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Performance on Physical Activities and Athletic Bias in Body Mass Index in Middle School Students

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ABSTRACT

Objectives: To determine whether an association exists between performance on various physical fitness activities (PFs) and body mass index (BMI) in a sample of U. S. middle school students. Are there sex based differences in this association and does an athletic bias exist regarding BMI as a measure of obesity?

Study Design: The Pennsylvania Department of Health instituted the Active Schools Program to encourage daily physical education (PE) in middle schools. This analysis uses the pre-assessment of 9,123 students on four PFs together with information that allowed calculation of BMI and BMI for age- and sex-percentiles (B%). Students were placed in a 16 cell partition based on their sex- and age-adjusted performance on four PFs. Various definitions of athletic and non-athletic are examined based on this partition. Regressions on the logistic transform of B%, L = Ln(B%/[100-B%]), and linear regressions on BMI were performed using the four PFs together with athletic and non-athletic dummy variables.

Results: All models place the rank ordering of the effect of increased PF on body mass as mile run then push-ups then curl-ups. Increasing push-ups and curl-ups decreases L and BMI at a decreasing rate but increased mile performance (faster mile times) decreases L and BMI at an increasing rate. Increased back-saver sit and stretch increases L and BMI. Females see greater effect from increased push-ups and curl-ups and males see greater effect from decreased mile run. An asymmetry exists between those defined as athletes and non-athletes. Athletic females have a smaller athletic bias than males. For example, if both have a B% of 85, the best guess is $\Delta B\%_{\text{Athletic Female}} = 2.5$, 95% CI [0.3, 4.7] and $\Delta B\%_{\text{Athletic Male}} = 5.1$, [2.8, 7.5]. BMI regressions allow estimating Δweight = ΔW and estimated percentage Δweight = $\Delta W\%$ associated with being athletic: $\Delta W_{\text{Athletic Female}} = 3.4$, [0.9, 5.9] pounds and $\Delta W\%_{\text{Athletic Female}} = 3.0\%$, 95% CI [0.8%, 5.2%], and $\Delta W_{\text{Athletic Male}} = 6.2$, [3.8, 8.5] pounds and $\Delta W\%_{\text{Athletic Male}} = 5.6\%$, [3.4%, 7.7%] for students of median height and BMI.

Conclusion: Strong performance on individual PFs does decrease B% and BMI, but doing well on multiple PFs has the reverse effect as long as one of the PFs is the mile run. This provides evidence of an athletic bias in middle school aged students.

INTRODUCTION

Body mass index (BMI = kg·m^{-2}) is used to define obesity in children and adults due to its ease of measurement, its inexpensiveness, and its relatively noninvasive nature. BMI does not measure body fat directly, unlike underwater weighing, skin-fold thickness or bioelectric impedance, but it does correlate to direct adiposity measures (Mei et al., 2002; Sweeting, 2007).

Given the indirect nature of the BMI measure, it is not surprising that it is an imperfect proxy for adiposity. Since muscle is more dense than fat, athletes will tend to have higher weight, and hence higher BMI than a similarly sized non-athlete (Prentice & Jebb, 2001).This has led coaches and trainers to question the validity of BMI (Riewald, 2008; Wein & Palmer, 2008). This bias is likely to be greater for college and elite athletes who emphasize increasing muscle mass through nutrition and weight training programs to enhance their athletic performance (Garrido-Chamorro, Sirvent-Belando, Gonzalez-Lorenzo, Martin-Carratala, & Roche, 2009; Ode, Pivarnik, Reeves, & Knous, 2007).

Nevill et al. (2010) used skinfold thickness and BMI data from elite athletes in seven sports with age-matched controls to examine the adjustments required for elite athletes that would allow BMI for athletes to reflect the adiposity in nonathletic populations. They find that the adjustments required differ by sport. In particular, middle-distance runners require a greater adjustment in BMI than other sports studied (including lightweight- and heavyweight-rowers, long-distance runners and triathletes). Consider, for example, two athletes who are categorized as overweight because both have a BMI of 26. Their BMIs should be “scaled down to more realistically reflect the actual adiposity as measured by their sum of four skinfolds, adjusted to be 20.52 kg·m^{-2} and 15.88 kg·m^{-2} for the heavyweight rower and the middle-distance runner respectively” (Nevill et al., 2010, p. 1014). On a percentage basis, these are adjustments of 21% to 39% and they would place the heavyweight rower in the 18.5 ≦BMI < 25.0 Normal BMI range and the middle-distance runner in the BMI < 18.5 Underweight BMI range (Donato et al., 1998). The Diet and Fitness Today discusses this issue and lists a number of Olympic Gold Medal winners including all members of the 2004 Great Britain coxless four rowers who are overweight or obese according to the Centers for Disease Control (CDC) guidelines (Diet and Fitness Today, 2013). A substantial athletic bias exists in interpreting BMI for highly trained athletes.

The same propensity may exist within a younger and less specialized population as well – but simply to a lesser extent. In their review of the literature, Reichert, Menezes, Wells, Dumith, and Hallal (2009) suggest on p. 290 that this may be behind the lack of association found between physical activity and BMI in boys in some studies. This chapter examines whether an athletic bias exists among middle school students using individual student data from 31 schools in Pennsylvania.

The interpretation of BMI is both sex and age specific for children and teens. As a result, age- and sex-adjusted BMI Percentiles (B%) are obtained using growth charts or using BMI calculator tools such as the one provided by the CDC (Centers for Disease Control and Prevention, 2009). Four B% categories are delineated by the CDC: (a) Underweight, B% < 5.0; (b) Normal, 5.0 ≦B% < 85.0;

(c) Overweight or "at risk for obese," 85.0 $\leqq$B% < 95.0; and (d) Obese, B% $\geqq$ 95.0.

Middle school is noted as a time when students typically become less physically active (Dumith, Gigante, Domingues, & Kohl, 2011). Males and females also develop at different rates as they enter puberty. Males increase muscle mass and reduce body fat and women increase body fat due to hormonal changes in puberty (Knutson, 2005). These differences are considered in calculating B%. Based on these differences, it seems reasonable to conclude that differences may exist with regards to athletic bias between males and females.

In order to test for athletic bias, one must, of course, determine who is, and who is not, an athlete. The measure used in this chapter is performance based – rather than based on a survey of participation in athletic activities (Aaron, Storti, Robertson, Kriska, & LaPorte, 2002). Performance on various physical fitness activities (PFs) is used to determine who is athletic.

METHODS

The Pennsylvania Department of Health (PADoH) instituted the Active Schools Program (ASP) to encourage daily physical activity in middle schools throughout the Commonwealth. Forty schools received a $5,000 grant from PADoH and a 2:1 matching grant from and a number of statewide foundations. The schools agreed to institute a regiment of 30 minutes of daily PE and to assess students on a series of PFs and collect height and weight at the start and the end of the 2009-10 academic year. Nurses and physical educators completed these assessments. They were provided with a modified version of the CDC BMI tools for Schools Excel file that allowed input of PF information, protocols for measuring physical activities, height and weight, and were required to participate in an assessment webinar in September 2009. The present analysis is based on the first assessment from this program.

PADoH received partial information on 11,668 students and complete information on 10,018 from 37 schools. Preliminary analysis found significant outlier issues at 6 of the schools, especially with regard to mile run times. These schools comprised 8.9% of the 10,018 students. These schools had more than three times as many students running the mile in 15-20 minutes and more than twenty times as many students taking at least 20 minutes to run the mile than the rest of the schools. The distribution of “slow milers” cuts across B% categories at these schools. It seems fair to conclude that the students at the excessive mile time schools were not encouraged to do their best on the assessments. These schools were excluded from the present analysis in order to preclude bias that may have been introduced from including a cohort of students that were not encouraged to perform at their best. Therefore this chapter is based on data from 9,123 students at 31 schools.

Median performance by sex × grade is presented in Table 1 for BMI, B% and each of 4 PFs. Standard deviations by sex for each PF are also provided and the bottom of the table provides calculations of standard deviation ratios (whose use will be discussed below). For now, focus on the median values of PF by sex and grade.

*****Insert TABLE 1 about here*****

There is a noticeable jump in performance between grade 6 and grade 7, especially for males. A smaller jump in performance is apparent between grade 7 and grade 8. There is also a noticeable difference between male performances and female performances on the various PFs. Males have lower mile time, higher curl-up and higher push-up performances than females in the same grade. They also tend to be less flexible than females. In deciding on what constitutes superior athletic performance, one must account for these sex- and age-based differences.

Each student will have a performance on a particular activity that places the student in the top half or the bottom half of that activity, relative to others in their grade and sex. A student is placed in the high half of that activity if their performance exceeds the median performance on that activity for their sex and grade; otherwise they are in the low half of that activity. By doing this for each of the four PFs, one can create a 2^4 partition of the data in which each student is placed in one of 16 cells based on their performance with regard to each activity. One partition was created for females and another for males. The partitions thus created are shown in Table 2. Each of the 16 cells in the partition contains three elements. The first, at the left of each cell, is an identifying code that denotes the number and which of the activities for which the student performs in the superior half. The second, at the top center of each cell, is the percent of females or males in this cell (hence these percentages must sum to 100%). The third, at the bottom right of each cell, is the ratio of average cell B% to the gender average B% of 67.2 for females or 66.5 for males. If this ratio exceeds 100%, then students in this cell have a higher average B% than all students of that sex.

*****Insert TABLE 2 about here*****

Defining Athletic and Non-Athletic students

The most restrictive definition of Athletic one could create based on this partition is that a student is Athletic if they are in the top half of all four PFs (cell 4 in the lower right corner of both partitions). Similarly, the most restrictive definition of Non-Athletic would be cell 0, in the lower half of all four PFs (cell 0 in the upper left of both partitions). This, however, is only one definition, and it is not necessarily the best. Before considering alternative definitions, it is worthwhile to notice some of the patterns that emerge from these partitions.

