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Body Mass Bias in a Competition of Muscle Strength and Aerobic Power

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Abstract

Recently, a fitness competition, called the Pump and Run (PR), has been popularized. Comprised of two events, a 5K road race time (RT, in sec) and a maximum repetitions bench press (BPR) with resistance based on a percentage of body mass (M), the final score (RTadj) equals RT – 30(BPR). Based on published findings, we hypothesized that the PR would impose a bias against heavier competitors. Furthermore, the potential for age bias in this event has not been evaluated. Therefore, the purpose of this study was to investigate M and age bias in the PR for men and women. For 74 female and 343 male competitors in a large PR event, RT, BPR, M, and age were collected from official competition results. Two sub-samples were randomly created from the original sample: the Validation (VAL, 54 women and 258 men) and the Cross-Validation (CVAL, 20 women and 85 men). For the VAL sample, the RTadj demonstrated significant bias against heavier runners (women $r^2 = 0.35$, men $r^2 = 0.28$, $p < 0.01$ for both) but no age bias (women $r^2 = 0.04$, men $r^2 = 0.005$, $p > 0.05$ for both). Using allometric modeling, we developed a set of M-based correction factors (CF) to be multiplied by each RTadj to yield new adjusted run times (NRTadj) that would be free of M bias. As applied to the CVAL sample, the NRTadj values virtually eliminated the M bias (women $r^2 = 0.04$, men $r^2 = 0.002$, $p > 0.05$ for both) of the current PR scoring system and retained the absence of age bias (women $r^2 = 0.02$, men $r^2 = 0.0002$ $p>0.05$ for both). We recommend use of the NRTadj scores for future PR competitions.

Key Words: fitness, testing, age, weight, allometry

INTRODUCTION

To promote recognition of fitness dimensions other than aerobic capacity, a new type of distance road race, the “Pump and Run,” (PR) has been popularized. This event adds a bench press for maximum repetitions (BPR) to the 5K run time (RT). A brief review of internet sites for such races indicates that there are over 20 PR events in the United States. All use a variant of the basic algorithm in which BPR, multiplied by some constant and subtracted from RT, yields an adjusted race time (RTadj). The mass lifted for the BPR is usually an age-based percentage of body mass (M). One popular example of a PR tabulates a winner based on upon the competitor’s performance in the BPR and the RT using the following equation (1):

$$RTadj = RT\ (sec) - 30(BPR) \qquad \text{Eq. (1)}$$

Although the PR internet site speaks to fairness and balance of the PR with respect to fitness dimensions, published research findings suggest that a protocol like this would impose a systematic physiological bias against heavier competitors (4,7,8,11,13,14).

For example, recent empirical and theoretical research evidence make a compelling case that the 5K distance run imposes a bias against heavier, not just fatter, runners (11,15). The foundation of this bias lies in the connection between run speed, maximal oxygen uptake, and M (16). Nevill and colleagues (9) showed that mean 5K run speed was directly proportional to relative maximal oxygen uptake, expressed per M. Vanderburgh and Laubach (16) used this relationship and the well-documented relationship that absolute maximal oxygen uptake is proportional to $M^{2/3}$ (2,3,9) to model the finding that run speed should be proportional to $M^{-1/3}$. This suggests that, as M increases from M_1 to M_2, run speed decreases by $(M_2/M_1)^{-1/3}$.

In practical terms, a number of conclusions can be drawn from these findings. First, a compelling case can be made that distance run time is not only a measure of fitness but M as well, thus penalizing heavier runners (4,8,11). Second, run time expressed as $RT \cdot M^{-1/3}$, is an index of distance run performance that is generally free of M bias (4,11). In this case, bias, defined as the correlation between M and $RT \cdot M^{-1/3}$, is essentially zero. Third, though existing only in the hypothetical, an exact scale model of an adult runner, only larger, would be slower in a distance run time by the ratio of the two M values raised to the 1/3 power. Regarding the confounding effect of body fat, Vanderburgh & Laubach (16) have reported that gaining weight consisting of 100% body fat, would lead to a net poorer performance in $RT \cdot M^{-1/3}$, because the "reward" for the extra weight is less than the actual decrement in performance due to the added body fat. Conversely, they also found, via modeling, that gaining only muscle mass, assuming that aerobic training is maintained, would improve the $RT \cdot M^{-1/3}$ score. Their findings suggest that the $RT \cdot M^{-1/3}$ score provides incentive to increase lean body mass, not just reduce weight.

Similar findings for tests of muscular endurance, such as the push-up test, make the case that when M is the primary resistance, then maximal repetitions (REPS) are proportional to $M^{-1/3}$ and the resulting index, $REPS \cdot BW^{1/3}$, is free of M bias (7,8,14). Since the PR competition is based on bench-pressing a percentage of one's M, then the bench press portion of this competition becomes much like the push-ups test and therefore is likely to impose a M bias against heavier competitors.

