96	0.94	0.93	0.91	0.90	0.88	0.87	0.86	0.85	0.83
9	0.98	0.96	0.94	0.93	0.91	0.90	0.88	0.87	0.86	0.84	0.83

One might argue that if absolute measures of fitness are important, then they should be measured directly. For example, absolute strength can be measured as a one-repetition maximum bench press to indicate one's ability to move a resistance independent of body mass. For muscle endurance, an analogous test would be the maximum repetitions of lifting a fixed amount of resistance (e.g., everyone lifts the same weight in the bench press for maximum repetitions). These both have apparent face validity for military applications since heavy loads are often lifted either in single or multiple repetitions. Unfortunately, unlike the current tests in Table 1, these tests are equipment-intensive and, as previously mentioned, probably not preferred by the military.

The use of these corrections factors also preserves the norms-based characteristics of the scoring tables in that each service member's actual score is statistically recomputed based on what he/she would have scored at a lighter, standardized body mass. In essence, adjusted scores based on the correction factors indicate differences in fitness levels without the confounding effect of body mass. Furthermore, Nevill (1) suggests that use of scaled scores (correction factors are the functional equivalent) leads to even more normally distributed scores. Of course, the mean physical fitness test scores for a unit would increase using correction factors, based on the higher scores for the heavier personnel. This could lead to the sentiment that the scoring tables are "too easy" or that heavier people are being given an unfair advantage. The research evidence makes a compelling case, however, that the unfair advantage is to the lighter personnel and that the adjustment is defensible. Were the services to consider using correction factors such as these, the scoring tables could be re-scaled to provide more variance in physical fitness test scores.