Students are not evenly distributed within each partition. Students tend to be good (or bad) at multiple PFs – not one single PF. The most populated cell for both sexes (cell 0) has more than twice as many students as one would expect based on random placement since random placement would give 1/16 = 6.25% in each cell. For both sexes, the most sparsely populated quarter is the second column – slower half and higher push-ups – has approximately 70% of the population density produced by random placement. The single most sparsely populated cell for both sexes, 2CM, is not in this column and has 64% for females and 53% for males of the population density produced by random placement. Another interesting pattern is that each cell on the faster half on mile run has more students in the high stretch 16th than the associated low stretch 16th but the reverse pattern holds true for the slower half on mile run.

Relative B% is also distributed in a systematic fashion within each partition. The most dramatic differences exist between the first and the fourth columns. Each of the relative B%s in the first column are substantially above 100% while those in the fourth are substantially below 100%. Note also that all 16 cells in the faster half on the mile (the right half of both partitions) are below 100%. Similar cell counts for other PFs are: 10 of 16 for curl-ups and push-ups and 8 of 16 for stretch are below 100% (and these 8 are all in the faster half on the mile). An asymmetry exists with regard to mile run and its association with B%.

The average change in relative B% in going from a slower half on the mile cell to its counterpart in the faster half is a -19.5% (for example, the difference between 1M and 0 for females is -27.0% = 91.0% - 118.0%). The second largest average decline in relative B% due to being in the higher performance half is an average decline of 10.8% in moving from low push-up to high push-up half. Third largest average decline is curl-ups with a decline of 3.2%. Stretch works in the opposite direction: the high stretch half is, on average, 4.7% higher than the low stretch half. The hierarchy of PFs as they reduce B% is seen to be mile run, push-ups, curl-ups, stretch. These cross-PF comparisons mask relative difference between males and females as it relates to the effect of PF on B%. Although both males and females show this same rank ordering in relative B% differences, the magnitude of relative B% change is larger for males for the mile run, curl-ups, and stretch, and for females for push-ups. The same categorical rank ordering will be seen in a number of ways in the subsequent analysis.

Performance on various PFs is used to define individuals as being Athletic or Non-Athletic. Given the hierarchy of relative differences between PFs noted above, performance on the mile run must be included in any definition of Athletic and Non-Athletic. For each of the fractional definitions below, cells from Table 2 and number of females, n_f, and males, n_m, are provided in parentheses. The most restrictive version, the Athletic 16th, requires superior performance on all four PFs (cell 4, n_f = 574, n_m = 566). We weaken this requirement by allowing low stretch in the Athletic 8th (cells 3CPM and 4, n_f = 1,004, n_m = 1,090). The Athletic 4th requires superior performance on the mile and push-ups (the right column in each partition, n_f = 1,377, n_m = 1,529). Inverse image counterparts produce three Non-Athletic fractional groups: the Non-Athletic 4th (the left column, n_f = 1,448, n_m = 1,560); the Non-Athletic 8th (cells 0 and 1S, n_f = 1,024, n_m = 1,122); and the Non-Athletic 16th (cell 0, n_f = 588, n_m = 658). Interestingly, even though the partitions utilize sex- and grade-adjusted performance standards, there are more athletes and non-athletes that are male than female using all three definitions.

The distribution of B% across Athletic and Non-Athletic students

Table 2 provides information about the relative sizes of mean B% for various fractional definitions of Athletic and Non-Athletic but it does not describe how students are distributed across the B% spectrum. Figure 1 depicts the distribution of B% across the 0-100 percentile spectrum. Eight 100% basis histograms are shown, the first four (striped) are for females and the second four (solid) are for males. In each set of four, the first three are Non-Athletic fractional subsamples arranged from the most restrictive to the least restrictive definition and the final (white) is the full sample histogram for that sex. All eight are strongly skewed to the right – this is the obesity crisis in visual form.

*****Insert FIGURES 1 & 2 about here*****

Before focusing on the differences between the Non-Athletic subsamples and the full sample it is worth comparing the female and male full sample histograms. Given twenty bins with a 100% basis histogram, each column would be 5% high if students were distributed uniformly across the B% spectrum (bin labels are the top B% in the 5 percentile wide bin). For all bins prior to 75 both sexes are underrepresented and all bins from 80 to 100 are overrepresented (except 85_{Male} = 5.0%). There are more females that are overweight (bins 90 and 95) and there are more males that are obese (bin 100) using CDC's guidelines (Centers for Disease Control and Prevention, 2009). Despite these differences, the male and female full sample histograms are quite similar to one another. The correlation between these two histograms is r = .975.

It is clear from the Non-Athletic fraction subsample histograms that there is more commonality than difference between the various definitions of Non-Athletic. Different numbers of students are included in each definition, but the BMI percentile profile of a non-athlete remains the same. The average correlation among the six Non-Athletic fraction histograms is r = .991. Since each histogram is on its own 100% basis, the height of the subsample columns relative to the full sample signifies whether individuals within the subgroup are underrepresented or overrepresented at this percentile relative to the group as a whole. Non-athletes have a similar profile to the population at large (average r = .970) except that non-athletes are more skewed towards the obesity end of the spectrum. For females, non-athletes are underrepresented prior to the 80^{th} percentile and overrepresented thereafter. For males, the switch-point appears to be the 90^{th} percentile. The heights of the 100 bin Non-Athletic subsamples are almost twice as high as their full sample counterparts: the likelihood of being obese appears to be almost twice as high for non-athletes than the group as a whole.

Figure 2 presents the distribution of B% for Athletic subsamples. The full sample counterparts are included for all but the last two bins. (As can be seen in Figure 1, the last two bins have full sample values in the 10 to 20% range – their inclusion would necessitate extending the figure's vertical axis and thereby compressing the patterns in the Athletic subsamples that are the focus of Figure 2). Also included are best fit cubic curves for the female and male Athletic 4th (the other four curves provide similar patterns and are suppressed to reduce clutter). While there is a greater difference between subsamples for athletes than non-athletes, the average correlation among the three female Athletic subsamples is r = .946 and among males is r = .936 and the average male versus female Athletic correlation is r = .625. The general pattern to emerge from the Athletic subsample histograms is thus one of commonality across definitions as well as sex. Athletes show increasing representation across the bins at least until about the 85th percentile. Substantial numbers of female and male athletes are in the overweight to obese range according to the categorical B% boundaries.

With a few exceptions, all Athletic subsample columns are higher than their associated full sample columns for CDC's healthy range (bin 10 through bin 85). Broadly stated, the portion of athletes in the normal B% range is larger than the population at large. But they are not evenly distributed within the healthy range. Recall that a column height of 5% is required to achieve an average number of students in each category. Given this, Athletic students have below average amounts of students for the lower half of the B% spectrum. The first set of female Athletic columns achieving the average height of 5% is the 45th; for males this does not happen until the 50th percentile. (This is also seen as the point where the female and male curves cross the 5% boundary.) Using the average height of the three fractional versions of Athletic, 40.3% of female athletes have a B% of 50 or less and 59.7% have B% above 50. For male athletes, the distribution is a bit more skewed: 38.3% have a B% of 50 or less and 61.7% have a B% above 50. Athletes are distributed more than proportionately in the upper half of the B% distribution. Indeed, 17.7% of female athletes and 18.7% of male athletes are categorized as overweight or obese and 4.6% of athletic females and 6.0% of athletic males are obese according to CDC's B% guidelines (and these percentages do not differ appreciably depending on which definition of Athletic is under consideration). Put another way, more than one in six athletes have B% of 85 or higher and are hence categorized as overweight or obese according to CDC guidelines.

Regression analysis

We can refine the tabular and graphical analysis of the relation between body mass and PFs using regression analysis. We are interested in explaining body mass (the dependent variable) as a function of a variety of independent variables such as performance on various PFs as well as other contributing factors such as age and overall performance across activities. Regression allows us to examine the effect of each independent variable on the dependent variable, holding all other independent variables constant. Most basically, regressions estimate slope, therefore, regressions allow us to provide best guess estimates to how body mass will change as a given PF changes.

We must be more explicit about what we mean by body mass. As noted earlier, BMI is age- and sex-specific for children. As a result, BMI for age- and sex-percentile, B%, is used as the dependent variable for the bulk of the analysis below. Nonetheless, BMI is also used as the dependent variable since BMI regressions allow us to back-out estimates of weight change we might expect in a student from altering their performance on various physical activities.

Because B% is bounded by 0 and 100 it is theoretically possible to produce estimates of B% outside this range. A common solution to this problem is to logistically transform the dependent variable, L = L(B%) = Ln(B%/[100-B%]). L is a positive monotonic transformation of B% – higher values of B% imply higher values of L and visa versa. L ranges over the entire number line from $-\infty$ to $+\infty$ as B% ranges from 0 to 100. It is not possible to estimate B% outside of its theoretical bounds if L is used rather than B%.

In the analysis to come, we are less interested in estimates of B% (or L) based on a given set of PFs than we are in interpreting the various slopes of those PFs. We know B% from height, weight, age, and sex – there is no need to estimate it from levels of PF. What we are interested in knowing, however, is: what is the expected change in B% given an incremental change in PF?

Body mass should be a negative function of physical performance, all else held equal. This would confirm the average B% ratio results discussed in Table 2, at least for curl-ups, the mile run, and push-ups. We saw above that stretch appears to work in the opposite direction. This pattern should hold for B% and BMI. But it would not be surprising that there are nonlinearities involved with regard to each PF. To put it simply, the difference between a 6 and a 7 minute mile is likely to be greater than between a 12 and a 13 minute mile. As a result, quadratic terms are included for each of the three activities that do not take on negative values. About 3% of the students exhibited a negative value for stretch. A check of nonlinear alternatives for stretch confirmed that the linear form was appropriate for stretch; therefore, a linear form was used for this activity.