The effect of aging on aerobic power (and, therefore, on RT) can also be examined using empirical data. Jackson and colleagues (5,6) determined the age-related decline in maximal oxygen uptake, independent of body composition and self-reported physical activity to be 0.25 and 0.26 $ml \cdot kg \cdot min^{-1}$ for women (ages 20 – 64 yr) and men (ages 25 – 70 yr), respectively. Vanderburgh and Laubach (15,16) have used these findings to develop and validate an age and M handicap system for the 5K run. Application of Jackson's findings to the PR competition, however, is problematic because the bench press resistance loading protocol (Table 1) varies the percentage of M lifted by age so that the age adjustment occurs in the bench press event, not the run. This age adjustment is, at most, norm-based but its effect on eliminating age bias also has yet to be validated. While the effect of aging on muscle strength has been studied at length, no data, to our knowledge, exist to model maximal repetitions as a percentage of one's weight as in the BPR test.

Based on this review of the relevant literature, we hypothesized that the PR competition's RTadj score would impose a bias against heavier competitors. Therefore, the primary purpose of this paper was to test this hypothesis and, if appropriate, recommend practical solutions. A secondary purpose was to examine the presence of age bias, given that the PR resistance protocol specifies age-adjusted bench press resistance to allow comparisons of RTadj between competitors of all ages within the same gender.

APPROACH TO THE PROBLEM

The study's approach was multi-phased. First, a validation sub-sample (VAL, 54 women, 258 men) was created from randomly selecting 75% of the subjects of each gender. The other 25% comprised the cross-validation sub-sample (CVAL, 20 women, 85 men). Second, M and age bias were assessed in the VAL sub-sample. Third, correction factors (CF) were developed from the VAL sub-sample to eliminate biases. CFs, dimensionless numbers, were multiplied by the RTadj values, to yield new scores (NRTadj), free of age and/or M bias. Fourth, the CFs were used to compute the NRTadj values for the CVAL sub-sample and examined for age and M bias, to ascertain external validity. The goal was to produce a single table of CFs, each based on a single value of M for either gender, which could be multiplied by RTadj using the current convention of the PR, to yield the NRTadj, which would be free of age and M bias.

SUBJECTS

At a large PR competition in the midwestern U.S., 343 male and 74 female competitors participated in this study. Prior to data collection, all procedures were approved by the University of Dayton's Institutional Review Board (IRB) and data used for the study were only those obtained as part of the official competition. Subject selection criteria included: BPR > 0, and RT faster than 30 minutes. The former was an official requirement for participation in the PR and the latter was based on previous findings (14) showing that slower run times can confound bias analyses. Subjects' descriptive data are shown in Table 2. Comparison of variables shown in Table 2 (age, M, BPR, and RTadj) between the VAL and CVAL sub-samples was done via independent groups t-test at an alpha level of 0.01 (to adjust for the multiple tests). No significant differences between the two groups were found for either gender.

PROCEDURES

Runners first reported to the race's official weigh-in station where M was recorded by race staff to the nearest 2.67 kg (5 lb). This level of precision was designed to facilitate the use of quick-reference tables for testers at the bench press site since bench press weight was assigned as a percentage of M. After a self-monitored warm-up, runners reported to the bench press station, where this M value was used to determine the weight setting on the bench press. Each competitor then performed as many repetitions of the bench press as possible until failure, thus yielding the BPR score. Trained strength and conditioning specialists judged the quality of each repetition according to the standards shown in Table 1. Competitors then reported to the 5K run no earlier than 30 min and no later than 1.5 hr from the completion of the bench press testing and ran the race en masse. Race conditions were sunny with start and finish (30 min. after the start) temperature of 15°C and 16°C, respectively. The race route was essentially a co-located start and finish on a flat course. Subjects' performance data are shown in Table 2. The race director computed each RTadj score using Eq. 1.

STATISTICAL ANALYSES

The principal statistical analysis of this study was the assessment and evaluation of M and age bias, defined as the Pearson product moment correlation coefficient between age or M and RTadj and NRTadj (non-zero correlations indicate bias). Statistical power for all correlations was ascertained from the minimum sample size to detect a statistically significant correlation coefficient that would explain 20% of the variance of the outcome variable. Specifically, the smallest statistically significant sub-sample size at the 0.05 alpha level with a minimum r^2 value of 0.20 for any correlation would be 20.

The secondary statistical tool used was that of allometric modeling to develop the CFs which would eliminate the M bias. In accordance with the procedures detailed elsewhere (3,7-11), regression analysis, applied to log-transformed RTadj and M values for each gender-specific group within the VAL sub-sample, was used to determine the scaling exponent, *x*, such that $RTadj \cdot M^{-x}$, had zero correlation with M. This M^{-x} term, essentially, then, became the CF. Because this term, however, would likely yield very small numbers, the values of $RTadj \cdot M^{-x}$ would be of a strange “currency” and difficult to interpret. To make the resulting score more meaningful, we added an integer coefficient that would scale its values so that the mean $RTadj \cdot M^{-x}$ for each sub-sample was close to that of the associated RTadj score. Though allometric models are, by definition, curvi-linear (unless the exponent is one), they are often fitted to data that may appear linear in a scatterplot. This is primarily because, within the range of normal human values, the best-fit allometric curve is often near-linear in shape, only showing its significant curvature near the origin, where no human values are found (12).