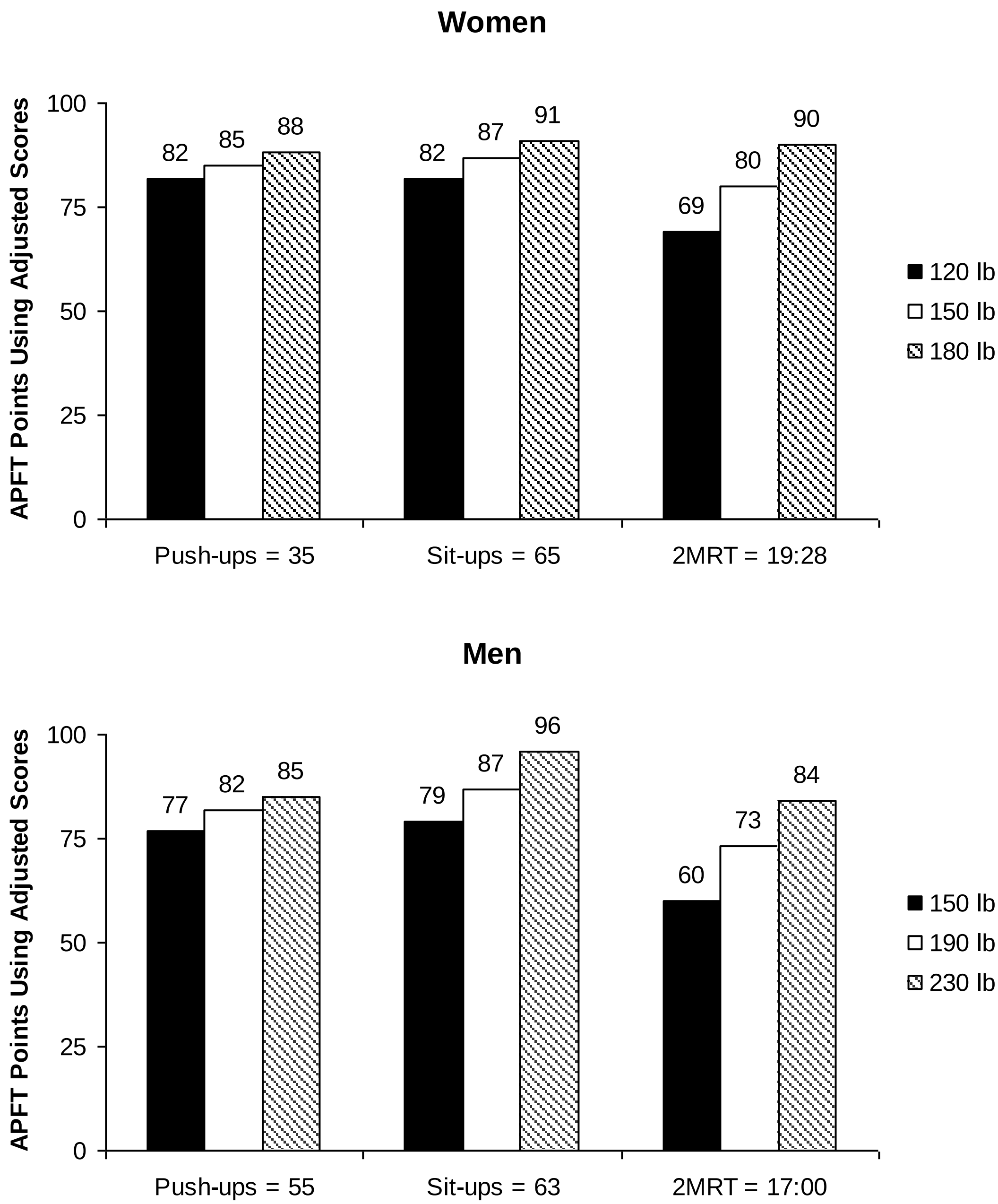

Figure 1. U.S. Army Physical Fitness Test (APFT) points earned using adjusted scores based on identical actual scores (shown below the x-axis) for individuals of different body mass (lb). For example, compared to the 120 lb woman, the 180 lb woman scored 6, 9, and 21 pts higher on the push-ups, sit-ups and two-mile run time (2MRT), respectively, for a total of 269 points. This represents, for the same performance, a 33 total point difference.

In conclusion, recent research evidence indicates that military physical fitness tests penalize heavier servicemembers and do not measure levels of absolute fitness, arguably just as important as relative fitness. The correction factors offered here make statistical adjustments of actual scores to yield adjusted scores that are free of this body mass bias and are better indicators of both relative and absolute levels of fitness. Furthermore, they work with current test events, do not reward body fatness, preserve the original units, and provide a fairer basis upon which military performance can be evaluated for the purposes of promotions and/or rewards. Each of the military services should explore the use of such correction factors to yield more physiologically and occupationally defensible physical fitness test scores.

References

1. Nevill AM, Ramsbottom R, Williams C. Scaling physiological measurements for individuals of different body size. Eur J Appl Physiol 1992; 65: 110-7.

2. U.S. Air Force Instruction 10-248. Fitness Program. January 2004; pp. 55-59.

3. U.S. Army Field Manual 21-20. Physical Fitness Training. October 1998; pp. 14-4 – 14-6.

4. U.S. Navy OPSNAVINST 6110.1G. Physical Readiness Test (PRT). October 2002; p.14.

5. Vanderburgh PM, Crowder TA. Body weight penalties in the physical fitness tests of the Army, Air Force, and Navy. Mil Med 2006; 171: 753-756.

6. Vanderburgh PM, Mahar MT. Scaling of 2-mile run times by body weight and fat-free weight in college-age men. J Strength Cond Res 1995; 9: 67-70.

7. Vanderburgh PM, Edmonds T. The effect of experimental alterations in excess mass on pull-up performance in fit young men. J Strength Cond Res 1997; 11: 230-233.

8. Bilzon JLJ, Allsopp AJ, Tipton MJ. Assessment of physical tasks for occupations encompassing load-carriage tasks. Occupational Med – Oxford 2001; 51: 357-361.

9. Vanderburgh PM, Flanagan S. The Backpack Run Test: A model for a fair and occupationally relevant military fitness test. Mil Med 2000; 165: 418-21.

10. Markovic G, Jaric S. Movement performance and body size: The relationship for different groups of tests. Eur J Appl Physiol 2004; 92: 139-149.

11. Jaric S, Mirkov D, Markovic G. Normalizing physical performance tests for body size: A proposal for standardization. J Strength Cond Res 2005; 19: 467-474.

12. Vanderburgh PM. A simple index to adjust maximal strength measures by body mass. J Exerc Physiology^online 1999; 2: 7-12.

13. Vanderburgh, PM, Laubach LL. Derivation of an age and body weight handicap model for the 5K run. Meas Phys Ed Exerc Sci 2007; 11: 49-59.