We can test for an athletic bias in B% and BMI by including a dummy variable taking the value of 1 when the student's performance on the various PF activities places that student in the Athletic fraction (16^{th}, 8^{th} or 4^{th}) of all students and otherwise taking the value of 0. Table 2 suggests that stronger performance on the each of the three activities mile run, push-ups, and curl-ups is associated with lower B%. If strong performance on multiple dimensions occurs, the question is: does this further reduce B% or does it act in the reverse fashion and increase B%? If it increases B%, then an athletic bias has been established.

We can test whether performing poorly on multiple physical activities acts in a similar fashion by including a Non-Athletic dummy variable. There is no reason to expect that a variable representing age (Grade is used here) should be significant predictors of B% because it is age (and sex) adjusted. On the other hand, precisely because of the need to consider age and sex adjustments in interpreting BMI in children, we would expect grade to affect BMI differently in the male and female equations, all else equal.

Table 3 presents eight regression equations (in column format). Equations 3.1 – 3.6 show three pairs of regressions – one each for female and male for each of the three definitions of Athletic and Non-Athletic fraction created in Figures 1 and 2 using L as the dependent variable. A quick perusal of these regressions suggests that none of the fractions clearly dominates the other two as a descriptor of L. As expected there are significant differences between male and female models. However, an initial expectation that the most restrictive definition would lead to significantly higher Athletic and Non-Athletic impacts is not borne out in the resulting equations. The Athletic 8^{th} coefficient for males (0.26, $p = .004$) is substantially smaller in magnitude and has a larger p value than either the 16^{th} (0.42, $p < .001$) or 4^{th} (0.40, $p < .001$). At the same time, the Athletic 8^{th} coefficient for females (0.25, $p = .006$) is larger in magnitude and has a smaller p value than either the 16^{th} (0.21, $p = .033$) or 4^{th} (0.20, $p = .027$). The differences across fractional definitions of Non-Athletic are minimal. This should not be surprising, given the similarity of the shape of the Non-Athletic 4^{th}, 8^{th} and 16^{th} in Figure 1. Each of the fractions exhibits significant results, and no fraction dominates. Given this, Athletic 4^{th} is chosen for further analysis – primarily on the basis of practicality. In the absence of significant differences between how the various definitions relate to L, the parsimonious solution is the one that requires the least information.

*****Insert TABLE 3 about here*****

The final two equations in Table 3 change the dependent variable to BMI using the Non-Athletic and Athletic 4th. It is worth noting that the Athletic 4th criterion leads to an approximately even split in number of students in each of the three categories Athletic (right column of Table 2, 30.6% for females, 33.1% for males), Non-Athetic (left column of Table 2, 32.1% for females, 33.8% for males) and mixed athletic (two middle columns of Table 2, 37.3% for females, 33.1% for males).

RESULTS

The regressions provide us with a number of results regarding how PF relates to body mass. We will first examine relative differences between females and males with regard to both PFs and with regard to athletic bias. We next will examine the magnitude of those differences in L and how that can be translated into differences in B%. Finally we will interpret the BMI regressions in order to obtain estimates of weight change associated with changes in PF or from being in the Athletic 4th or Non-Athletic 4th.

Gender differences with regard to PFs

The four pair-wise comparisons of female versus male exhibit a great deal of consistency across specifications. Each of the PFs that are modeled by quadratic terms has linear and quadratic coefficients of opposing signs. This is as expected – there are nonlinear effects of each PF on L and BMI. Increasing PF performance by increasing (the number of) curl-ups and push-ups decreases L and BMI at a decreasing rate. By contrast, increased mile performance (faster mile times) decreases L and BMI at an increasing rate. As noted in the discussion of

Table 2 above, increasing stretch increases L and BMI. The magnitude of those effects differs by sex. Females have larger magnitude and more statistically significant coefficients for curl-ups and larger magnitude coefficients for push-ups than males. Males have larger magnitude and more statistically significant coefficients for mile and stretch than females. Grade is significant in all L(B%) regressions for males despite the fact that B% is theoretically adjusted for age. A similar pattern does not hold for females. Males have larger magnitude and positive coefficients for Grade meaning that B% is increasing across grades, all else held equal. We see from Table 1 that that is not the case (at least in terms of median – the same can be said of mean values had mean values been reported). Given the positive significant coefficient for Grade, this only occurs because all else is not held equal: students are increasing their physical performances over the same time frame (as is also seen in Table 1).

Quadratic coefficients for three of the activities make comparison a bit more challenging. In this instance, the effect of a change in activity level depends on the level of performance of the activity in question.

The net effect of these differences is most readily seen by graphing the parabola created by the linear and quadratic term for each activity. The three panels in Figure 3 graph the parabolic silhouettes created by the coefficient estimates for females (in white) and males (in black) for the three PFs using the coefficients in equations 3.5 and 3.6. The horizontal axis in each panel is the level of performance on the activity, and the vertical axis is the effect of that performance on L. Each curve focuses on the linear and quadratic term (and for ease of comparison, each silhouette intercept is set at zero). For instance, the female curl-up curve in the upper panel is based on the curl-up portion of equation 3.5: $L(C) = -0.038C + 0.048C^2/100$. Each panel also includes a number of other graphic elements; each of these elements maintains the white for females, black for males color coding.

*****Insert FIGURE 3 about here*****

The most obvious of these elements is a second pair of curves in Figure 3 – these represent the distribution of PF performance by females and males. The vertical scale on each pair of distributions has been adjusted so that their shapes can be shown on the same graph as the quadratic curves. To obtain the most balanced comparison across activities, the vertical lines in each panel represent the median level of performance on that activity for females and males. As noted in Table 1, males outperform females on each of these three activities (but females outperform males on the stretch).

At the intersection of the vertical median value line and the quadratic curve is a tangent to the curve. If the quadratic curve is $L(x) = bx + cx^2/100$, then the slope m at any point x is $m(x) = \Delta L/\Delta x = b + 0.02cx$. For example, the slope of L(C) from equation 3.5 is $\Delta L/\Delta C = -0.038+0.00096C$. The tangent shown represents the slope $\Delta L/\Delta C$ at the median level of curl-up performance. It is worth noting that the slope of the tangent to curl-up and push-up curves decreases (in absolute value) as performance on these metrics increases but the slope of tangent to the mile curve increases as performance increases (shorter mile run times). This is a visual portrayal of the decreasing returns to increased performance on curl-ups and push-ups but increasing returns to increased performance on mile run discussed above.

The final graphical element starts at the median point of tangency. The horizontal portion of this “L-shaped” element, Δx, represents an increase in activity x that is closest to being comparable to a decrease in mile run time of 1 minute. These increases are based on the ratio of standard deviation calculations at the bottom of Table 1. These calculations are predicated on the notion that variability in PF performances is related to the inherent difficulty students perceive in achieving a higher level of performance on that PF dimension. An activity with a large standard deviation is likely to be perceived as easier to increase performance than one with a small standard deviation. The ratio of standard deviations across PF metrics provides information on the relative difficulty of achieving different levels of performance on each PF dimension, especially if that comparison starts at median performance for each fitness activity. The closest whole number to the standard deviation ratio calculations is chosen for curl-ups and push-ups. Therefore, 3 additional push-ups for females and 4 for males or 5 additional curl-ups for both females and males are achievements of roughly the same degree of difficulty as a 1 minute decrease in the mile run if each PF starts from its median performance level. For simplicity we will call these Δxs *one-minute-equivalent-ΔPF*. The vertical portion of this element (the vertical distance between diamonds) represents ΔL associated with this increase in performance on that PF (since $\Delta L = \Delta x \cdot m(x) = \Delta x \cdot \Delta L/\Delta x$). Six ΔLs are shown in Figure 3 – one for female and one for male for each of the three activities. Since the vertical scales differ across panels, actual values for these ΔLs are provided here to more readily see differences in magnitude across PF activities: $\Delta L_{F,Curl}$ = -0.044; $\Delta L_{M,Curl}$ = -0.017; $\Delta L_{F,Mile}$ = -0.20; $\Delta L_{M,Mile}$ = -0.28; $\Delta L_{F,Push}$ = -0.14; and $\Delta L_{M,Push}$ = -0.13. Both sets of three ΔLs confirm the rank ordering that emerged in the discussion of Table 2 – the mile run has the greatest effect, followed by push-ups then curl-ups. But, just as we saw with the coefficients in Table 3, there is more of an effect for males from the mile run and more of an effect for females from curl-ups and push-ups.

Figure 4 provides a generalized graphical description of change in L associated with a one-minute-equivalent-ΔPF provided in Figure 3. This figure allows alternative analyses based in alternative PF starting points from the median PF analysis in Figure 3. The vertical axis in each panel of Figure 3 is L – in Figure 4 the vertical axis is the change in L associated with a one-minute-equivalent-ΔPF, labeled ΔL(x). As noted above, the slope of a quadratic is a linear function of PF level x where x is the number of curl-ups, minutes on the mile run, or push-ups prior to the increase in PF. The six lines shown in Figure 4 are the slope lines for each activity × sex multiplied by the number of extra curl-ups (+5) or push-ups (+3 for females, +4 for males) associated with an increased PF achievement that is similar in magnitude to running the mile one minute faster. The mile slope lines are therefore multiplied by -1 (one minute faster time on the mile) to create ΔL(m) for the mile for females and males. The vertical axis coordinate of the points marked on each of the ΔL(x) lines represent the ΔLs listed above and shown graphically in Figure 3. Each starts from the median value for that sex for that activity (the horizontal axis coordinate) and contemplates the expected effect on L of a one-minute-equivalent-ΔPF of each activity. The rank ordering between PFs as well as the sex differences noted above are readily seen in Figure 4. The ΔL(x) lines in Figure 4 generalize the display in Figure 3 and allow the user to create alternative comparisons across PFs based on different starting points for individual performance on each PF.