RESULTS

In the VAL sub-sample, the Pearson product moment correlation coefficients for M vs. RTadj indicated M bias for both women ($r^2 = 0.35$, $p < 0.01$) and men ($r^2 = 0.28$, $p < 0.01$) in the PR competition. More specifically, M accounted for approximately 30% of the variance in RTadj scores and provided an advantage for lighter runners of either gender. Interestingly, the age vs. RTadj correlation coefficients were not different from zero for women ($r^2 = 0.04$, $p > 0.05$) or men ($r^2 = 0.005$, $p > 0.05$), thus suggesting no age bias for the current PR scoring system. Although, to our knowledge, no published information exists to explain how this age-based resistance protocol was established, it does appear to be effective in eliminating any scoring advantage for older or younger competitors of either gender. Figure 1 graphically depicts the scattergrams of the RTadj vs. M and age relationships.

Indeed, the correlations of M vs. BRP and RT support these findings. Specifically, within the VAL sub-sample, age and M showed significant correlations between BPR and M for women ($r^2 = 0.20$, $p < 0. 0.05$) and men ($r^2 = 0.38$, $p < 0.05$). Because the corresponding r value was negative, this suggested a clear trend for BPR to decrease with increasing M. The correlations between RT and M showed a similar and expected trend for men ($r^2 = 0.22$, $p < 0.05$) and the same for women but not at a statistically significant level ($r^2 = 0.05$, $p < 0.05$) with both in the direction of RT increase with M increase.

Before using allometry to develop CFs and thereby eliminate the M bias, we compared best-fit modeling of the scatterplots of RTadj vs. M, between both linear and allometric models. Each model yielded nearly the same goodness-of-fit for both genders. Specifically, the Pearson product moment correlation coefficients (r^2) for M vs. RTadj were 0.35 (women), and 0.28 (men) for the linear models; and 0.34 (women), and 0.28 (men) for the allometric models. The allometric modeling applied to the present data indicated that RTadj was directly proportional to $M^{1.76}$ for women and $M^{1.84}$ for men. The 95% confidence intervals for the exponents were 1.06 – 2.47 for women and 1.46 – 2.21 for men. Therefore, the optimal scaling indices for adjusting RTadj by M would be $RTadj \cdot M^{-1.76}$ for women and $RTadj \cdot M^{-1.84}$ for men (6,7). While these exponent values look very different from those published in the literature (3,4,7-11), one should note that there is no precedent in the literature for scaling composite scores like RTadj, which consist of two or more fitness scores.

Since both exponents could be rounded to 1.8, clearly within the 95% confidence interval for both, we determined that the index $RTadj \cdot M^{-1.8}$, was a body mass-bias-free measure of PR performance for both genders. This would prove advantageous in that only set of CFs would be needed for both men and women. From this common index and the definition of the CF specified above, we determined that the CF would equal $M^{-1.8}$ for each M value (in multiples of 5 lb, as is the convention in the PR competition). Since these values, however, consisted of strange units and magnitude, we experimented with multipliers to scale the CF values to produce NRTadj scores more in the range of the present RTadj scores.

The index $10{,}000M^{-1.8}$, which equals the CF value, met this need well. The coefficient of 1000 essentially moved the decimal point four places and created a distribution of NRTadj scores that can be interpreted similarly to those of the present PR convention. One should note that any such coefficient change does not change the relative scores among competitors of the same gender; rather, it simply creates scores that are more user-friendly. Furthermore, in choosing to treat this CF as a dimensionless number, we could preserve the units (sec) of the RTadj. Table 3, then, shows the CF values used for each value of M within the range of competitors in this investigation (100 – 295 lb). For each competitor, male and female, we multiplied the CF value from Table 3 by their RTadj score to yield their NRTadj score (the corrected or new adjusted run time). Figure 2 shows graphically that, in the VAL sub-sample, the NRTadj exhibited no M or age bias.

To examine the external validity of the CFs, we reproduced the scatterplots and statistical data of Figure 2 but applied to the CVAL sample as shown in Figure 3. The NRTadj values virtually eliminated the M bias of the current PR scoring system for women (r^2 = 0.04, $p > 0.05$) and men (r^2 = 0.002, $p > 0.05$) and retained the absence of age bias for women (r^2 = 0.02, $p > 0.05$) and men (r^2 = 0.0004, $p > 0.05$). This suggests that the CFs appears to be valid for future PR competitions.

DISCUSSION

To the practitioner and athlete, the finding that the PR competition presents a bias against heavier competitors might be counter-intuitive given the apparent nature of distance running and bench pressing, the former being advantageous for lighter and the latter usually favoring the heavier. This bias is not unexpected, though, given that this bench press event is more like the push-up test in that both require movement against a resistance that is M-dependent. As previously discussed, maximal repetitions push-ups have been shown to be proportional to $M^{-1/3}$ (4,8) and, therefore advantageous to lighter competitors. Therefore, the combination of the distance run and the BPR and the present scoring system *should* and *does* impose a M bias against heavier competitors.

The common exponent for both genders in the $RTadj \cdot M^{-1.8}$ term, used to develop the CFs, is congruent with empirical findings regarding a number of different fitness measures (7-10,12). Despite the well-documented differences in body structure and composition between men and women, these findings suggests that, while the best-fit curves for the outcome vs. M variables are not coincident, they are generally of the same shape and are roughly parallel, thus contributing to similar exponents when allometric modeling is applied. Indeed, Figure 1 corroborates this notion. Because the CFs for men and women were the same and the men were generally faster, stronger, and heavier than the women, the NRTadj convention tended to increase women's scores more than men's as compared to the RTadj scores. Since PR performances between men and women are not compared, this common CF approach seems appropriate and practical.

The impact of these findings suggests that differences between competitor scores in the PR competition are significantly impacted by M, not just aerobic fitness and muscle endurance. Therefore, the heavier a competitor, the more his/her order of finish would stand to improve compared to the current scoring system if a scoring system free of M bias were employed. Indeed, Table 4 shows how the use of the CFs can affect such results with four runners. With the current PR scoring system, Subject B earns a significantly better RTadj score than Subject A because she is faster and achieved more bench press repetitions. Subject A, however, is 13.6 kg heavier. With the CF of 1.29, she earns a better NRTadj score (lower is better) than Subject B, who has a CF of 1.96. A similar result is shown for men in Subject C and D. One should note that these results are not arbitrarily or artificially produced to give advantages to heavier competitors. Rather, they are the result of a specific protocol designed to eliminate the well-established and documented M bias in many fitness tests.

Table 5 compares the order of finish, using the CF scoring for the top 15 men and women in the PR, compared to that of the current scoring system. As expected, those of larger M values showed large improvements. The female Subject F, 70.3 kg, for example, improved from 26th place to 6th. Conversely, female Subject K, 45.4 kg, was a 3rd place finisher overall but, with corrections factors, moved to 11th. Similarly, male Subject H, 88.5 kg, improved from 17th to 8th place and Subject G, 59.0 kg, went from 2nd to 7th. Yet, the male and female winners in the PR were also the winners using the CF system because both were elite level performers.

The use of CFs to "adjust an already adjusted score" (i.e., converting RTadj to NRTadj) may seem unwieldy or impractical. One might argue rather compellingly that only one adjustment would be simpler and easier to "sell" to PR race directors. In fact, this two-step adjustment comprises one formula:

$$NRTadj = (10{,}000M^{-1.8})[RT - 30(BPR)] \qquad \text{Eq. 2}$$

Race directors could enter this formula into the race spreadsheet and thereby compute the NRTadj with the inputs of RT, BPR, and M. The only difference, then, between the current (RTadj) and proposed (NRTadj) scoring systems is the addition of the CF. Nonetheless, because of the influence of M on the combined score of RT and BPR, any adjusted score must take into account all three variables. Articulating the change this way may be easier for race directors and competitors to both understand and implement.

The CFs exhibit certain characteristics of note. First, dimensionless CFs preserve the original units (sec) of RT and RTadj. Scaled values, on the other hand, do not. For example, the scaled value of $RT \cdot M^{-1/3}$ with units of $sec \cdot kg^{-1/3}$, results in a strange currency of scores with cumbersome units. A CF multiplied by a RT or RTadj, results in scores with units of seconds and values that are more easily interpretable. Second, CFs, unlike scaled values, have no exponents and the calculations for NRTadj, at the very least, can be done by hand. Third, the CF convention added to the already existing scoring system imposes minimal disruption or confusion as to how scores are calculated. Race directors interested in employing the CF system in future PR competitions could simply explain how and why M influences on RTadj should be accounted for.

The influence of body fat on M adjustments is an important consideration in any such modeling because if the "extra credit" granted is directly proportional to M, then one could argue that excess body fatness could be rewarded. This would be undesirable from a health outcomes perspective. Recent analysis, however, provides insight to this issue.

Vanderburgh et al. (14,15,16) have shown that adding fat weight is disadvantageous to the $RT \cdot M^{-1/3}$ score to due its detrimental effect on RT, despite the slight favorable gain from the $M^{-1/3}$ term (low score wins). In essence, the detriment is greater than the gain, thereby contributing to a worse score. This finding, however, is based on both theoretical and empirical data and is therefore not directly applicable to the present data which are only empirically based. In fact, if most of the M differences among competitors in the present competition were due to body fatness, the allometric modeling would yield CFs that would remove much of the performance penalty for being fatter. While body fat measures are unavailable for the present PR sample, 90% of women and 95% of men had M values less than 70 kg and 100 kg, respectively. Therefore, the likelihood that body fatness exhibited a major effect on RT differences was minimal. Nevertheless, the present data do not rule out this possibility.

The influence of effort, particularly during the run, could also unduly influence the present data, particularly if effort were associated with other variables such as age and/or M. This would lead to an inadvertent adjustment not only for age and M but effort as well – clearly an undesirable outcome. In the present data, because effort was not assessed, we can only conjecture that effort was distributed quite evenly across RT, M and age levels within each gender. A ripe area of future study, then, involving age and M biases in the various fitness tests and competitive events, would be quantification of the influences of body fat and effort on the adjusted scores.