*****Insert FIGURE 4 about here*****

Gender differences with regard to athletic bias

In each of the eight equations in Table 3, the Athletic fraction coefficient is a statistically significant positive predictor of L and BMI. The information presented in Table 3 and Figures 3 and 4, suggest that increasing performance on each of three dimensions of PF decreases body mass. The positive Athletic fraction coefficient suggests that superior performance on multiple dimensions of PF counteracts this decline. That is, there is an athletic bias associated with L(B%) and BMI.

At the opposite end of the athleticism spectrum, the Non-Athletic fraction coefficient is a statistically significant positive predictor of L and BMI across models. Weak performance on individual dimensions of PF is associated with increased body mass. The positive Non-Athletic fraction coefficient suggests that weak performance on multiple dimensions of PF compounds this increase in body mass. There is an asymmetry between the two ends of the athleticism spectrum.

In each of the four pairs of regressions, the evidence suggests that females face a smaller athletic bias than males. In three of the four comparisons the difference in magnitude is approximately two to one (the Athletic 8^{th} suggests equal effects for both sexes). In all four comparisons, the t-statistic is smaller for females than males. The same can be said of Non-Athletic differences although the differences in magnitude are minimal (and the Non-Athletic 8^{th} female coefficient of 0.20 is greater than the male coefficient of 0.19).

Interpreting slope from logistic models

The first six equations are based on the logistic transformation of BMI percentile, L(B%). As noted above, we are less interested in estimates of L (and hence B%) that may be obtained from the logistic regression models than we are in estimates of how L changes as incremental performance of a PF changes. The estimated slope coefficients from these models are $\Delta L/\Delta x$ where x is an independent variable. These slopes are constant in terms of L but L is a non-linear function of B%, therefore, they are not constant as a function of B%. To transform $\Delta L/\Delta x$ into $\Delta B\%/\Delta x$ slopes, we need a scaling factor S that connects L to B; we need $S = \Delta B\%/\Delta L$ in order to calculate $\Delta B\%/\Delta x = \Delta B\%/\Delta L \cdot \Delta L/\Delta x$. Given the logistic transform $L(B\%) = \ln(B\%/[100-B\%])$ and its inverse function $B\%(L) = 100 \cdot e^L/(1+e^L)$, the scaling factor S can be written as a function of L: $S(L) = 100 \cdot e^L/(1+e^L)^2$; or as a function of B%: $S(B\%) = B\% \cdot (100-B\%)/100$. The S(B%) version makes clear that S is symmetric about B% = 50 (and L = 0). Table 4 shows S for a variety of B% and L values.

*****Insert TABLE 4 about here*****

Suppose you wish to know the expected change in B% associated with a one minute decrease in mile run time for both females and males from their sample medians. The calculations described above and shown in Figures 3B and 4 produced answers of $\Delta L_{F,mile}$ = -0.20 and $\Delta L_{M,mile}$ = -0.28. If both students have a B% of 90, this decrease in mile time would be associated with a best guess decrease of B% of 1.8 for the female and 2.5 for the male. These numbers are obtained by multiplying ΔL times S(90) = 9 from Table 4 to get these values of ΔB% (since ΔB% = ΔL·ΔB%/ΔL). Had both individuals been at a B% of 85, they would instead have a best guess decline in B% from the one minute faster mile of 2.6 for the female and 3.5 for the male (based on S[85] = 12.75).

This same calculation can be performed for any of the coefficients in equations 3.1 – 3.6. Perhaps the most instructive is to examine the Non-Athletic and Athletic 4th coefficients in equations 3.5 and 3.6 examined above. Rather than performing this calculation at a specific B% level, graphs are provided that show the expected change in B% associated with being in the Non-Athletic or Athletic 4th for females and males for different levels of B%. Figure 5 shows these four ΔB% profiles. The dark curve in the middle of each panel depicts the best guess change in BMI percentile as a function of BMI percentile (ΔB% = S[B%]·Coefficient) and the other two curves provide a 95% confidence interval (CI) on this estimate. Each curve is parabolic because S(B%) is parabolic. The 95% CI includes only positive values because all four coefficients are significant at the 95% level. Also included in each panel is a dashed horizontal line at the magnitude of the coefficient in a symmetric equation (not shown) using B% as the dependent variable (rather than L = Ln[B%/{100-B%}]).

*****Insert FIGURE 5 about here*****

These profiles show in graphic fashion that males have larger magnitude (higher best guess curve) and more significant (tighter 95% CI) athletic bias than females at the same B%. Consider, for example, a male and female with B% = 85 who are therefore considered borderline overweight. If the female is in the Athletic 4^{th}, our best guess is that 2.5, 95% CI [0.3, 4.7] of the 85 is due to being in the Athletic 4^{th} while a similarly situated male would have a best guess of 5.1, [2.8, 7.5] of the 85 is due to being in the Athletic 4^{th}. Put another way, a more accurate description of the athletic female's B% is 82.5 and the athletic male's B% is 79.9 despite having a B% of 85.0 based on their height, weight, age and sex.

Implied weight change from changing PFs and from being athletic

The last two equations in Table 3, 3.7 and 3.8, use BMI as the dependent variable. The calculated slopes from these models, $\Delta BMI/\Delta x$, can be used to estimate expected weight change in pounds due to this change in x. These estimates of change in weight, ΔW, are calculated from the formula that ties BMI to weight. Since BMI = kg/m^2 = weight in pounds·703/(height in inches)^2, $\Delta W_{kg} = \Delta BMI \cdot m^2$ and $\Delta W_{lbs} = \Delta BMI \cdot height^2/703$. To translate the expected change in BMI from a change in PF into an expected change in weight one need only know the height of the student involved. The median height of both males and females was 62 inches.

Each of the slope coefficients in equations 3.7 and 3.8 can be interpreted as ΔW using the above transformation. When x is modeled in quadratic form we know that slope in the x direction is a function of x. These calculations are shown in Table 5 using the median levels of PF as the starting point and calculating the effect of a one-minute-equivalent-ΔPF on BMI and weight, just as was done above for L (in Figures 3 and 4). The resulting ΔW calculations range from 3.7 pounds lost for males from one minute faster on the mile run to less than one half pound lost for males from five more curl-ups. The same rank ordering seen earlier for ΔL holds for ΔW – mile produces the greatest change, next comes push-ups then curl-ups. And the same sex differences also hold – males are more impacted by the mile run, while females are more impacted by curl-ups and push-ups.

*****Insert TABLE 5 about here*****

The Athletic 4th coefficients are among the largest in equations 3.7 and 3.8 and both are significant at the .01 level (p_{female} = .008 for p_{male} < .001). Both are larger in magnitude than the decline in BMI associated with a 1 minute lower time on the mile calculated in Table 5. Rather than calculate the implied weight change associated with being in the Athletic 4th at a single height, change in weight as a function of height together with the distribution of height is shown for both females and males in Figure 6. Figure 6 includes three elements in each panel. The probability of achieving a given height is shown (based on 1 inch wide height histograms that have been turned into percentages). For example, 13.3% of the females and 8.8% of the males have a height between 61 and 62 inches (shown as the height of the curve at H = 62). The second element is the best guess increase in weight associated with being in the Athletic 4th for females and males as a quadratic function of height H in inches ($\Delta W_{Athletic\ Female} = 0.62 \cdot H^2/703$ and $\Delta W_{Athletic\ Male} = 1.13 \cdot H^2/703$). The third is a 95% CI for this best guess. Since the standard errors of coefficients are essentially the same (0.233 vs. 0.220) the 95%

CIs for females are males are approximately the same width. The 95% CIs are an expanding function of height. At the median height, our best guess is that athletic females are 3.4, 95% CI [0.9, 5.9] pounds heavier, all else held equal, and athletic males are 6.2, [3.8, 8.5] pounds heavier, all else held equal. Both 95% CIs are approximately 5 pounds wide at this height (5.0 for females and 4.7 for males) but males have a higher expected weight gain from being athletic.

*****Insert FIGURE 6 about here*****

One can avoid weight and height's units of measurement issue (kg and m versus pounds and inches) by calculating weight change on a percentage basis as $\%\Delta W = \Delta BMI/BMI$. Because both sexes get taller and heavier from grade 6 to grade 8, their median BMI varies by less across grades than does their height or weight. Table 1 shows that for both sexes, BMI increases modestly across grades with the largest jump between grades 7 and 8. For the full sample, the median BMI for females is 20.8 and for males is 20.2. This means that BMI slope coefficients can be scaled to $\%\Delta W$ using a scaling factor of approximately 4.8% to 1 for females and 5.0% to 1 for males if both are median BMI students (because .048 = 1/20.8 and .050 = 1/20.2). Given this, the female Athletic 4th coefficient of 0.62 in equation 3.7 can be reinterpreted as an approximately 3.0%, 95% CI [0.8%, 5.2%] increase in weight from being in the Athletic 4th and the male Athletic 4th coefficient of 1.16 in equation 3.8 can be reinterpreted as an approximately 5.6%, [3.4%, 7.7%] increase in weight from being in the Athletic 4th given a median BMI student.

CONCLUSION

This chapter examines the association between four PF measures and two measures used to describe overweight and obesity, B% and BMI. This chapter uses a cross-sectional analysis of the correlates of PF and BMI instead of longitudinal analysis that focuses on the temporal relation between PF and adiposity (Reichert, Baptista Menezes, Wells, Carvalho Dumith, & Hallal, 2009).

When viewed from a variety of perspectives, the same hierarchical pattern emerges regarding the relative importance of the PFs analyzed in explaining both indices. The most important is the mile run, followed by push-ups and curl-ups. Broadly speaking, if we examine comparable performance improvements across PFs we see that the best guess change in B% and BMI from decreased time on the mile run is about 1.5 times as large as the change in B% and BMI associated with a similar magnitude increase in push-ups and 3.5 to 10 times as large as the change in B% and BMI associated with a similar magnitude increase in curl-ups. The mile tends to have a greater effect on males while curl-ups and push-ups tend to have a greater effect on females.

Increasing performance on push-ups and curl-ups decreases B% and BMI at a decreasing rate but increasing performance on the mile does so at an increasing rate. Increased back-saver sit and stretch is positively associated with B% and BMI but the magnitude of that effect is small. Other researchers, using a different set of four PAs and examining a different research question, found a similar asymmetry existed between flexibility and other PAs (800/1600 meter run, standing long jump, bent leg curl-ups) with regard to how PA performance affected BMI (Freedman et al., 2005).

To examine whether athletic students differ from non-athletic or students of mixed athleticism, we created a two partitions, one for males and the other for females, based on their grade-adjusted performance on each of the activities. We utilized the hierarchy among these activities noted above to create three alternative fractional definitions of athletic and nonathletic performance. Histograms of B% frequency for each version of athletic and nonathletic suggests that little is gained from defining athletic and nonathletic performance using all four PF metrics – it is sufficient to define athletic and nonathletic performance on the basis of the mile run and push-ups.

Regression analysis confirms that an athletic bias exists for both genders. This bias appears to be more important for males than for females. This is consistent with other research that argues that gender based differences emerge in early adolescence (Knutson, 2005).

No clear rationale requires using median performance to create the partition that forms the basis for this analysis. Above median performance on both the mile run and push-ups produces a situation in which approximately one third of students are in each of the three classifications (in Table 2, the right column is the Athletic 4^{th}, the left column is the Non-Athletic 4^{th} and the two middle columns are the mixed athletic [half]). This is clearly a broad definition of athleticism. Another cut-off may produce superior models to those presented here. Chen et al. (2002), suggested using the 43% of students who scored higher than the lowest quartile on all four physical activities to define the fitter subgroup on which BMI norms could be based. An analysis similar to this one could easily be performed using performance cutoffs provided by external sources such as the *President's Challenge* for various activities.

A worthwhile extension of this analysis would be to examine how nutritional differences affect the model. Another extension would be to examine the distribution of the components of BMI as fat mass and fat-free mass for athletic and nonathletic performers. One would expect a substantially higher fat-free component for athletes than non-athletes (Freedman et al., 2005). It would be interesting to see whether that component remains relatively constant across BMI categories for different classes of PF activity performers. This information could be used to revise BMI interpretation protocols employed by health professionals and physical educators.

It would also be worthwhile to examine the extent of athletic bias in elementary and high school age groups as well as among the adult population. Nevill et al. (2010) have shown that a substantial bias exists for elite athletes, but the vast majority of athletic individuals are not elite. We have shown a more modest, but, nonetheless, statistically significant athletic bias exists for middle school students. It may well exist for other students as well as for adult athletes of non-elite stature.

Some states have implemented mandatory BMI report cards for children in their state (Evans & Sonneville, 2009). If parents are provided with BMI report cards, then those report cards should be provided with the caveat that if their child is athletic, then the BMI on their report card overstates their adiposity status.

BMI is widely used to classify weight status but many who use it also view it with skepticism (Jonnalagadda, Skinner, & Moore, 2004; Riewald, 2008; Wein & Palmer, 2008). Some of that skepticism may be eased if physical fitness activity metrics are included with BMI information. Coaches would no longer have to complain that they simply do not trust BMI because it says that they, as well as the athletes they are coaching, are overweight or obese despite evidence to the contrary.

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Table 1. *Median Performance by Sex and Grade and Variability in Performance by Sex.*

Grade	BMI		B%		Curl-Ups		Mile		Push-Ups		Stretch		*N* Students	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
6	20.1	19.7	76.1	77.9	30	34	12.1	11.1	7	13	9.5	8.3	1,034	1,130
7	20.5	19.9	74.4	71.8	31	38	11.5	10.0	8	16	11.3	9.0	1,771	1,839
8	21.4	20.8	75.1	74.1	32	38	11.3	9.8	8	17	11.2	9.0	1,701	1,648
6-8	20.8	20.2	75.1	74.0	31	37	11.6	10.1	8	16	11.0	9.0	4,506	4,617
				Fitness SD	14.0	14.9	2.83	2.92	9.4	12.95	4.3	4.4		
Comparable increase in performance of other fitness activities to 1 minute faster on the mile run.														
					SD_{Curl}/SD_{Mile}				SD_{Push}/SD_{Mile}		$SD_{Stretch}/SD_{Mile}$			
					Female	Male			Female	Male	Female	Male		
					5.0	5.1			3.3	4.4	1.5	1.5		

Note. BMI = body mass index, B% = BMI percentile, SD = standard deviation for grade 6 - 8 by sex.

Table 2. *Using 16 Cell Physical Fitness Performance Partitions to Define Athletic and Non-Athletic Fractions: Percent of females and males and relative body mass index percentile in cell for 2^4 performance partition based on sex- and grade-adjusted median values on each of four fitness activities from Table 1.*

Female Partition: Curl-ups	Back-Saver Sit & Stretch	Non- Athletic	Slower Half on Mile, Low Push-ups: Code	% of Students / Relative B%	Slower Half on Mile, High Push-ups: Code	% of Students / Relative B%	Faster Half on Mile, Low Push-ups: Code	% of Students / Relative B%	Faster Half on Mile, High Push-ups: Code	% of Students / Relative B%	Athletic
Low Curl-ups	Low Stretch	16th	0	**13.0%** **118.0%**	1P	**5.6%** **103.8%**	1M	**5.2%** **91.0%**	2MP	**3.9%** **83.3%**	4th
	High Stretch	8th	1S	**9.7%** **118.2%**	2PS	**4.0%** **101.7%**	2MS	**5.6%** **99.8%**	3M-PS	**4.4%** **90.6%**	
High Curl-ups	Low Stretch	4th	1C	**4.9%** **107.4%**	2CP	**4.3%** **99.5%**	2CM	**4.0%** **95.4%**	3C-MP	**9.5%** **82.8%**	8th
	High Stretch		2CS	**4.5%** **115.2%**	3C-PS	**4.2%** **100.3%**	3C-MS	**4.4%** **96.9%**	4	**12.7%** **84.8%**	16th

Male Partition: Curl-ups	Back-Saver Sit & Stretch	Non- Athletic	Slower Half on Mile, Low Push-ups: Code	% of Students / Relative B%	Slower Half on Mile, High Push-ups: Code	% of Students / Relative B%	Faster Half on Mile, Low Push-ups: Code	% of Students / Relative B%	Faster Half on Mile, High Push-ups: Code	% of Students / Relative B%	Athletic
Low Curl-ups	Low Stretch	16th	0	**14.3%** **115.3%**	1P	**4.3%** **100.6%**	1M	**4.5%** **86.5%**	2MP	**4.2%** **84.8%**	4th
	High Stretch	8th	1S	**10.0%** **124.0%**	2PS	**3.6%** **103.7%**	2MS	**5.1%** **98.0%**	3M-PS	**5.3%** **91.9%**	
High Curl-ups	Low Stretch	4th	1C	**4.9%** **115.4%**	2CP	**4.2%** **99.99%**	2CM	**3.3%** **82.5%**	3C-MP	**11.3%** **81.6%**	8th
	High Stretch		2CS	**4.6%** **115.5%**	3C-PS	**4.2%** **103.0%**	3C-MS	**3.8%** **92.3%**	4	**12.3%** **86.9%**	16th

Note. B% = body mass index percentile. C = curl-ups. M = mile. P = push-ups. S = Stretch. Each of the 16 cells has three items: (a) an identifier code (left), delineating the number and which athletic halves; (b) percent of females out of 4,506 or percent of males out of 4,617 (top); and (c) cell average B% relative to the gender average B% of 67.2 for females or 66.5 for males (bottom right). Three Athletic and Non-Athletic fractional definitions based on these partitions are shown in the right column and left column, respectively.