In conclusion, these correction factors applied to the present PR competition appear to eliminate the M bias and preserve the zero age bias. They are easy to use and require no other modification of the PR protocol. Furthermore, the original units of seconds for the actual race time are maintained and calculator use is not mandatory, though race directors will find spreadsheet use most effective for determining the scores of all participants. While larger M is given credit, previous evidence suggests that this credit does not reward excess body fat, which imposes a performance decrement larger than the credit gained. Finally, the order of finish of competitors changes considerably as compared with the current scoring system. Because of variations in protocols, we recommend that all PR-type competitions use the procedures as shown in Table 1 along with the correction factors proposed in the present paper.

PRACTICAL APPLICATIONS

The Pump & Run competition has recently been popularized because it consists of two events: a 5K run and a maximal repetitions bench press, the combination of which balances tests of aerobic fitness with muscular strength/endurance. Recent research evidence has made a compelling case that distance runs and muscle endurance tests such as push-ups or sit-ups impose a bias against heavier, not fatter individuals. This study's purpose was to examine if the Pump & Run competition imposed a body mass bias against heavier competitors. Using 74 women and 343 from the largest such event in the U.S., we found that lighter competitors had a significant advantage because the run and the bench press (like the push-up test), each required competitors to lift a percentage of one's body mass. Said differently, an exact scale replica of an individual, only larger, would not be able to run as fast in a distance run, or do as many bench press repetitions. To correct this bias, we developed a set of correction factors which, when applied to the competitors of this Pump & Run, essentially eliminated the body mass bias so that neither lighter nor heavier athletes showed an advantage. We recommend use of the correction factors for future Pump & Run competitions.

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Table 1. Pump & Run (PR) Bench Press Weight Protocol (Ref. 1)

Age	**Bench Press (% of body weight)**	
	Women*	**Men**
39 and under	70%	100%
40-49	60%	90%
50-59	50%	80%
60-69	40%	70%
70+	40%	60%

*Minimum lift for women = 45 lb

The standards for the bench press are as follows:

- An athlete will reduce their run time by 30 seconds for each successful lift (maximum 30 reps) which will allow a runner to reduce their run time by 15 minutes based on 30 reps (maximum allowed).
- Minimum age 18.
- No bench press warm-up will be provided.
- Body weight will be rounded to nearest 5 pound increment (weigh in with; shoes, shorts and shirt - required).
- Lift starts with the bar in the extended position.
- Feet must remain in contact with the floor during the lift. (no hooking bench support with feet/legs).
- Bar must touch the chest and be fully extended on each press- stopping terminates the lift. No bouncing bar off chest.
- Body (shoulder and rear) must stay in contact with bench during lifts.
- If necessary plates may be placed under lifters feet.
- No belts, wraps or lifting suits.

Table 2. Subject Descriptives

	Age (yrs)	**Body Mass (kg)**	**Bench Press Reps**	**5K Run Time (sec)**
	Women (N=74)			
Mean	37.9	59.4	15.0	1537.4
Std Dev	8.5	7.0	9.3	156.6
	Men (N=343)			
Mean	37.5	81.8	18.6	1381.4
Std Dev	9.2	11.4	8.0	174.3

Table 3. Pump & Run Body Mass (M) Correction Factors for Women and Men

M (kg)	M (lb)	CF	M (kg)	M (lb)	CF	M (kg)	M (lb)	CF	M (kg)	M (lb)	CF
45.4	100	**2.51**	68.0	150	**1.21**	90.7	200	**0.72**	113.4	250	**0.48**
47.6	105	**2.30**	70.3	155	**1.14**	93.0	205	**0.69**	115.7	255	**0.47**
49.9	110	**2.12**	72.6	160	**1.08**	95.3	210	**0.66**	117.9	260	**0.45**
52.2	115	**1.95**	74.8	165	**1.02**	97.5	215	**0.63**	120.2	265	**0.43**
54.4	120	**1.81**	77.1	170	**0.97**	99.8	220	**0.61**	122.5	270	**0.42**
56.7	125	**1.68**	79.4	175	**0.92**	102.1	225	**0.58**	124.7	275	**0.41**
59.0	130	**1.57**	81.6	180	**0.87**	104.3	230	**0.56**	127.0	280	**0.39**
61.2	135	**1.46**	83.9	185	**0.83**	106.6	235	**0.54**	129.3	285	**0.38**
63.5	140	**1.37**	86.2	190	**0.79**	108.9	240	**0.52**	131.5	290	**0.37**
65.8	145	**1.29**	88.5	195	**0.75**	111.1	245	**0.50**	133.8	295	**0.36**

Note: Body Mass is recorded to the nearest 5 lb to facilitate ease of determining bench press resistance, which is a set percentage of M, depending on age (from Table 1).