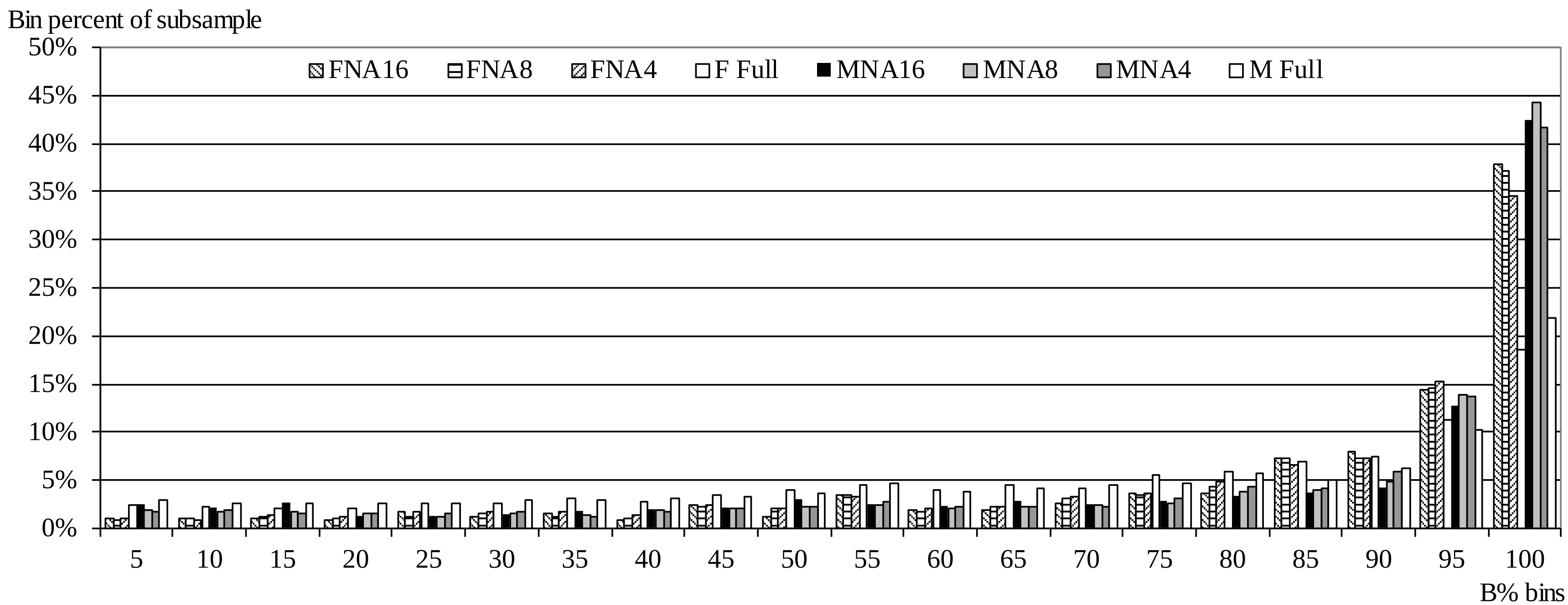


Figure 1. Frequency histograms of body mass index percentile (B%) for full and 3 Non-Athletic (NA) fractional subsamples defined in Table 2 by sex. Each of the eight histograms is on its own 100% basis. The left portion of each bin is for females (F) and the right portion is for males (M). Bin labels are the top of the 5 percentile wide bin.

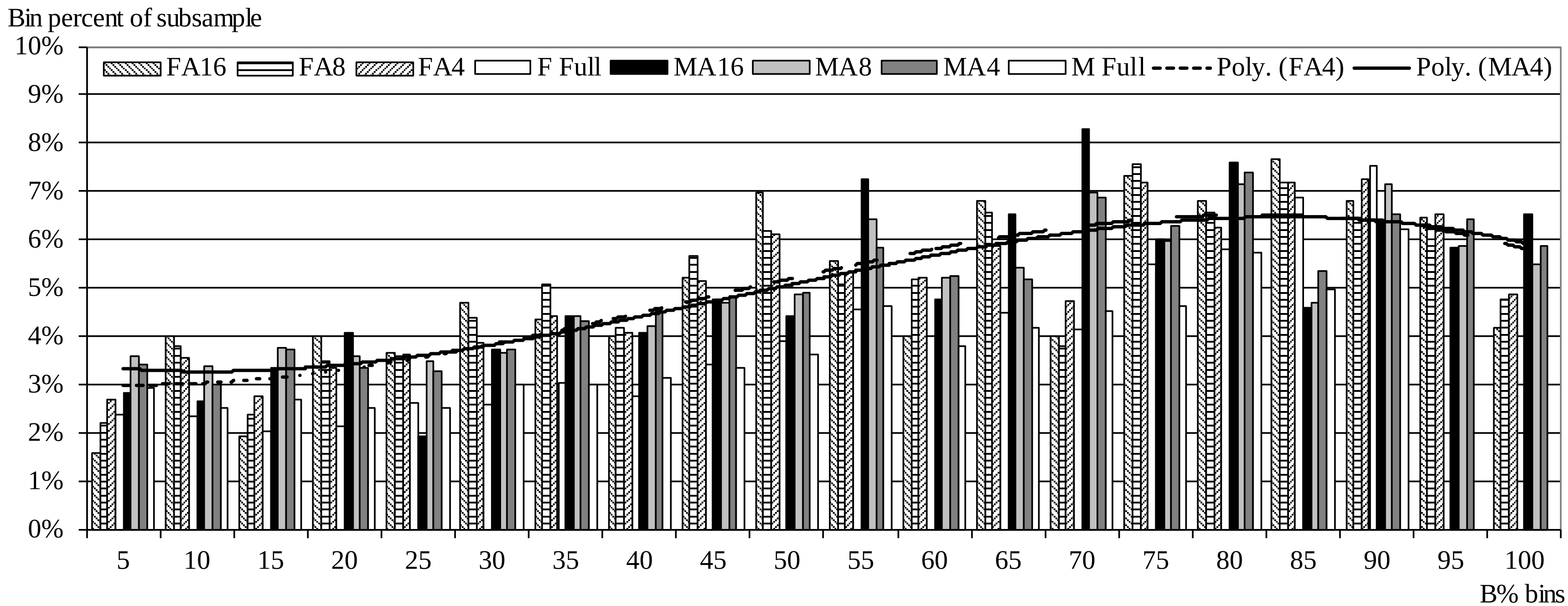


Figure 2. Frequency histograms of body mass index percentile (B%) for full and 3 Athletic (A) fractional subsamples defined in Table 2 by sex. Each of the eight histograms is on its own 100% basis. Full sample histograms are suppressed for bins 95 and 100 because their inclusion would require expanding the vertical axis to 22% thereby compressing the Athletic fractional subsample histograms. The left portion of each bin is for females (F) and the right portion is for males (M). Bin labels are the top of the 5 percentile wide bin. The curves are best fit cubic functions based on Athletic 4th subsamples.

Table 3. *Logistic(B%) and BMI as a Funtion of Physical Fitness Performances and Athletic Fraction*

Dependent variable	L = logistic(B%) = Ln(B%/[100-B%])						BMI=703·wt.lbs/(ht.in.)^2	
Athletic fraction	16th		8th		4th		4th	
Equation and Sex	3.1 Female	3.2 Male	3.3 Female	3.4 Male	3.5 Female	3.6 Male	3.7 Female	3.8 Male
Intercept	-1.57 **	-3.15 ***	-1.72 ***	-2.85 ***	-1.61 **	-3.11 ***	11.21 ***	7.10 ***
	0.49	0.50	0.51	0.46	0.54	0.50	1.41	1.19
Curl-up	-0.038 ***	-0.014 *	-0.037 ***	-0.012	-0.038 ***	-0.014 *	-0.143 ***	-0.054 ***
	0.0069	0.0066	0.0070	0.0069	0.0068	0.0066	0.0177	0.0158
Curl-up^2/100	0.048 ***	0.014	0.045 ***	0.012	0.048 ***	0.014	0.166 ***	0.052 **
	0.0090	0.0074	0.0090	0.0074	0.0090	0.0074	0.0235	0.0175
Mile	0.34 ***	0.51 ***	0.35 ***	0.48 ***	0.34 ***	0.50 ***	0.60 ***	0.95 ***
	0.059	0.057	0.062	0.052	0.065	0.057	0.169	0.135
Mile^2/100	-0.597 **	-1.131 ***	-0.644 **	-1.034 ***	-0.586 *	-1.118 ***	-0.201	-1.291 **
	0.2236	0.2092	0.2288	0.2004	0.2327	0.2095	0.6097	0.4988
Push-Up	-0.059 ***	-0.047 ***	-0.059 ***	-0.044 ***	-0.057 ***	-0.047 ***	-0.173 ***	-0.137 ***
	0.0074	0.0072	0.0080	0.0063	0.0092	0.0072	0.0242	0.0172
Push-up^2/100	0.071 ***	0.044 ***	0.070 ***	0.042 ***	0.069 ***	0.043 ***	0.248 ***	0.135 ***
	0.0186	0.0109	0.0193	0.0104	0.0208	0.0109	0.0544	0.0260
Stretch	0.017 *	0.035 ***	0.017 **	0.035 ***	0.017 **	0.035 ***	0.029	0.076 ***
	0.0069	0.0062	0.0062	0.0062	0.0062	0.0062	0.0162	0.0147
Grade	0.063	0.098 **	0.063	0.094 *	0.064	0.097 **	0.991 ***	1.096 ***
	0.035	0.038	0.035	0.037	0.035	0.038	0.092	0.090
Non-Athletic xth	0.19 *	0.25 **	0.20 *	0.19 *	0.21 *	0.25 **	0.60 **	0.66 **
fraction x	0.094 16th	0.091 16th	0.086 8th	0.092 8th	0.084 4th	0.091 4th	0.219 4th	0.218 4th
Athletic xth	0.21 *	0.42 ***	0.25 **	0.26 **	0.20 *	0.40 ***	0.62 **	1.13 ***
fraction x	0.098 16th	0.092 16th	0.092 8th	0.091 8th	0.089 4th	0.092 4th	0.233 4th	0.220 4th
R^2	.1645	.1883	.1658	.1852	.1651	.1878	.2119	.2388
F	88.5 ***	106.9 ***	89.3 ***	104.7 ***	88.9 ***	106.5 ***	120.9 ***	144.5 ***

Note. BMI = body mass index and B% = BMI percentile. Female regressions based on N = 4,506 and male regressions based on N = 4,517. Athletic and Non-Athletic fractions are based on the performance partitions in Table 2. Raw regression coefficients with SEC beneath each coefficient. * p < .05; ** p < .01; *** p < .001.