Table 4. Effect of Correction Factors

Subject	**Gender**	**5 km Run Time**	**Age (yrs)**	**Body Mass (kg)**	**BPR[1]**	**RTadj[2]**	**CF[3]**	**NRTadj[4]**
A	F	26:56	45	65.8	14	19:56	1.29	25:43
B	F	22:02	27	52.2	16	14:02	1.96	27:22
C	M	22:30	51	95.3	18	13:30	0.66	8:55
D	M	19:38	26	63.5	25	7:08	1.37	9:46

[1] BPR: Bench Press Repetitions, maximal (according the protocol shown in Table 1

[2] Adjusted Run Time which equals Run Time (sec) minus (30 sec)*BPR

[3] Correction Factor which equals $10{,}000 \cdot (\text{body mass})^{-1.80}$

[4] New Adjusted Run Time which equals RTadj*CF

Table 5. Comparison of Order of Finish, Top 15 runners with and without correction factors

		With Corrections Factors		Without Correction Factors	
Subject	**Body Weight (kg)**	**Adjusted Race Time (sec)**	**Order of Finish**	**Adjusted Race Time (sec)**	**Order of Finish**
Women					
A	54.4	396	1	219	1
B	56.7	825	2	491	4
C	59.0	865	3	552	6
D	49.9	872	4	412	2
E	52.2	963	5	493	5
F	70.3	1036	6	908	26
G	61.2	1109	7	758	14
H	54.4	1127	8	623	8
I	56.7	1136	9	676	9
J	59.0	1156	10	738	12
K	45.4	1176	11	468	3
L	61.2	1209	12	826	17
M	54.4	1241	13	686	10
N	61.2	1254	14	857	20
O	79.4	1275	15	1390	57
Men					
A	63.5	163	1	119	1
B	70.3	170	2	149	3
C	70.3	185	3	162	7
D	68.0	189	4	156	5
E	65.8	197	5	153	4
F	65.8	206	6	160	6
G	59.0	207	7	132	2
H	88.5	230	8	304	17
I	93.0	244	9	353	34
J	77.1	250	10	259	10
K	81.6	256	11	294	16
L	68.0	266	12	220	8
M	68.0	274	13	226	9
N	83.9	286	14	344	27
O	83.9	288	15	347	29

FIGURE LEGENDS

Figure 1. VAL sample (n = 54 women and 258 men) scatterplots of body mass and age vs. adjusted run time using the current scoring system of the Pump & Run competition. The Pearson product moment correlation coefficients for body mass vs. adjusted run time indicated bias for both women ($r^2 = 0.35$, $p < 0.01$) and men ($r^2 = 0.28$, $p < 0.01$). The age vs. adjusted run time correlation coefficients were not different from zero for women ($r^2 = 0.04$, $p > 0.05$) or men ($r^2 = 0.005$, $p > 0.005$), thus indicating little to no bias.

Figure 2. VAL sample (n = 54 women and 258 men) scatterplots of body mass and age vs. adjusted run time using the correction factor system applied to the Pump & Run competition. The Pearson product moment correlation coefficients for body mass vs. adjusted run time indicated no bias for both women ($r^2 = 0.01$, $p > 0.05$) and men ($r^2 = 0.01$, $p > 0.05$). The age vs. adjusted run time correlation coefficients also indicated no bias for women ($r^2 = 0.0002$, $p > 0.05$) or men ($r = 0.00005$, $p > 0.05$).

Figure 3. CVAL sample (n = 20 women and 85 men) scatterplots of body mass and age vs. adjusted run time using the correction factor system applied to the Pump & Run competition. The Pearson product moment correlation coefficients for body mass vs. adjusted run time indicated no bias for both women ($r^2 = 0.04$, $p > 0.05$) and men ($r^2 = 0.002$, $p > 0.05$). The age vs. adjusted run time correlation coefficients also indicated no bias for women ($r^2 = 0.02$, $p > 0.05$) or men ($r = 0.0002$, $p > 0.05$).

Figure 1.

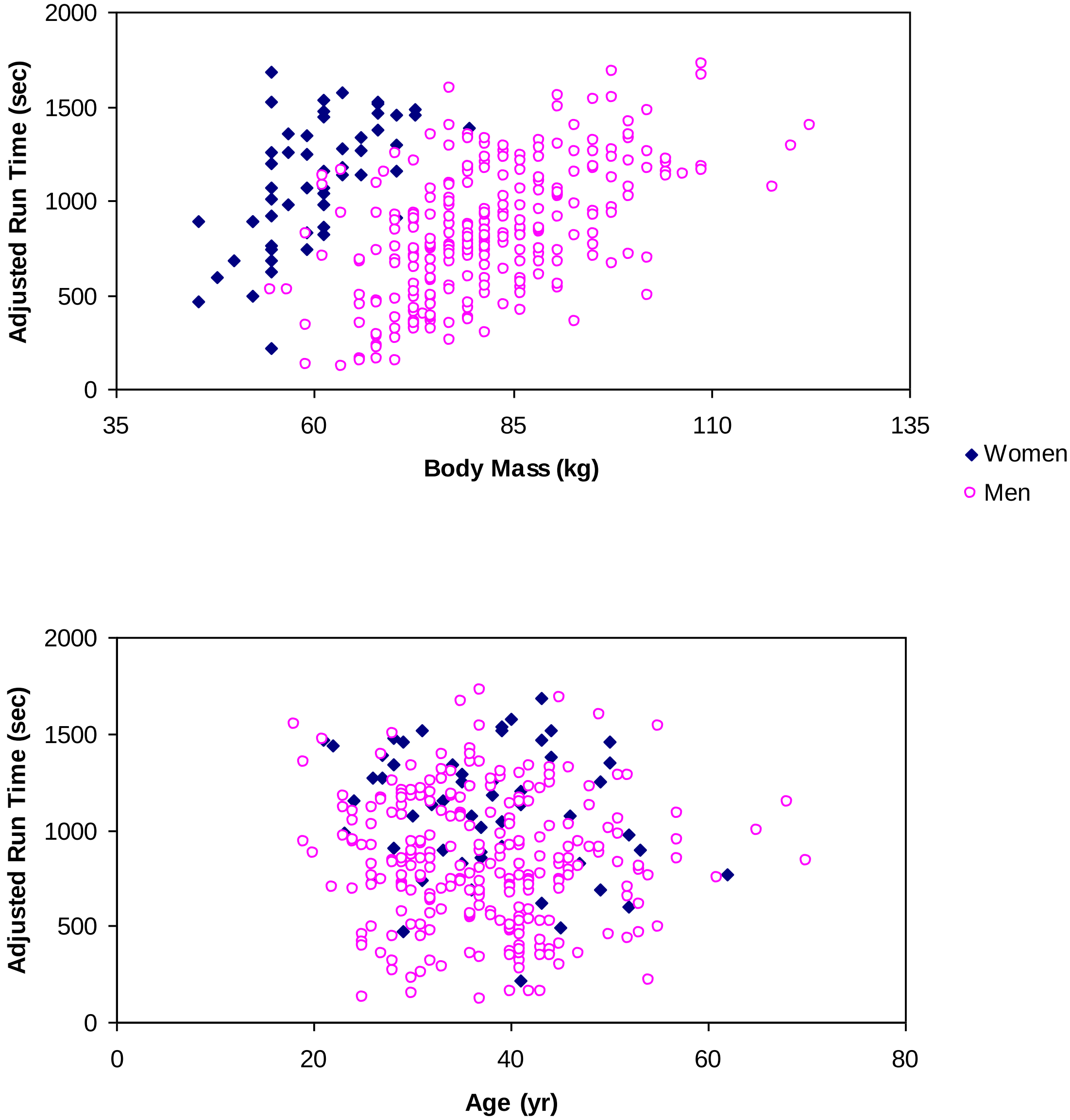
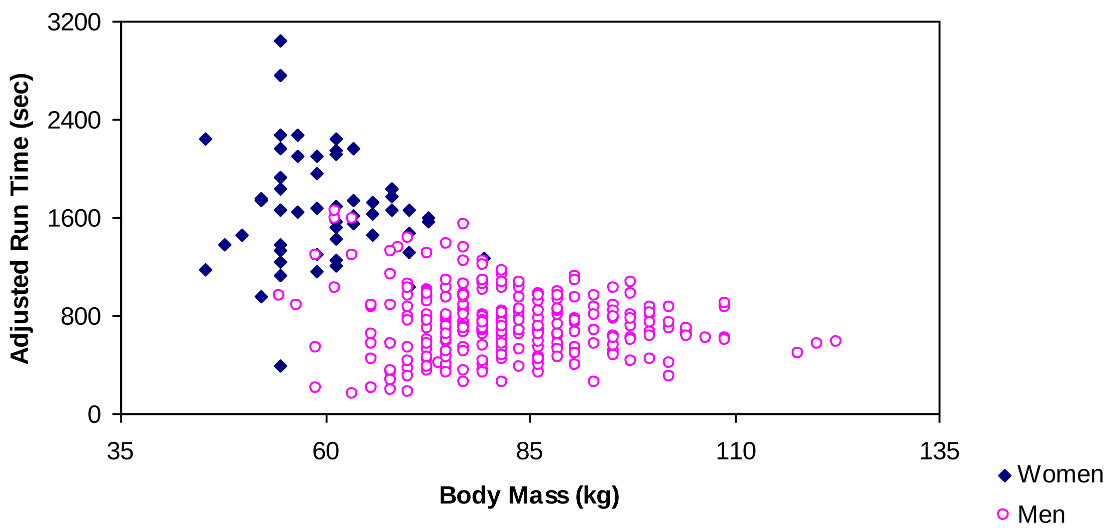

2000
1500
1000
500
0
Adjusted Run Time (sec)
35
60
85
110
135
Body Mass (kg)
Women
Men
2000
1500
1000
500
0
Adjusted Run Time (sec)
0
20
40
60
80
Age (yr)

Figure 2.