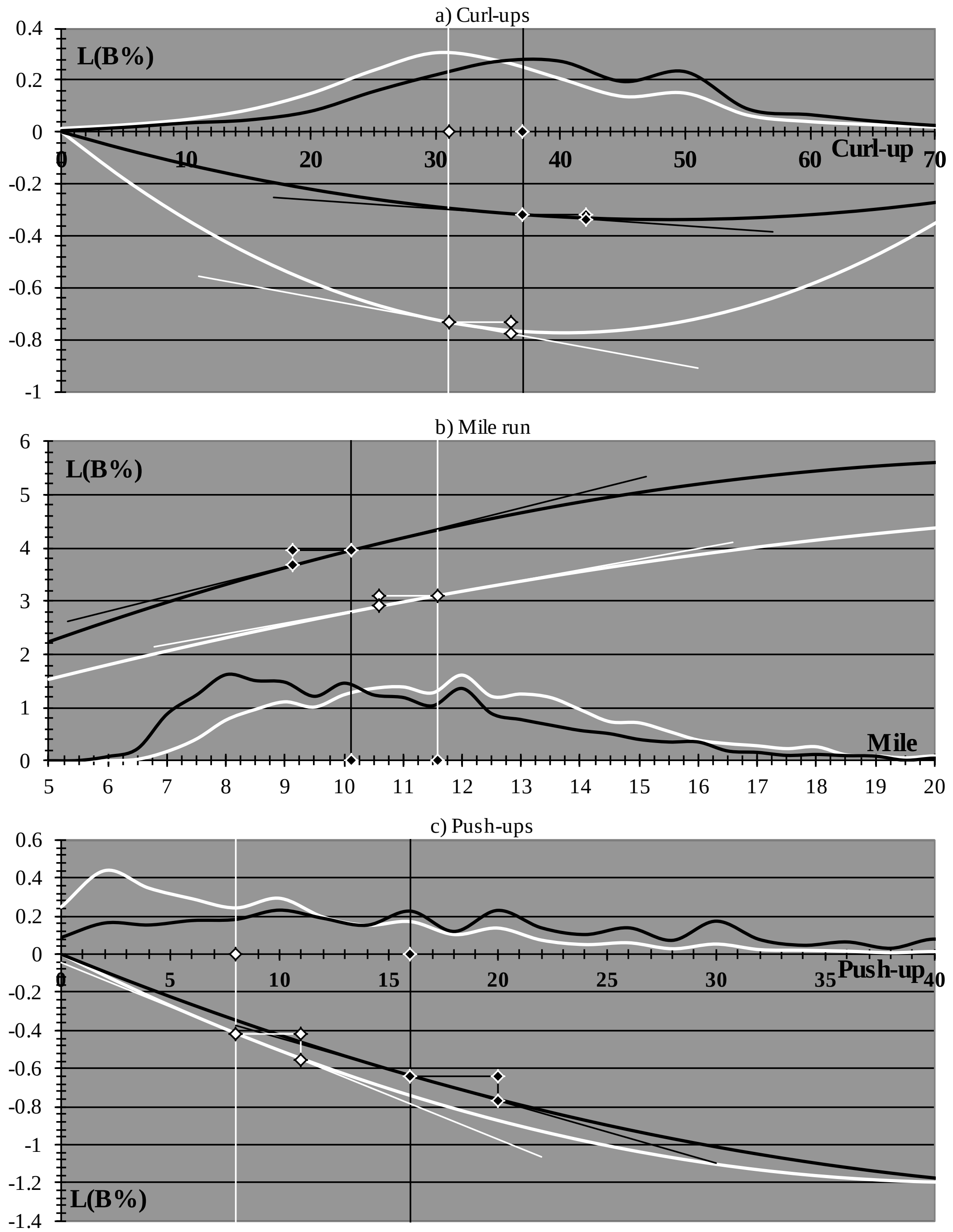


Figure 3. Estimating the effect of a change in physical fitness, ΔPF, on logistic of body mass index percentile, L(B%), for Females (F-white) & Males (M-black). Panels show the distribution and median values (vertical lines) of curl-ups, mile run and push-ups and the quadratic silhouette of regressions 3.5 (F) & 3.6 (M) in those directions. Tangents to each curve at the median are shown together with the effect of an increase in performance from the median similar in size to a 1 minute faster mile time on L(B%) based on relative SD values in Table 1.

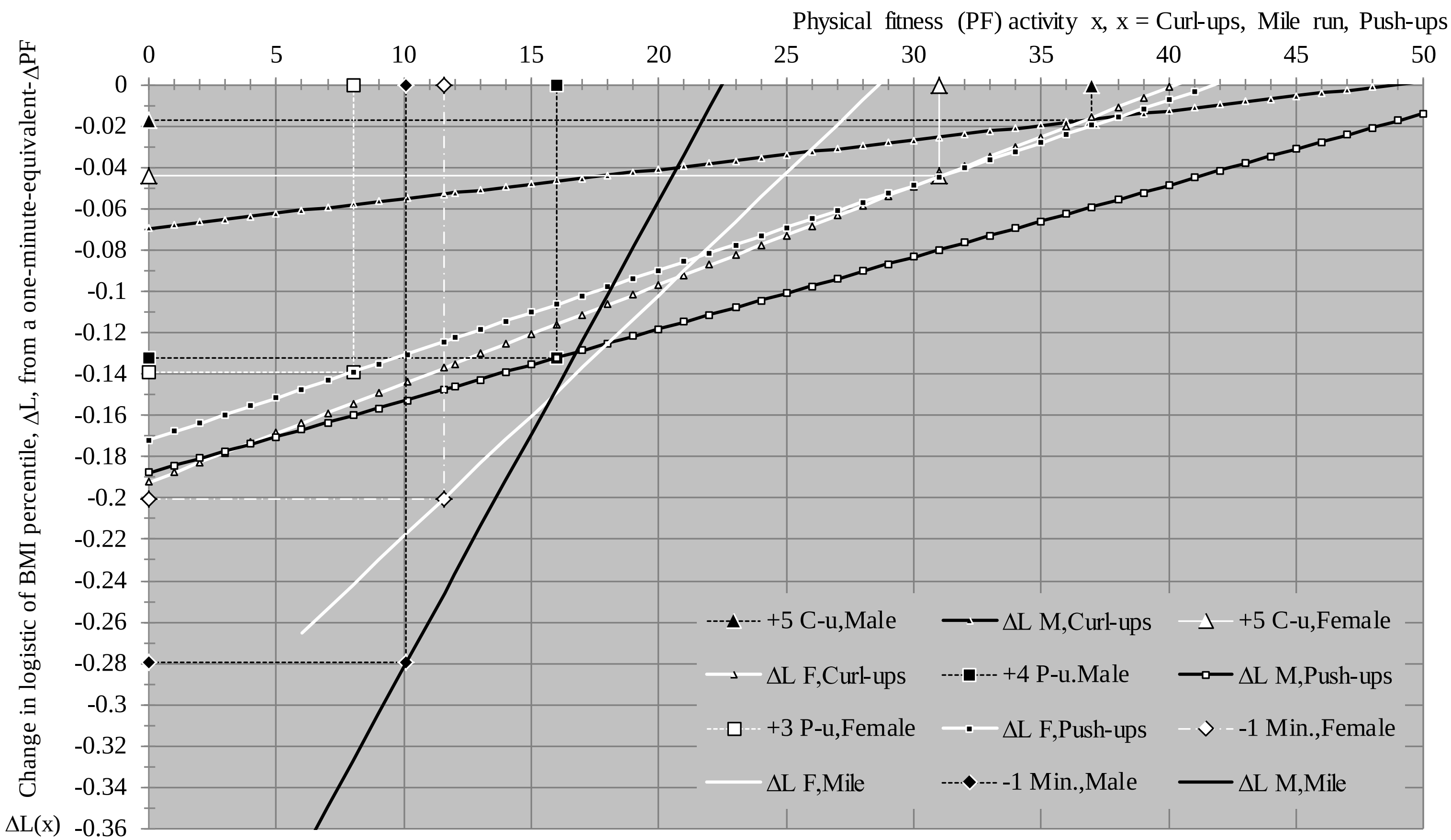


Figure 4. Estimating the effect of a "one-minute-equivalent-ΔPF" on L, ΔL, for Females (F-white) and Males (M-black). ΔL = Δx·ΔL/Δx with Δx noted for each activity in the legend (relative SD in Table 1) and ΔL/Δx estimated from linear and quadratic slope coefficients in equations 3.5 (F) and 3.6 (M). The locations marked on the ΔL lines use the median value of each activity (Table 1) as the starting point for the ΔL depicted in Figure 3.

Table 4. *Scaling Factor (S) for Interpreting Logistic Slope Coefficients.*

B%	99 or 1	95 or 5	90 or 10	85 or 15	70 or 30	60 or 40	50	B% = BMI percentile
L	± 4.595	± 2.944	± 2.197	± 1.735	± 0.847	± 0.405	0	L = Ln(B%/[100-B%])
S	0.99	4.75	9	12.75	21	24	25	S = ΔB%/ΔL

Note. $S(L) = 100 \cdot e^L/(1+e^L)^2$ is obtained by taking the derivative of the inverse of the logistic function, function $B\%(L) = 100 \cdot e^L/(1+e^L)$. Slope as a function of B%, $S(B\%) = B\% \cdot (100-B\%)/100$ is the inverse of the derivative of the logistic transform, dL/dB%.

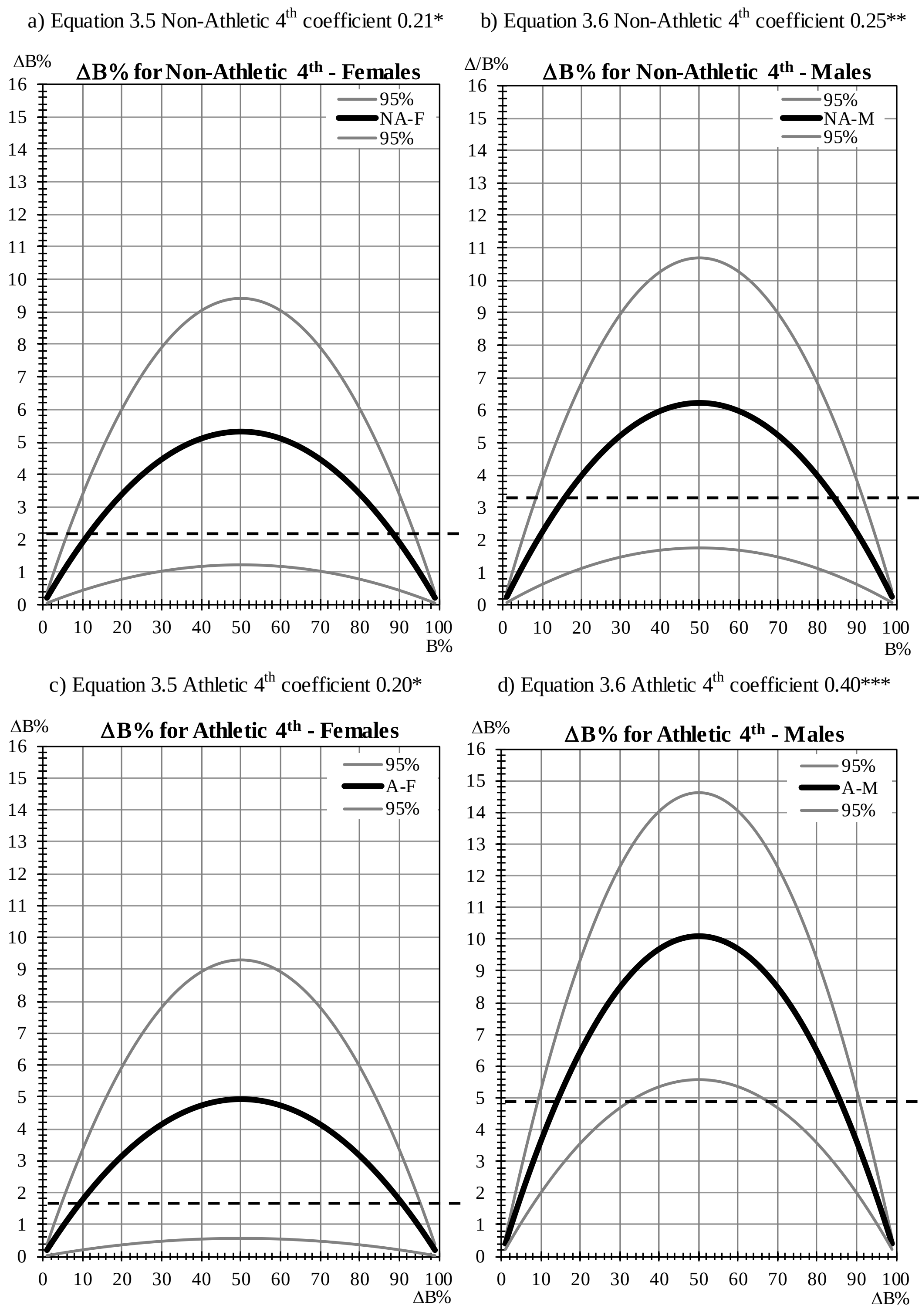


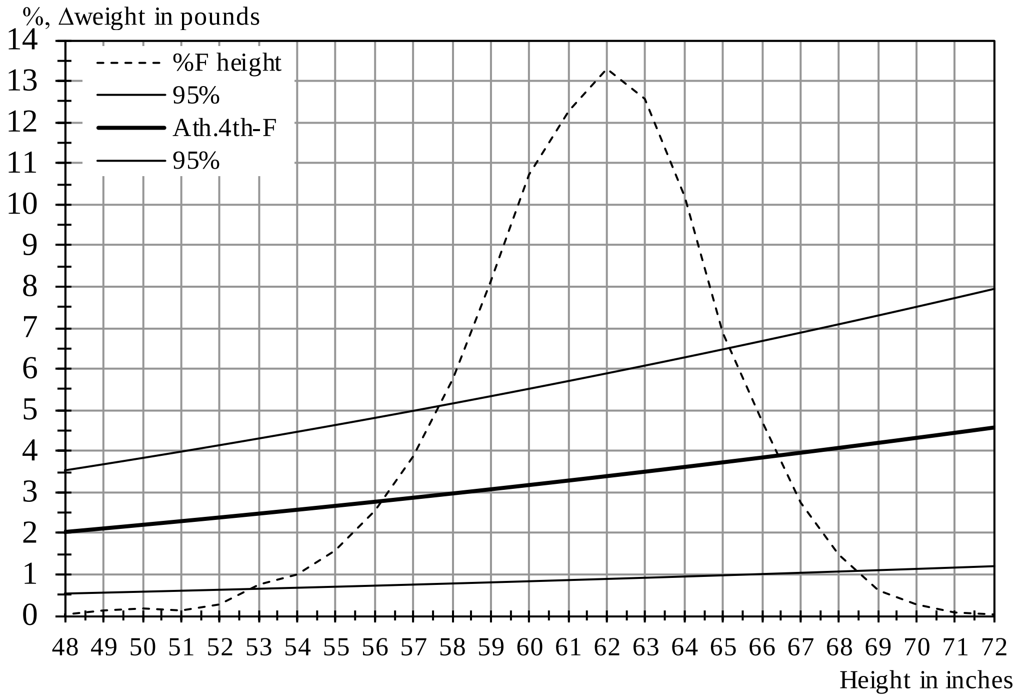
Figure 5. Estimated change in body mass index percentile (ΔB%) and 95% confidence interval of being in the Non-Athletic 4th or Athletic 4th as defined in Table 2. The dashed line is the magnitude of that variable in symmetric linear B% regressions (not shown in Table 3) whose coefficient, [95% CI] in panels a - d are 2.27, [-0.24, 4.77], 3.34, [0.64, 6.03], 1.77, [-1.00, 4.32], and 4.85, [1.01, 6.47], respectively.

Table 5. *Estimating the change in weight in pounds associated with a change in physical fitness (PF) performance using coefficients from equations 3.7 and 3.8.*

PF = x =	Curl-ups		Mile run		Push-ups	
	Female	Male	Female	Male	Female	Male
Median x (Table 1)	31	37	11.58	10.12	8	16
Slope ΔBMI/Δx at median x $coef_x + 0.02 \cdot (coef_x^2/100) \cdot x$ =	-0.039	-0.016	0.56	0.68	-0.13	-0.094
Δx (see relative SD, Table 1) =	5	5	-1	-1	3	4
ΔBMI at median x, $\Delta x \cdot \Delta BMI/\Delta x$ =	-0.20	-0.08	-0.56	-0.68	-0.40	-0.37
Δweight from Δx increase in x given 62 inch student = $\Delta BMI \cdot 62^2/703$ =	-1.1	-0.4	-3.0	-3.7	-2.2	-2.0

Note. BMI = body mass index. coef. = coefficient.

a) Females, Athletic 4th coefficient 0.62** in equation 3.7.



b) Males, Athletic 4th coefficient 1.13*** in equation 3.8.

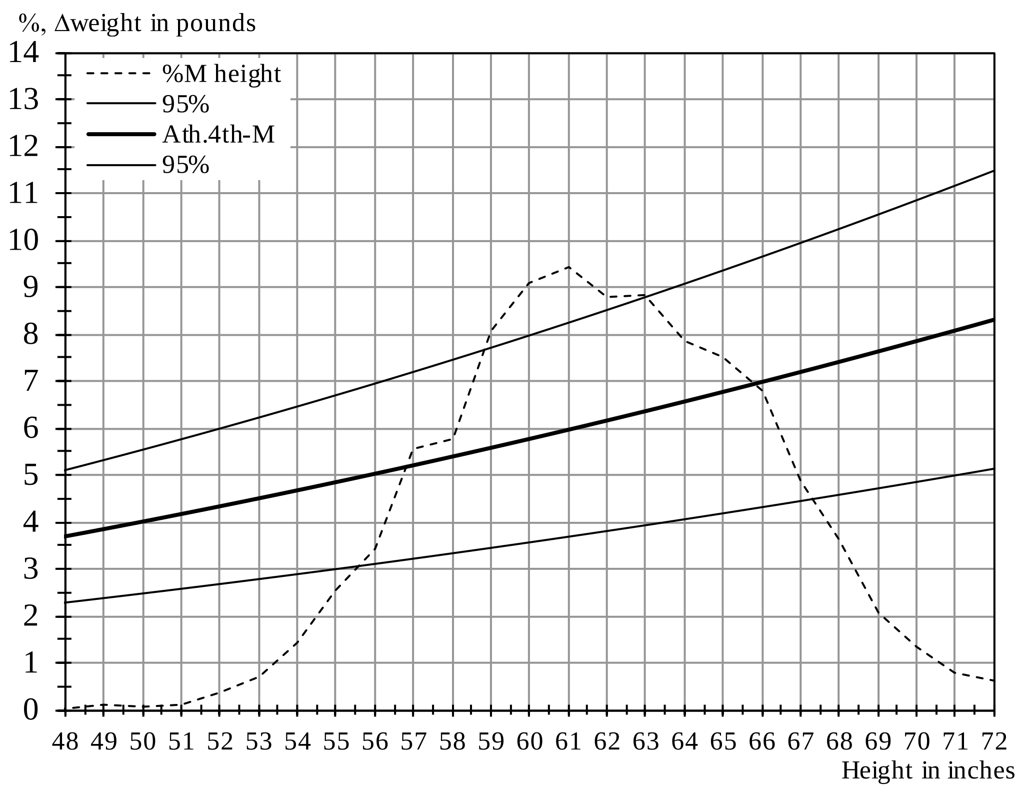


Figure 6. Estimated change in weight (and 95% CI) from being in the Athletic 4th as a function of height and the distribution of height for Females and Males.