Adjusted Run Time (sec)
3200
2400
1600
800
0
35
60
85
110
135
Body Mass (kg)
Women
Men

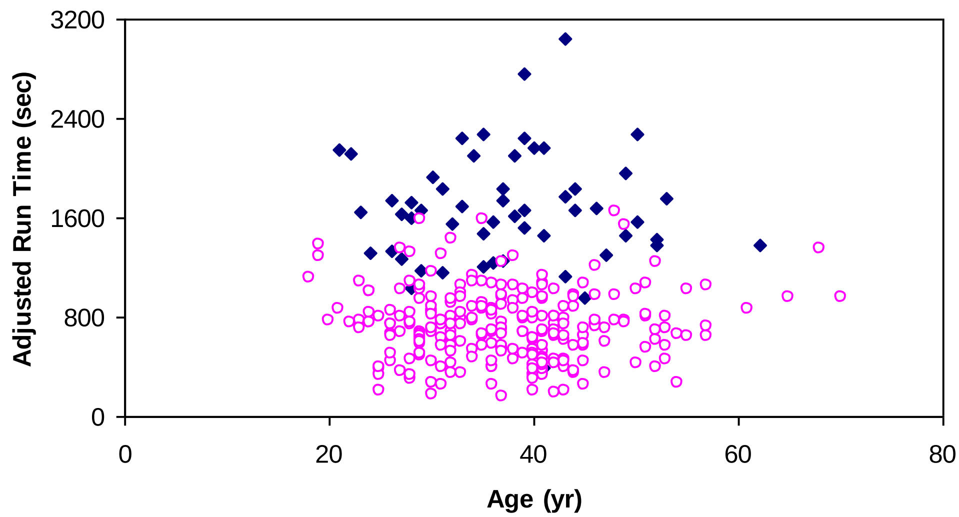
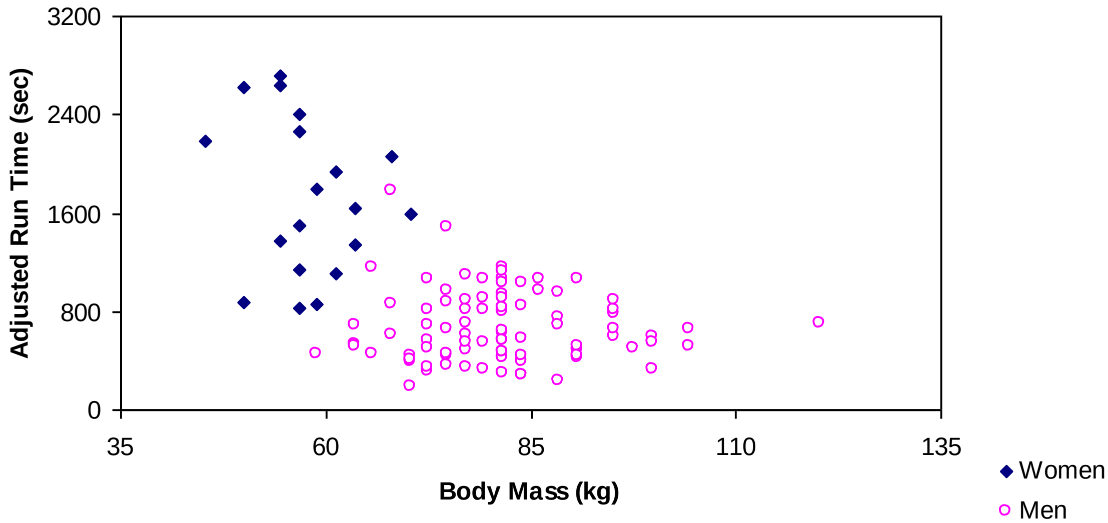
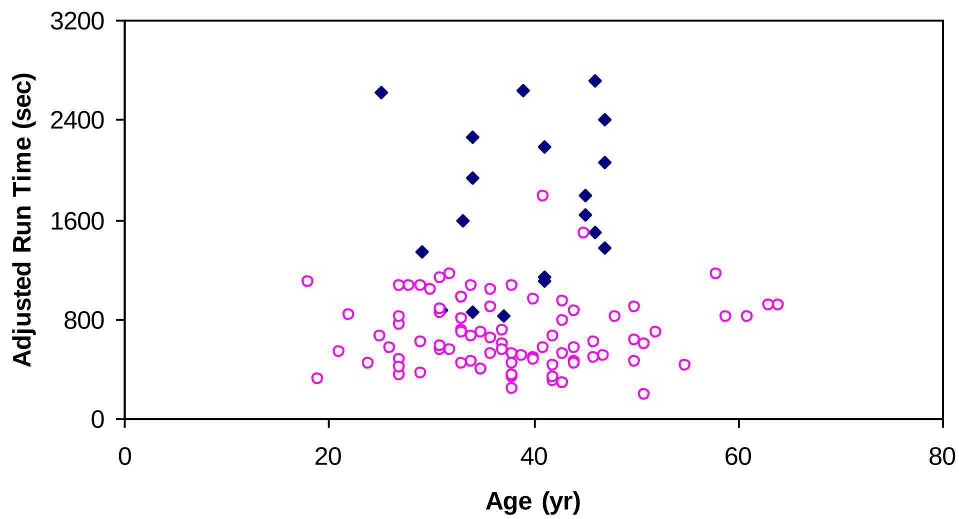

Adjusted Run Time (sec)
3200
2400
1600
800
0
0
20
40
60
80
Age (yr)

Figure 3.


3200
2400
1600
800
0
Adjusted Run Time (sec)
35
60
85
110
135
Body Mass (kg)
Women
Men


3200
2400
1600
800
0
Adjusted Run Time (sec)
0
20
40
60
80
Age (yr)